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# Unlocking the Hidden Potentials of Organization Through Merging of Humans and Digitals

## PROCEEDINGS

**SYMORG 2024  
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**XIX INTERNATIONAL SYMPOSIUM**

**UNLOCKING THE HIDDEN POTENTIALS OF  
ORGANIZATION THROUGH MERGING OF  
HUMANS AND DIGITALS**

**SYMPOSIUM PROCEEDINGS**

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Jovan Krivokapić, Ph.D.**

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# FOREWORD

It is with great pleasure that we present the Proceedings of the XIX International Symposium of Organizational Sciences – SymOrg 2024.

Comprising 149 contributions from esteemed scholars hailing from 15 diverse countries, the XIX International Symposium of Organizational Sciences – SymOrg 2024 marks yet another successful gathering of researchers and professionals dedicated to fostering robust academic networks. Centred around the theme “UNLOCKING THE HIDDEN POTENTIAL OF ORGANIZATION THROUGH MERGING OF HUMANS AND DIGITALS”, this symposium attracted 310 scholars and practitioners who have authored and co-authored research articles, all of which have been meticulously curated for inclusion in this Book of Abstracts.

Each contribution within the Book of Abstracts is categorized into 15 key topics, reflecting the breadth and depth of research presented at this prestigious event.

- Applied Software Engineering
- Blockchain Technology in Business and Information Systems
- Challenges of Green and Digital Transformation
- Creativity, Innovation and Sustainable Management
- Data and Business Analytics
- Designing Organizations for Digitally Transformed Business Ecosystems
- Digital Operations and Logistics Management
- E-Business Ecosystems and Technologies
- Financial Innovations and Challenges in Changing Business Environment
- Integrated Humans and Digitals in Marketing and Communications
- Lean Management and Organization – Purpose, Process, People
- Managing Human Resources in the Digital Age
- Organizational Strategy and Hybrid Project Management
- Quality Management and Standardization
- Transformational Potential of Generative AI

The extensive participation of both domestic and international authors, coupled with the diverse range of topics explored, underscores the significance of our endeavours in organizing the SymOrg 2024. Positioned traditionally at the crossroads of academia and business, we anticipate this year's symposium will engender rich discussions, foster potential collaborations, and cultivate stronger ties within the academic and business realms. Moreover, we are confident that the symposium will facilitate the exchange of knowledge, research findings, and experiential insights among industry experts, research institutions, and faculties, all of whom share a vested interest in contemporary organizational sciences.

Our heartfelt gratitude extends to our distinguished keynote speakers: Professor Swee Hoon Ang from the National University of Singapore, Professor Dimitris Karagiannis from Vienna University, and Professor Jelena Pokimica from Boise State University. We greatly appreciate our moderators for orchestrating the panels, business forums, and workshops showcasing students' startup achievements.

The Faculty of Organizational Sciences wishes to extend sincere appreciation to the Ministry of Education, Science, and Technological Development and all partners and individuals whose support and contributions have been instrumental in organizing this symposium. We express particular gratitude to the contributors and reviewers whose invaluable efforts have culminated in the realization of this publication. Above all, our deepest thanks are reserved for the authors and presenters whose contributions have contributed to making SymOrg 2024 a resounding success.

Belgrade, June 12, 2024

Milica Kostić Stanković, Ph.D.  
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# **APPLIED SOFTWARE ENGINEERING**

# REACTIVE PROGRAMMING: UTILIZING RXJAVA LIBRARY FOR CLASSROOM RESERVATION SOFTWARE DEVELOPMENT

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**Abstract:** *This research paper conducts a theoretical exploration of reactive programming, with a focus on the RxJava library, a widely adopted tool for developing reactive systems. The initial section provides an overview of the core concepts of reactive programming, emphasizing its benefits in managing asynchronous operations and enhancing system responsiveness and scalability. Key principles outlined in the Reactive Manifesto, including responsiveness, resilience, elasticity, and event-driven systems, are discussed. The paper delves into the specifics of the RxJava library, elaborating on its fundamental components and mechanisms such as Observables, Subscriptions, and reactive streams. Additionally, a case study illustrating the development of a classroom reservation software system using RxJava is presented to demonstrate the practical application and advantages of reactive programming in meeting user requirements for efficient execution of required functionalities, real-time updates, and data integrity. Finally, the paper concludes with an evaluation of the benefits of reactive programming in software development and suggests avenues for future research, including comparative analyses with other reactive libraries such as Project Reactor, Akka, and Mutiny, as well as comparisons with the Observer pattern.*

**Keywords:** *Reactive programming, RxJava, Application in education*

## 1. INTRODUCTION

In contemporary software development trends, an increased number of client requests related to software development has become commonplace. One of the key features that becomes significant to end-users upon software delivery is the system's prompt response to client requests. Responsiveness and scalability of software systems have become implicit characteristics. Due to the rise of distributed systems, software systems increasingly need to communicate with a certain number of external sources. Before the emergence of reactive programming, the primary drawbacks of traditional synchronous programming threads, as delineated by Goetz et al. (2006), included blocking program execution, reduced program scalability, and diminished program responsiveness. With the emergence of these needs and drawbacks, reactive programming arises as a response to fulfilling them. Reactive programming emerged precisely as a concept that manages the processing of asynchronous operations in a more systematic and scalable manner. (Nurkiewicz & Christensen, 2016) But reactive programming wasn't asynchronous from the beginning, and there are still many examples of synchronous approaches to using reactive programming. In such cases, reactive programming is often implemented using graphical languages such as STATECHARTS and ARGOS. (Poigné et al., 1998)

Reactive Programming has become more prominent lately due to its benefits in user interface development. Unlike imperative programming, reactive languages don't process statements one by one. Instead, they recalculate values whenever their inputs change. This methodology enables the representation of programs as signal-flow graphs, with nodes indicating signals or behaviors (time-varying values) and change propagation occurring along the edges. (Bainomugisha et al., 2013)

In the field of reactive programming, the RxJava library has emerged as one of the most prevalent tools for software system development. Despite its name implying that this library is used for developing programs in the Java programming language, there are versions of the library that enable program development in other languages such as Kotlin, etc. Additionally, besides this library, a wide range of other libraries for reactive programming have been developed for different programming languages. Some of the well-known libraries are Reactor, Mutiny, Akka, RxJS and others. (Morgillo, 2015)

## 2. FUNDAMENTAL CONCEPTS OF REACTIVE PROGRAMMING

Chakraborty (2017) states that reactive programming represents a paradigm based on managing reactive streams and propagating changes using asynchronous communication threads. Programs are considered reactive if they propagate information to interested parties (users, program components, etc.) about changes occurring within the program that affect its data. Maglie (2016) states that reactive programming “takes functional programming a little bit further, by adding the concept of data flows and propagation of data changes.”

Chakraborty (2017) identifies several key advantages of using reactive programming. These include the elimination of callback mechanisms, which typically involve passing callback methods upon certain events. Additionally, reactive programming offers a standard error handling mechanism, simplifies the management of programming threads, and facilitates easier management of asynchronous operations. It also provides a unified API for executing all functionalities, resulting in increased functionality of the programming code. Moreover, code written with reactive programming principles is easily testable and maintainable.

Authors Bainomugisha et al. (2013) listed a few disadvantages of reactive programming and reactive systems. They are prone to errors, as developers may overlook marking some dependencies as reactive, resulting in incorrect updates of dependent values. Planning reactivity in advance requires identifying all sources of reaction, which can be a challenging task. Additionally, existing applications demand considerable effort to manually identify all sources of change and wrap them with reactive types.

In order to standardize some of the basic characteristics of reactive programming and establish its paradigms, a document called the “*Reactive Manifesto*” has been developed, providing fundamental paradigms of reactive programming. Within it, authors Bonér et al (2014) states the following paradigms:

1. **Responsiveness** – System responsiveness indicates how quickly problems can be detected and resolved. In modern programming, responsiveness is imperative in software system development. Responsive systems focus on providing fast and consistent responses to end-users. Additionally, these systems set an upper time limit for providing a response to the user's query.
2. **Resilience** – The fundamental characteristic of this feature is that the software system remains responsive even in the event of an error. This implies that regardless of the type of software system, if it is not resilient, it stops reacting after an error occurs. Authors (Boner et al., 2014) mention four concepts enabling this characteristic: replication, retention, isolation, and delegation. Errors in the system can occur in any component. These errors, which are retained within a component, should not affect the operation of other components. Therefore, isolating components from each other is one of the primary goals of reactive programming, as it prevents problems occurring in one component from affecting others. The resolution of the problem that occurred in one component is delegated to another component representing its replication. End-users are not responsible for managing any errors that occur within the software system.
3. **Elasticity** – This characteristic refers to the system remaining responsive regardless of the current load it is experiencing. The system responds to input requests by increasing or decreasing the allocation of resources to service the given inputs. For this to be possible, it is assumed that the given systems do not have central bottlenecks, allowing components to be shared and replicated to service specific inputs. Elasticity in reactive systems is supported by the use of reactive and predictive algorithms, which in real-time ensure satisfactory resource availability. These algorithms optimize resource usage, thereby increasing the efficiency of software and hardware resource utilization.
4. **Event-driven System** – In reactive systems, messages are asynchronously passed. This establishes loose coupling, isolation, and location transparency among components. Considering that the main characteristic of a reactive system is emphasized to be event-driven, this implies that errors occurring in the system are also delegated as messages. This approach enables load management and system elasticity, as well as handling feedback, which occurs during asynchronous communication between system components. Less system load is achieved by allowing end-users to utilize certain resources only while they are active.

### 2.1. Back Pressure in Reactive Programming

Back pressure represents a mechanism that controls the flow of information and determines the amount of information consumers can receive at any given moment. This concept has enabled servers to send their data not all at once, but to send data concurrently as soon as it becomes available. This way, users can process information for shorter periods and in a timely manner. However, this also leads to challenges related to user overload. Overload can occur if back pressure sends new information at a rate that the user cannot process in a timely manner. (Baeldung, 2024)

Baeldung (2024) site outlines three fundamental methods for managing back pressure during event emission by the publisher: sending new requests only upon subscriber request, restricting the number of requests the

client and server sides can handle, and terminating data streams when the client side is unable to process them.

Properly managing back pressure is crucial, as mishandling it can lead to permanent data loss, software system failures, or the freezing of reactive data streams. (Galilée et al., 2018)

## 2.2. Reactive Streams

Reactive streams act as guidelines and tools for asynchronous communication. They include features like feedback and event-driven models, enabling software engineers to ensure system responsiveness, regardless of user demand. (Ponge et al., 2021)

Main four reactive streams are:

1. **Publisher** - This component sends requests and events without keeping track of subscribers, requiring subscribers to subscribe to receive emitted events.
2. **Subscriber** - This component subscribes to specific Publishers to receive and process emitted events.
3. **Subscription** - This component establishes a connection between Publisher and Subscriber components, facilitating the flow of events between them.
4. **Processor** - This component combines the functionalities of both Publisher and Subscriber, allowing it to emit events similar to a Publisher and process events like a Subscriber.

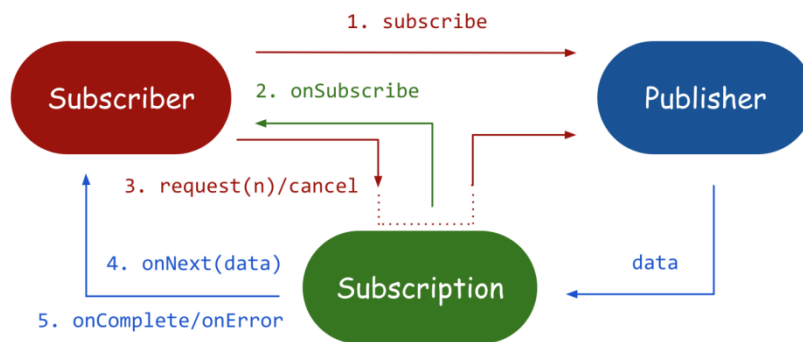


Figure 1 Interactions Among Reactive Streams (Um, 2020)

The simplified process and communication of reactive streams are depicted in Figure 1. Communication between components within reactive streams is established by invoking the subscribe method from the Subscriber to the Publisher. In response to this request, the Publisher component responds by sending the onSubscribe event, which includes a reference to the created Subscription component. The Subscription component serves as a medium of communication between Publisher and Subscriber components. The exchange of information and events involves sending data from the Publisher component to the Subscription component, which then notifies the Subscriber component through mechanisms such as onNext, onComplete, or onError methods. The onNext method is called by the Subscription component to deliver data emitted by the Publisher to the Subscriber. The onComplete method may be called if the Subscriber no longer wishes to receive events from the given Subscription. The onError method is called in case of errors. Additionally, the cancel method is available to stop back pressure when the Publisher emits requests at a faster rate than the Subscriber can process.

## 3. FUNDAMENTAL CONCEPTS OF RXJAVA LIBRARY

The techniques used by RxJava for optimization include the following: (Ponge et al., 2021)

1. Reactive stream handling isn't always strict, especially when coordinating asynchronous messages between senders and receivers.
2. Operators are merged into a single one to reduce the number of steps items go through. This can mean consolidating operators or simulating parallel execution.
3. Subscribers can store data before Publishers emit events, reducing the need for frequent requests.

Main concept used in RxJava library is the Observable type. This type represents a stream of data or events. Observable type can be used reactively (as a push mechanism that emits events through the stream) or interactively (as a pull mechanism that doesn't emit events until requested by an interested party). The primary behavior of the Observable type implies the application of a push mechanism. This mechanism enables Observable components to autonomously decide when to emit messages or events. In response to

emitted events, back pressure streams can be created, with their operation dictated by back pressure. (Nurkiewicz & Christensen, 2016)

Observable<T> in the RxJava library accepts a generic type T as a parameter, which can represent either a concrete type T or its generic representation. Additionally, it can signal events indicating the end of program execution or subscription to a specific data stream, as well as events signaling errors of any type (Nurkiewicz & Christensen, 2016).

Another one important concept is the Subscription type. The Subscription component is created to listen to the data and events emitted by the Observable component. It is generated as the return value of calling the subscribe method on the Observable component. Subscription data type enables software engineers to invoke the unsubscribe method, allowing the cessation of data and event reception from the Observable component when they are no longer of interest to the concerned party.

Within the library, an abstract type Subscriber<T> is also introduced, which combines Observable and Subscription components. This enables this data type to simultaneously receive emitted events and data while controlling the behavior of the Subscription component itself. A characteristic of the Subscriber<T> component is its ability, in specific cases, to remove itself from the list of interested parties when the emitted events and data are no longer relevant.

```
Observable<Classroom> classroomObservable = Observable.create(emitter -> {
    for (Classroom classroom: classroomsArray) {
        if(!emitter.isDisposed()) {
            emitter.onNext(classroom); //emitting values for each classroom
        }
    }
    emitter.onComplete(); //sending signal for data emission completion
});

Subscriber<Classroom> classroomSubscriber = new Subscriber<Classroom> {
    @Override
    public void onSubscribe(Disposable d) {
        System.out.println("Subscribed");
    }

    @Override
    public void onNext(Classroom classroom) {
        System.out.println("Classroom received!");
        System.out.println("Classroom number: " + classroom.getNumber());
    }

    @Override
    public void onError(Throwable e) {
        System.err.println("Error: " + e.getMessage());
    }

    @Override
    public void onComplete() {
        System.out.println("All classrooms are emitted!");
    }
}

classroomObservable.subscribe(classroomSubscriber);
}
```

**Figure 2** Code example of using RxJava library

In the provided example in Figure 2, an Observable component is primarily created to emit objects of the Classroom class. For this component, a check is made to see if the dispose() method has been called on it, as in that case, emission of values ends. If not, the component will emit the next classroom. When all classrooms have been emitted, a signal is sent indicating that emission has completed to all components interested in it (Subscriber components, which can be unlimited). In the continuation of the example, one such Subscriber component can be observed. As mentioned earlier, this component has three defined methods: onComplete, onNext, and onError. In this example, each of these methods is implemented in a specific way. To enable the Subscriber component to receive events from the Observable component, the subscribe method is called on the Observable component at the end of the example, with the Subscriber component passed as an argument (there can be multiple). In this way, each of the given components passed will be considered significant for receiving notifications about any event emitted by the Observable component. For example, if the onComplete method is called in the Observable component, each of the Subscriber components will be notified, and the specific implementation of the onComplete method for that Subscriber object will be invoked within it.



## 4. CASE STUDY OF CLASSROOM RESERVATION SOFTWARE SYSTEM

### 4.1. Description of Software System

The practical aspect of this scientific research work relates to the development of a software system for managing classroom reservations, developed in the Java programming language using reactive programming principles and the RxJava library. The system functionalities are simple and focus on performing basic operations on classroom reservations. The goal is to demonstrate the application of reactive programming and the RxJava library in practice, specifically addressing a concrete user requirement.

### 4.2. User requirements

**User requirement:** The software system should allow users to efficiently manage classroom reservations. Users should be able to perform basic CRUD operations (Create, Read, Update, Delete) on exam room reservations. The system should provide a responsive and intuitive interface for viewing existing reservations, creating new ones, updating details of existing reservations, and deleting reservations when necessary. Additionally, the system should handle concurrency and ensure data integrity, providing real-time updates and notifications about reservation changes.

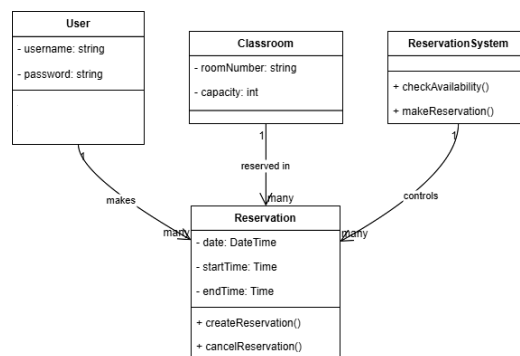


Figure 3 Simplified class diagram of software system

In Figure 3, a simplified class diagram of the classroom reservation software system is presented. The diagram distinguishes the reservation system, where reactive behavior will be applied, as well as entities for classrooms, reservations, and users who will initiate reservation operations. The ReservationSystem is subscribed to the Reservation Observable, so every call of the createReservation method is published and triggers calls to the checkAvailability method. Additionally, this method, if the classroom is available, triggers the call of the makeReservation method for creating a classroom reservation, etc.

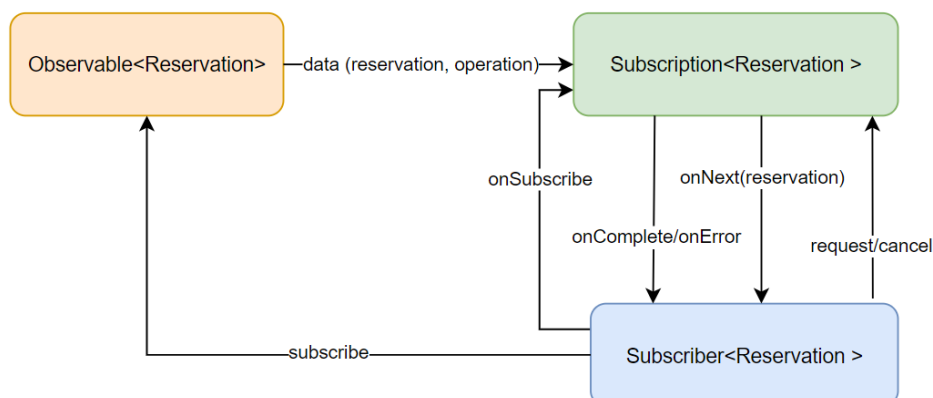


Figure 4 Reactive streams of software system

In a system utilizing the RxJava library presented in Figure 4, the Publisher component is responsible for emitting events or data, in this case, reservation requests. The Subscriber component, representing the entities interested in receiving and processing these reservations, subscribes to the Publisher to receive these events. Upon subscription, the Publisher responds by sending an acknowledgment event, typically the onSubscribe event, which includes a reference to the created Subscription component.

The Subscription component acts as a mediator between the Publisher and Subscriber components. It forwards the emitted reservation data from the Publisher to the Subscriber for processing. This forwarding is accomplished through method calls such as `onNext` to deliver the data to the Subscriber. Additionally, the Subscription component can signal the Subscriber in case of completion of data emission (`onComplete`) or error occurrence (`onError`).

The communication flow ensures that reservations are efficiently transmitted from the Publisher to interested Subscribers, allowing for timely processing of reservation requests within the software system.

Once the Subscriber component receives the reservation data emitted by the Publisher, it can further invoke system operations for storing, updating, deleting, and retrieving reservation data. These operations typically involve calling appropriate services and repositories responsible for communication with the database.

## 5. CONCLUSION

Reactive programming using the RxJava library in modern applications represents an efficient approach to building programs based on asynchronous operations. This paper has explained the theoretical concepts of reactive programming and reactive streams associated with the RxJava library. Reactive programming can serve as a versatile paradigm that addresses various challenges and user requirements in software system design. As a current area of research and programming approach, reactive programming is a suitable tool for application in various fields.

Currently, we are working on implementing a case study using synchronous communication and the Observer pattern to conduct a comparative analysis of these two paradigms and identify differences in their performances. In our further research, we will conduct a comparative analysis of the RxJava library with other libraries commonly used in reactive programming today (Project Reactor, Akka, Munit etc.), providing explanations of their differences and situations where the application of each of these libraries is preferable.

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# DEVELOPMENT PROCESS OF A FLEET MANAGEMENT SOFTWARE

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**Abstract:** *This paper explores the development of an advanced fleet management application, emphasizing agility and scalability in handling large volumes of data daily. The architecture of the application is microservice-based and it was developed utilizing several technologies, including Go, Java (Spring Boot), PostgreSQL, MongoDB, Vue.js, and their accompanying technologies. The application integrates GPS tracking, customizable alarms, geofencing, user management, vehicle and driver management as well as a comprehensive reporting module with the goal of meeting the specific needs of modern fleet operations. The project also relies on Google Maps API as well as OpenStreetMaps API in order to obtain and better display geolocation data. The two key parts of this project include the process of adapting to changes in software requirements that occurred after the project was put into production, as well as maintaining the performance of the system with a large number of geolocation data on a daily basis.*

**Keywords:** *fms, geolocation, development*

## 1. INTRODUCTION

Fleet management systems are key tools in modern companies that enable efficient monitoring and administration of the entire company's fleet. These systems typically contain functionalities that enable the administration and review of not only vehicles but also drivers, regular services, registrations, breakdowns, traffic violations as well as other logistical operations related to the fleet. Moreover, they often include modules for live tracking of vehicles, as well as a historical overview of data on the movement of certain vehicles, an overview of their mileage, fuel consumption, and the like.

One of the fundamental technologies that contributes to the existence of the FMS system in its current form is GPS (Global Positioning System). GPS was created in 1978 and belongs to the group of global navigation systems (GNSS) that provide geolocation information to the user of the GPS system anywhere on Earth, provided that there is an uninterrupted direct line from the user to four or more GPS satellites (Leick, Rapoport, & Tatarnikov, 2015). The initial purpose of the system was for military purposes, while in the 1990s the entire project was released for civilian use. This technology is based on a system of 24 satellites in orbit at a distance of about 20,000 km from the Earth's surface (United States Department of Defense, 2008). The satellites are placed so that at least 4 satellites can be seen at the same time from any point on Earth. Each of these satellites transmits data containing the position of the satellite as well as the exact time when the data was sent. These signals can be picked up by GPS devices on the ground, which then, based on the time it took for the signal to reach the device (the difference between the time the signal was received and the time the signal was broadcast from the message) and the known speed at which these signals travel, calculates the distance from the given satellite. For the GPS device to be able to determine an approximately correct position (latitude, longitude, and altitude), it must receive data from at least four satellites (three for latitude and longitude and one for altitude) (Guier & Weiffenbach, 1997).

Modern FMS systems are increasingly leaning towards a microservice-based architecture and are deviating from a more traditional, monolithic design. Microservice architecture is a way of creating a system using several smaller services that are independent and communicate with each other via API (application programming interface) (Newman, 2015). Each service focuses on a certain functionality. This approach enables teams to independently develop, implement and test services and thereby increase agility in system development (Taibi, Lenarduzzi, Pahl, & Janes, 2017). As FMS systems are modular in nature, this approach to architecture often seems like the best choice. The most common modules in FMS systems are tracking, movement history, reports, alarms and notifications, vehicles, etc. In addition to agility in production, the microservice structure brings other benefits. One of them is to reduce the chance that the load on one module (service) will affect the performance of other systems. This means that difficult operations that are, for example, performed on the reporting service should not affect users who are currently using live tracking. Also, the eventual termination of work of one service should not affect the operation of the rest of the system, which is often the case with monolithic applications (Balalaie, Heydarnoori, & Jamshidi, 2016).

This paper presents the process of developing, enhancing, and maintaining an FMS system that leverages GPS technology and microservice architecture to deliver multiple functionalities while ensuring optimal performance.

The idea of this project is to use advanced technology and adaptive design, to improve efficiency, reduce costs, and increase transparency of all operations related to a company's vehicle fleet. Special attention is paid to the process of adapting to changes in the project's hardware components, as well as the large daily amount of geolocation data that threatens to slow the system down.

The rest of the paper is organized as follows. Section 2 provides an overview of the technologies used, focusing on Spring Boot (and Java), Go, PostgreSQL, MongoDB, and Vue.js (JavaScript). Section 3 outlines the process of gathering software requirements. Section 4 delves into the system architecture, Section 5 describes the process of adapting to changes in the project's hardware components as well as data management strategies, and Section 6 concludes with the findings.

## 2. TECHNOLOGICAL FRAMEWORK

*Java* is a general-purpose, high-level, object-oriented programming language that is designed to have as few implementation dependencies as possible (Arnold et al., 1996). Java operates under the “write once, run anywhere” (WORA) principle, meaning that Java compiled code can run on any platform that supports Java virtual machine (Gosling, Joy, Steele, & Bracha). Java applications are compiled to bytecode that runs on any Java virtual machine (JVM) regardless of the underlying system architecture (Lindholm & Yellin, 1996). Java is not the only language that uses JVM (Programmer Interview). The most popular distributions of Java are OpenJDK and Oracle JDK.

*Java Spring Boot Framework* was first released by Pivotal Software in 2014 (Walls & Glover, 2016). It is an extension of the Spring Framework and is designed to simplify the development of enterprise applications. It is convention-based thus reducing the need for manual setup and configuration files (XML configuration). Spring Boot boasts features like auto-configuration, embedded servers (Tomcat, Jetty, Undertow), and easy dependency management, allowing developers to concentrate on writing business logic rather than boilerplate code (Johnson et al., 2005). Developers often use Spring Boot in combination with Spring Data, Spring Security, Hibernate, and other accompanying technologies (Pollack et al., 2012).

*PostgreSQL* is another open-source project, often referred to as just ‘Postgres’. Postgres is an object-relational database management system (ORDBMS) (Obe & Hsu, 2012). It is well-regarded for its many features, reliability, performance, and scalability making it a popular choice for developers around the world. It adheres to SQL standards. Key features of Postgres include SQL Compliance, Extensibility, Performance and reliability, advanced indexing, replication, and security.

*MongoDB* belongs to the newer generation of databases. It is a NoSQL database, which stores data in flexible JSON-like documents (Bradshaw et al., 2019). The basic structure of MongoDB is based on collections (analog to tables in most SQL databases) and documents (basic units of data). Collections represent a group of documents, which are most often (but not necessarily) similar in structure. The format in which the data is stored is called BSON (binary-coded version of JSON). MongoDB is often used in IOT applications, applications that have real-time analytics as well as applications that handle large amounts of data. The project is also open source.

*JavaScript* is a dynamically typed programming language and one of the core technologies of the Web. More than 95% of web applications use JavaScript on the client side, along with HTML and CSS (Haverbeke, 2018). It is a high-level language that conforms to the ECMAScript standard (Prusty & Mohan, 2018). JavaScript first appeared in 1995 and has since then been the necessary language to learn for any front-end developer. There are many popular frameworks built atop JavaScript, such as Angular, React, and Vue.

*Vue.js* is a progressive JavaScript framework designed for developing single-page applications (Eseme, 2023). It is an open-source project initially released in 2014. It is based on a model-view-viewmodel architecture. Vue is known for its features like virtual DOM, Vue CLI, Vuex, and Vue Router. Since its release, it has grown in popularity due to its simplicity and performance (Nelson, 2018).

*Google Maps API and Open Street Maps API* services provide users with a quick way to obtain and display geolocation data (Svennerberg, 2010). Google Maps API is a paid service of Google, while Open Street Maps API is an open-source project initially developed by Mapbox. These APIs provide various services such as:

- Geocoding API - converts addresses to latitude and longitude
- Reverse Geocoding API - converts latitude and longitude to detailed address
- Directions API - finds several best paths between two locations, taking into account one-way streets, traffic, etc.
- Maps Static API - generate a static map for simple display
- Places API - provides detailed information about different locations

### 3. GATHERING SOFTWARE REQUIREMENTS

The process of gathering software requirements started with the initial client meeting, focusing on understanding the challenges faced by the client. This meeting encompassed several phases: introduction of the company, examination of the vehicle fleet, assessment of hardware components (including two GPS devices installed in vehicles and their accompanying sensors), review of client requirements, and evaluation of existing solutions such as Wialon and Traccar. Furthermore, the future meeting dynamic was agreed upon.

The subsequent meetings aimed to deepen our understanding of the client's requirements, which were then translated into a functional specification. Following the completion of this process and client approval, we proceeded with the preparation of the technical specifications. After several iterations and discussions with the client, all aspects including technologies, system architecture, hosting methods, and others were finalized and agreed upon.

After the confirmation of the technical specification by the client, the development of the project officially began.

### 4. SYSTEM ARCHITECTURE

A microservices architecture was chosen to meet the system's requirements. This approach divides the system into several distinct components, each responsible for a specific function.

*GPS devices* (with additional sensors) that are installed in vehicles send information to the reception service (provided they have an Internet signal) in the form of a series of bytes. The software of these devices was developed on the Linux system. Its function is to regularly send data such as Latitude, Longitude, Measurement time, Fuel level (optional), Current speed, Status (on/off), and many others for the vehicle to which it is attached. Devices also have the possibility of buffering a certain amount of data in situations when the device cannot receive an Internet signal, so after receiving it, it does not send just one message to the receiving service, but all of them are saved in the buffer. These GPS devices with accompanying software already existed in the same form and were not the subject of the work.

*Reception service* whose purpose is to deserialize the data it receives from different GPS devices, save it in the database (MongoDB), and forward it to the web socket in case someone is currently following that vehicle. This service was created in the Go programming language. The reason for choosing this programming language was the need for better performance, especially with a larger number of vehicles (and devices).

MongoDB serves as the document database where all deserialized messages from GPS devices are stored. This data is organized into two collections, one for each type of GPS device. In this architecture, MongoDB is specifically chosen to store the data sent by vehicles (i.e., the aforementioned GPS devices). While this data can sometimes be incomplete, the system is designed to overlook missing parts due to the sheer volume of records and make use of the available information. The data has only one relation—the ID of the sending device—eliminating the need for a relational SQL database. MongoDB's capability to efficiently handle large volumes of data makes it the ideal choice.

A report service written in Java Spring Boot represents a classic REST service, whose purpose is to generate reports from the data found in the Mongo database. The reports that are created can easily encapsulate large amounts of data, so it is very important to optimize queries to the Mongo database, as well as the time complexity of the algorithms in this service. This service is also responsible for handling any missing data by ensuring that reports are generated using the available information, compensating for any incomplete records. Some reports also require the conversion of latitude and longitude into exact addresses, so this service relies on the Open Street Map Reverse Geocoding API.

The *main backend service*, or the *orchestrating backend service*, was also built using Java Spring Boot. In addition to the role of orchestrator, this service also stores information about users, drivers, vehicles,

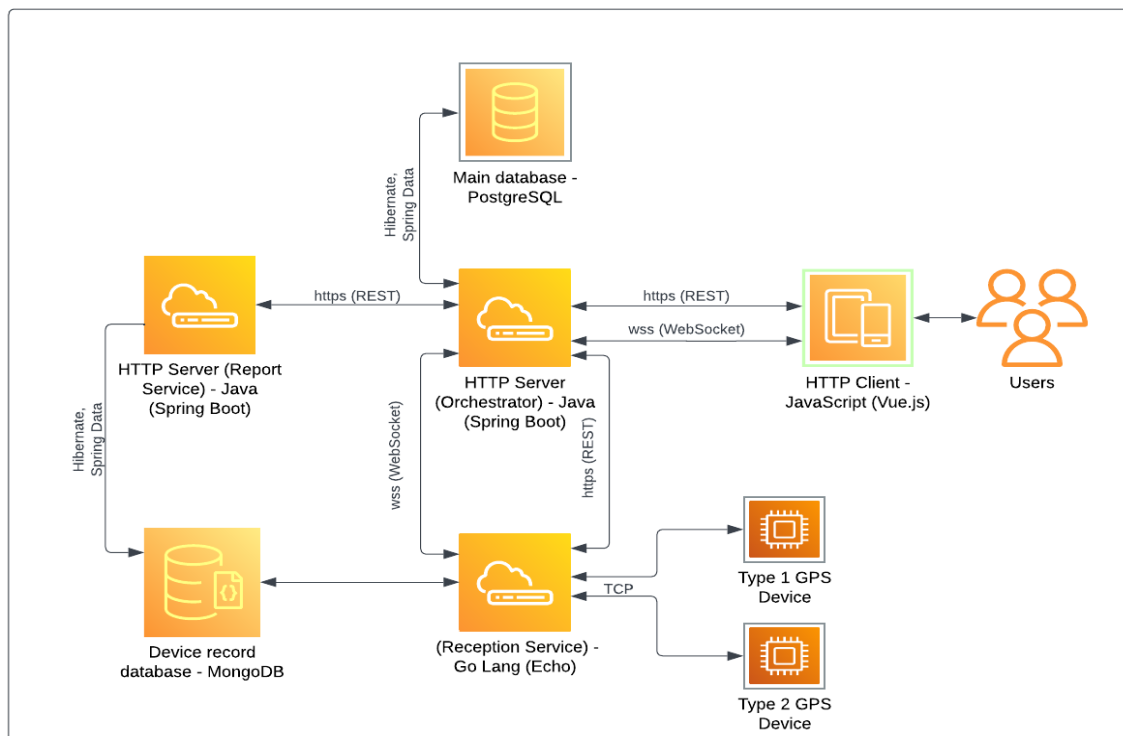


services, and similar data in the PostgreSQL database. PostgreSQL was chosen for this part of the system because the data it handles is logically separated from the data sent by the devices and stored in MongoDB, and it involves many relational connections that benefit from a relational database's capabilities. In PostgreSQL, each vehicle is assigned a GPS device ID, while in MongoDB, each record sent by a device includes that device's ID. This shared device ID links the data between the two databases, ensuring consistency and integration across the system.

The client side of the project (or front-end), is made in Vue.js technology. All communication is done through the orchestrating backend service. The Google Maps API is used to display data. It uses a web socket for the integration of live monitoring, while communication for other functionalities is via the https protocol.

Some parts of the application are not mentioned in the paper for the sake of simplicity, such as the integration of push notifications via Firebase, services for sending messages, etc.

This architecture is shown in Figure 1.



**Figure 1:** System architecture

## 5. ADAPTING TO HARDWARE CHANGES AND DATA MANAGEMENT

After the application was put into production, a short period of bug-fixing and slight adjustments to the functionality followed. After two months of alpha testing (customers who agreed to test the new application and provide feedback for the system), the application was put into production. In the following year, a problem arose with the system. Namely, the manufacturer of one of the two types of GPS devices had rolled out a new version of the device. This new device came with the same features but offered a quicker system and a slightly changed communication protocol. Further complicating the situation was the client's request to not upgrade all the vehicles to newer devices but to use both the older and newer devices in different vehicles. It is important to note that the data from the newer devices was also deserialized by the receiving service, however, many values were reversed. The data that remained accurate was basic tracking data, such as latitude, longitude, and timestamp. For this reason, data from the newer devices in its current form was valuable and semi-correct, but it was necessary to upgrade the receiving service as soon as possible so that the reversed values were also deserialized correctly.

As the system was in production, the idea was to minimize downtime and implement the changes as quickly as possible. Another point of consideration was whether to create a new collection (MongoDB) for this device or use the existing one.

Since both devices represented the same data, just sent in different formats, it was decided to store them in the same collection. A new version of the reception service was created, implementing a custom deserializer for the new devices. To minimize downtime, during the least busy time (Saturday at 11:00 p.m.), an NGINX proxy server was set up. This NGINX proxy directly received data from all devices (now three types) and proxied them. Data from the two older devices was proxied to the existing receiving service, while data from new devices was sent to both the existing service (in order to save latitude, longitude, and timestamps) and the new version of the receiving service. After a couple of fixes on the new service and data verification by the client, the new service was connected to the production database (MongoDB), and all data was now being proxied to this service, thus solving the new device issue.

A different challenge emerged around the same time. With over 2000 vehicles in the system at that time, the database (MongoDB) was filled up with large amounts of data (about a million rows daily). This influx of data began to affect application performance, specifically the latency of all functionalities that request data from the Mongo database. The majority of these functionalities are related to movement history and various reports. To solve the performance problem, several steps were taken. Profiling (measuring execution time) was performed for the movement history and reports for selected vehicles. Following that, statistics of all user requests were made. From these statistics, it could be noted that when users asked for movement history or reports, they rarely took a period older than 2 months. In the report service, a scheduled method was created that every day at 23:59 took data from both Mongo collections that were older than 3 months, compressed it, and stored it in a separate volume outside of the Mongo database. This data was then deleted from the collections. Also, a functionality for returning these archived data in case of need was implemented.

Following these adjustments, the number of rows in the database was reduced to around 90 million at any given moment. To verify the impact of these changes, we conducted a second round of profiling using the same vehicles and reports as before. The profiling involved measuring execution time, response time, throughput, and latency of key functionalities related to movement history and report generation. We executed user scenarios that mirrored typical usage patterns, particularly focusing on requests within the last two months. The test setup ensured consistent and accurate results, revealing a significant performance improvement. The average response time decreased by approximately 250%, throughput increased, and latency was significantly reduced. These improvements are attributed to the reduced data load in the MongoDB collections, enabling faster query processing and lower latency in data retrieval.

## 6. CONCLUSION

In conclusion, this paper has focused on the software development process of an FMS application, emphasizing the process of overcoming challenges with strategic system updates as well as data management improvements. Addressing these issues not only enhanced application performance but also notably improved the reliability and scalability of the system. This highlights the critical importance of adaptability and flexibility in software development and maintenance (Martin, 2008).

Future research and development on this system could focus on additional performance optimization. This could encompass further query optimization, algorithmic optimization, caching, load balancing, and other optimization techniques, as well as exploring the integration of emerging technologies with the idea of enhancing scalability and reducing operational costs.

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# DETECTION OF SCOLIOSIS

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**Abstract:** *The primary objective of this work is to detect scoliosis of the spine using a deep learning model integrated with web applications for analyzing and saving results. Using a dataset of 198 x-ray images, publicly available on the Roboflow platform, a model was developed for automatically detecting scoliosis. After the initial results from the full-image annotations proved unsatisfactory, a manual annotation process was undertaken. This effort resulted in a new dataset comprising 245 images, which were then augmented. This approach significantly improved model performance and enhanced the accuracy of detection on new data. Additionally, a web application was implemented using HTML, CSS, JavaScript, and Flask technologies, providing users with a simple interface for analyzing scoliosis detection results. For monitoring and data management, MySQL and phpMyAdmin were used to store images, comments, and doctor's advice. This method enhances scoliosis diagnostics and offers users relevant information and recommendations for further treatment steps.*

**Keywords:** *artificial intelligence, annotation, computer vision, scoliosis, YOLOv8*

## 1. INTRODUCTION

Artificial Intelligence (AI) is a branch of computer science that focuses on creating systems or machines capable of performing tasks that typically require human intelligence (Brownlee, 2019). These tasks include learning, reasoning, problem-solving, perception, understanding natural language, and even creativity. AI aims to simulate human-like intelligence in machines to enable them to adapt, learn from experience, and make autonomous decisions (Jacobs & Bean, 1963).

AI systems are built upon various techniques and approaches, including machine learning, deep learning, natural language processing, computer vision, robotics, and expert systems. Machine learning, a subset of AI, involves training algorithms on large datasets to recognize patterns and make predictions or decisions without being explicitly programmed (Jacobs & Bean, 1963; Russell & Norvig, 2021).

Computer vision is a field of artificial intelligence and computer science that focuses on enabling computers to interpret and understand the visual world. It aims to replicate human vision and perception by processing and analyzing digital images or videos (Krizhevsky et al., 2012). Through computer vision, machines can extract useful information from visual data, such as identifying objects, recognizing faces, detecting patterns, and estimating distances or poses.

Computer vision has numerous practical applications across various industries and domains. In healthcare, it can assist in medical imaging analysis, disease diagnosis, and surgical navigation. In automotive technology, it enables autonomous vehicles to perceive and navigate their surroundings. In retail, it facilitates product recognition, inventory management, and customer behavior analysis. In security and surveillance, it helps in facial recognition, activity monitoring, and anomaly detection. Additionally, computer vision finds applications in augmented reality, robotics, agriculture, entertainment, and many other fields (Van Gool et al., 2012; Geiger et al., 2013).

Scoliosis represents a spinal deformity characterized by the irregular bending of the lateral vertebrae, often resulting in the spine assuming a shape resembling the letters S or C. While a normal spine has a natural curvature in the sagittal plane, scoliosis signifies abnormal lateral bending. These medical conditions often occur during growth periods, especially in adolescence (Negrini et al., 2012). Today, due to spending a significant amount of time in front of computers or phones, both in youth and adults, this form of deformity is increasingly prevalent in the population, which is one of the main motivations for creating models for more efficient and faster detection of this disorder. The difference between a normal spine and a spine with scoliosis is reflected in the lateral bending and rotation of the spinal vertebrae. While a normal spine maintains balance and symmetry, scoliosis introduces imbalance, often causing unevenness in leg or shoulder length (Newton & Marks, 2002; Nachemson, 1965). People suffering from this spinal condition can experience various problems, including back pain, muscle fatigue, changes in posture, and limited mobility (Nachemson, 1965). In addition to physical

challenges, scoliosis can also have emotional and social impacts, especially in adolescents facing changes in physical appearance and whose spinal development stage is not yet complete (Asher & Burton, 2006) .

Treatment of scoliosis is of utmost importance to prevent worsening of the condition and alleviate the difficulties associated with this spinal deformity. Early diagnosis and appropriate interventions and advice from physicians, including monitoring using advanced technologies such as scoliosis detection through deep learning models as demonstrated in this study, can significantly improve the quality of life for patients (Adobor et al., 2012; Jain et al., 2021; Gracitelli et al., 2019).

## 2. MATERIALS AND METHODS

In this study, we utilized a diverse dataset for scoliosis detection. Two distinct models were trained using this dataset, and integrated into a web application using Flask for the backend and HTML/CSS for the frontend. A MySQL database was employed for data storage. Detailed diagrams illustrate our methodology, offering a comprehensive understanding of our approach.

### 2.1. Dataset preparation and annotation

The dataset represents the foundation of every scoliosis detection model, providing a rich source of data necessary for learning and evaluation. The dataset is selected to be as good and adaptable as possible to the problem the model will address, with a particular emphasis on the quality and representativeness of the data. One of the primary guidelines for selecting the dataset used was class balance (Jackson et al., 2018), specifically balancing the number of images with a normal spine and images with scoliosis present.

The first step in data preparation involved reviewing all images in the original dataset. Images that were inadequate for the model were identified, either due to low quality, unclear details, or other irregularities. These images were carefully filtered out and removed from the dataset to ensure a cleaner and more precise training set for the model.

The original dataset had annotations on each image, where the bounding box encompassed the entire image. Using the dataset in this manner had its advantages, but also limitations. We shifted our approach to manual annotation of images with a focus on the spine and the exact locations of curvature. In this model, the bounding box was precisely defined around the spine, thereby automatically reducing the complexity of the tasks the model must perform in a single pass (Figure 1). The results were significantly improved, and a dataset was obtained that could be used to train models to solve the same or similar problems. Reducing the bounding box to the spine enabled the model to more accurately recognize scoliosis characteristics and reduce prediction errors.



**Figure 1:** Difference between original annotation and new annotation

## 2.2. Training of two models

YOLOv8, or You Only Look Once version 8, is a state-of-the-art object detection algorithm that belongs to the YOLO family of models. YOLO algorithms are renowned for their efficiency and accuracy in real-time object detection tasks. It represents the latest iteration of this series, incorporating several improvements over its predecessors to achieve even better performance (Zeeshan et al., 2019; Talaat & ZainEldin, 2023).

Training two models with YOLOv8, where the only difference lies in the new annotation of the dataset and augmentation, can lead to distinct performance outcomes based on the quality and diversity of the data, as well as the effectiveness of the augmentation techniques employed.

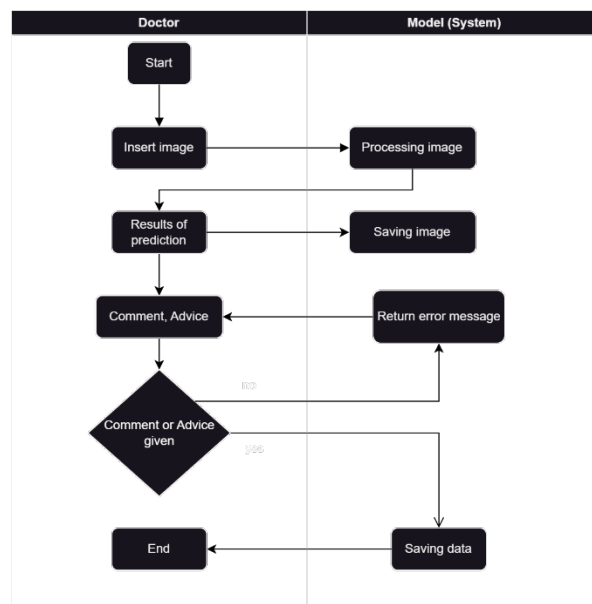
All the steps described in the previous chapters were implemented in Google Colab. Working in the cloud enabled efficient development and training without the need for local infrastructure. The YOLOv8 algorithm was used, proving to be a highly optimal choice for scoliosis detection (Wu, Cui, & Sun, 2023), especially after manual annotation of images and locating the parts of the spine that are of interest for model learning. Additionally, its relatively simple and easily understandable code made it a favorable option.

Various hyperparameters were experimented with to achieve optimal results. The dataset was divided in an 80:10:10 ratio for the training set, test set, and validation set, respectively. After several attempts, the final set of hyperparameters that proved to be the most effective included 35 epochs and a learning rate of 0.01. These parameters were tuned to establish a balance between the convergence speed and the accuracy of the model. Due to the relatively small size of the dataset (245 images in the new extended dataset), the training process was quite fast, averaging about 15 minutes. This rapid training cycle allowed for experimentation with different model configurations and hyperparameters within a relatively short period of time.

## 2.3. Methods, diagrams and tools

An application was created with an integrated model for prediction. The initial purpose of the created application was to assist doctors in analyzing scoliosis detection. In the process of integrating the scoliosis detection model into a web application, Flask was used as the backend framework. Flask enables the definition of routes that correspond to different functionalities of the application. For example, routes were implemented for image input, image processing, saving results, as well as leaving comments and advice. Flask also facilitated communication between the front-end and back-end parts of the application (Grinberg, 2018; Ronacher, 2018).

As for the front-end, HTML and CSS were used to create the user interface. HTML allowed for the creation of the website's content structure, while CSS added style and visual appeal. For example, HTML forms were designed for image input, displaying results, and allowing doctors to leave comments and advice (Duckett, 2011). Additionally, a MySQL database was integrated to store relevant information. For instance, data about doctors, images, comments, and advice are stored in the database, enabling permanent and organized storage and access to data. Through queries in the Flask application, a connection between the back-end and the database was established, allowing the application to dynamically access the stored data.



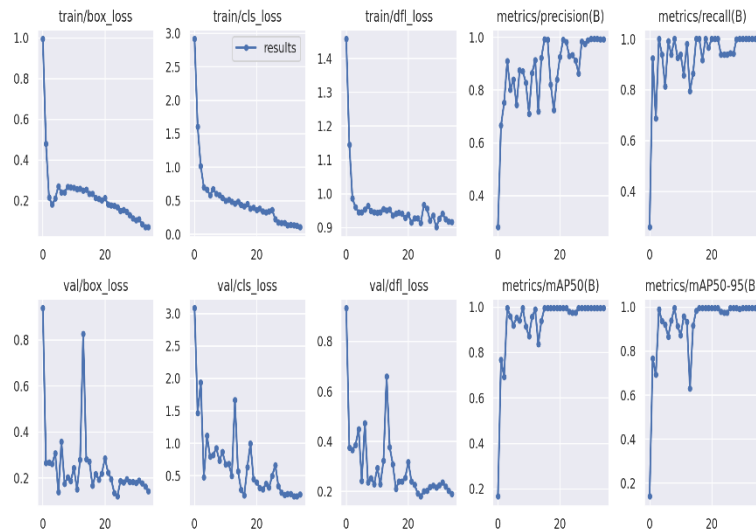
**Figure 2:** UML Activity diagram for communication

In the activity diagram (Figure 2), the activity flow begins with the "Enter Image" activity, where the doctor communicates with the system by inputting the X-ray image of the patient's spine. Immediately after that, the system proceeds to the "Image Processing" activity, which represents the crucial step of analyzing the image for scoliosis detection. Once the system completes the image processing, it moves to the "Save Image" activity, where it stores the processing data in the database. The doctor then has the option to review the system's prediction results in the "Review Prediction Results" activity. This step allows the doctor to examine and analyze the detected scoliosis information.

After reviewing the results, there is an option to leave comments or advice in the "Leave Comment/Advice" activity. At this stage, the system checks whether any fields, such as comments or advice, are filled out. If they are, the system saves the data. Otherwise, the system returns a warning message, and then returns to the "Leave Comment/Advice" step, allowing the doctor to fill in the appropriate field (Suriya & Nivetha, 2023).

### 3. RESULTS OF TWO MODELS

In order to analyze the obtained results and performance, key metrics were analyzed, and graphs were presented to adequately reflect the training and evaluation process for both models (Figure 3) and (Figure 4). The first metric analyzed is the loss function, which provides insight into the model's performance during training. The loss graph shows how the loss values change over epochs. It is expected that the loss will decrease during training, indicating that the model is adapting better to the data, which was achieved in the case of the second model.



**Figure 3:** First model prediction metrics

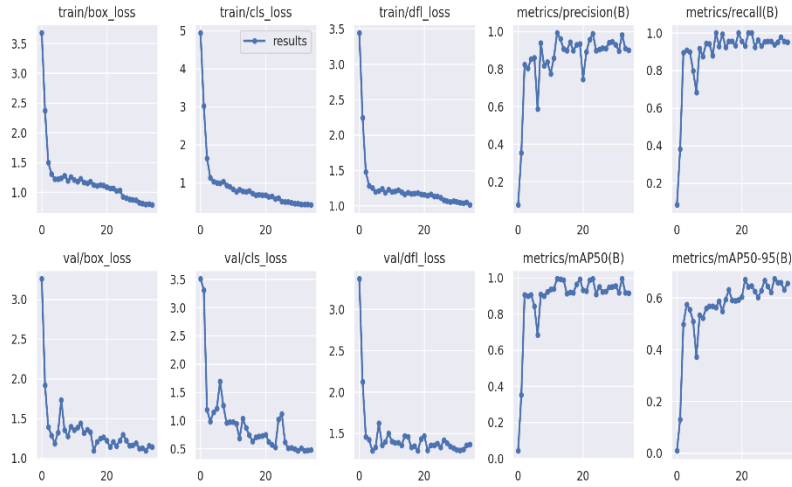
The first model exhibits noticeable oscillations in the values of the loss function during epochs. For example, in the 16th epoch, there is a significant sudden increase in loss, followed by a rapid decrease. Such large and abrupt oscillations indicate that the model did not stabilize adequately during training and that this lack of stability will negatively impact its performance when presented with new images. These oscillations may be one of the reasons why the model showed significant errors in predictions on new data. Additionally, it's observed that the model eventually suffered from overfitting, indicated by a high accuracy of 99.5%. This was the reason for developing the second model (Figure 3).

The overall results of the first model indicated that the model had indeed overfit. The mAP50 was 0.995, while the MAP50-95 was also 0.995 (Table 1). These high values suggest that the model performed very well on the training data, but its performance did not generalize well to unseen data, confirming the presence of overfitting. Overfitting occurs when a model learns the training data too well, capturing noise and irrelevant patterns that do not generalize to new data, resulting in poor performance on unseen data.

**Table 1:** First model performance summary

Class	Box	Recall	mAP50	mAP50-95
All	0.993	1	0.995	0.995
Normal	0.994	1	0.995	0.995
Scoliosis	0.992	1	0.995	0.995

The second model exhibits fewer oscillations in the values of the loss function during epochs. Instead of sudden jumps, there is a noticeable gradual decrease in loss as training progresses and the number of epochs increases. This stability in training suggests that the model adapted better to the data, resulting in greater consistency in performance (Figure 4).



**Figure 4:** Second model prediction metrics

Additionally, towards the end, but not less importantly, we observe that model number two did not overfit like model number one. In other words, model number two predicts better on new images and data.

**Table 2:** Second Model performance summary

Class	Box	Recall	mAP50	mAP50-95
All	0.929	0.936	0.955	0.678
Normal	0.859	0.909	0.916	0.542
Scoliosis	1	0.963	0.995	0.814

The results were indeed much better compared to the first model (*Table 2*). The mAP50 metric for all classes was 0.955, while the mAP50-95 was 0.678. The model exhibited satisfactory precision, as indicated by the results from above.

## 4. CONCLUSION

Amidst the rapid evolution of technology and ongoing innovations in medical diagnostics, the use of modern medical image analysis models to detect scoliosis in the spine heralds not only a technological step forward, but also heralds a profound change in the approach to diagnosing spinal disorders. This progress is not just a product of algorithmic skill and computational ability, it also emphasizes a commitment to improving health care and improving patient follow-up.

The assumed performance of the model when faced with different image submissions is substantiated in the study, showing results achieved in both predicted scenarios. It is important to emphasize that this model and its approach to advancing personalized medicine can be adapted to address other detection challenges with minor adjustments and a carefully selected data set. The support extended to healthcare professionals and the augmented diagnostic precision provided by these models significantly augment the efforts of medical practitioners. Beyond being a mere technological addendum, this tool empowers healthcare providers to make informed decisions and devise tailored treatment plans, fostering opportunities for ongoing advancements and refinements to the model over time.

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# DESIGNING VALUE CONSTRAINTS BY APPLYING THE INTERPRETER PATTERN

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**Abstract:** *This paper presents the application of the Interpreter pattern for the dynamic validation of value constraints in software systems. The Interpreter pattern enables the interpretation of language constructs and the evaluation of language sentences. Its application allows the flexible definition and modification of grammar rules at runtime without having to change existing code. The developed software system demonstrates the ability to interpret data dynamically by applying new rules for the validation of value constraints in runtime. This improves the system's ability to adapt to changing user requirements. The proposed method increases the modularity of the system and reduces the complexity of maintenance. The results show that this method not only ensures data consistency but also enables the seamless integration of new validation rules, which emphasizes its practical applicability in dynamic environments. The paper highlights the importance of value constraints in ensuring data accuracy and consistency. By analyzing the application of the Interpreter pattern, the paper provides an efficient example of a software system structure for dynamic data management and enforcement of value constraints.*

**Keywords:** *Interpreter pattern, value constraints, dynamic rule validation, software adaptability, runtime modification*

## 1. INTRODUCTION

Design patterns represent general solutions to problems that frequently occur in the development of software systems and provide a way to reuse software solutions (Gamma et al., 1995). Solutions provided by design patterns are now considered standard, as they are the result of years of research and development of software systems. By using them, a programmer can more easily create a sustainable, modular and understandable program that is easy to update and adapt to new user requirements. In addition to the numerous advantages, design patterns also have their disadvantages, which manifest themselves in an increased complexity of the software system structure. It is also crucial for a software developer to recognize when and which design pattern to apply in order to tailor the system to the customer's requirements. Otherwise, the unnecessary and inappropriate use of patterns can lead to reduced software efficiency and additional program complexity.

The importance of design patterns becomes apparent when client requirements change during program execution (dynamic requirement changes). In such cases, if a suitable pattern is applied in the software system, the system can adapt dynamically and effectively accommodate these changes. The ability of the system to adapt dynamically to changes means that it is flexible, adaptable and resistant to external influences. For example, by applying the Interpreter pattern, the grammar of a language can be defined (or modified) during program execution to interpret the input data according to the current requirements. In addition, the Decorator pattern enables the dynamic addition of new functionalities and/or features to objects during program execution.

The paper describes a software system in which the Interpreter pattern is used for the dynamic validation of value constraints (Lazarević et al., 2018). Instead of the static definition of grammar rules (rules defined in the program code), which cannot be changed, a file with value constraints is introduced. By creating this file, users can change its content (value constraints) during program execution, thus ensuring that the data is interpreted according to the latest requirements. This paper aims to demonstrate the importance of the Interpreter pattern for the dynamic validation of value constraints in a software system for processing student exam applications.

The paper is divided into 6 sections. The introduction and the discussion of basic concepts covered in the paper are followed by an explanation of value constraints and their importance for the development and implementation of software systems (Section 2). Section 3 contains a general definition and explanation of

the Interpreter pattern. Section 4 explains the process of interpretation on a conceptual level. Section 5 presents a case study in which the Interpreter pattern is applied to validate value constraints in a software system for processing student exam applications. The sixth section contains concluding remarks on this paper and directions for future research.

## 2. VALUE CONSTRAINTS

When creating a software system, value constraints are one of the basic mechanisms for ensuring data consistency. Value constraints are rules that define the conditions under which data can be stored in the system (Vlajić, 2020). They reduce the risk of inconsistent and/or incorrect data. These constraints not only ensure the consistency of data, but also allow the system to function according to the specific requirements and expectations of users. For example, in a banking system, value constraints can set the minimum and maximum amount a user can withdraw to prevent unauthorized transactions. Value constraint validation can also be applied in a software system for organizing exams at a faculty. They can be used to assign students to exam rooms and ensure that the number of students in a room is less than or equal to the capacity of the room. Another common example of value constraints is the verification of a username and password when creating a user account. For example, constraints can be defined to ensure that the username contains at least 7 characters and the password contains a combination of letters, numbers and special characters. Defining value constraints is an important step in the process of designing software systems, as it ensures that the system is consistent and correct in different usage scenarios.

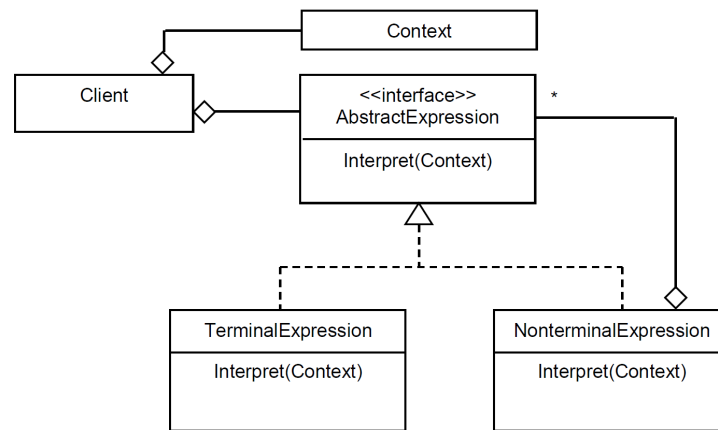
Value constraints contain the definition of the permissible values of attributes of domain classes and can be divided into simple and complex value constraints (Vlajić, 2020). Simple value constraints can define the following: data type (e.g. the user's name must be a String), value range (e.g. the user's year of birth can be greater than 1920 and less than 2024) and format of the attribute value (e.g. the email address should have the format name.surname@fon.bg.ac.rs). Complex value constraints define the interdependence of attributes at the level of one or more domain classes. They are often necessary in situations where simple value constraints are not sufficient to cover all requirements and use cases. For example, if a student wants to enroll in a specific study program at the faculty, they can only do so if they meet the following conditions: has graduated from high school, has the required documents, and has taken the entrance exam and achieved the required score. Such a complex value constraint combines data from several domain classes tracked in the system (school points achieved, documents submitted and points achieved in the entrance exam).

The challenges that programmers face when defining value constraints include efficiency, data accuracy and sustainability. The programmer must ensure that the validation of value constraints is performed efficiently (quickly and with minimal use of resources) in order to avoid delays and long waiting times during data processing. The system must also accurately detect inconsistent data, as this can lead to an unreliable system.

The aim of this paper is to enable the modification of value constraints during program execution. This is achieved by moving value constraints to a separate file and using the Interpreter pattern. The Interpreter pattern enables the interpretation of expressions and provides flexibility in changing value constraints during program execution. In the following section, we will explain the Interpreter pattern used for the dynamic definition and modification of value constraints in more detail.

## 3. INTERPRETER PATTERN

The Interpreter pattern is one of the behavioral patterns published in the book *"Design Patterns: Elements of Reusable Object-Oriented Software"*, which enables the interpretation and evaluation of language sentences (Gamma et al., 1995). It aims to define, for a given language, the representation of the grammar of the language together with an interpreter that uses this representation to interpret sentences in the language (Gamma et al., 1995). The operation of the interpreter usually involves the definition of syntactic rules or rules that use abstract syntax trees (ASTs). AST represents a hierarchical structure that describes the structure of the language (rules) through which the interpreter goes and performs defined operations. The structure of the Interpreter pattern comprises five basic elements: context, expression, terminal expression, non-terminal expression and client (Figure 1).



**Figure 1:** The general structure of the Interpreter pattern (Gamma et al., 1995)

The *Context* represents the environment in which the sentences of the language are interpreted. It contains global information that is necessary for the interpretation of expressions (Gamma et al., 1995). The *AbstractExpression* component represents an abstraction (abstract class or interface) that defines the interpretation operation, i.e. the operation that is common to all nodes of the abstract syntax tree (Vlajić, 2014). Each tree node must implement the operation *Interpret(Context)*, which is responsible for executing the interpretation of the corresponding language element. The *TerminalExpression* component implements the *Interpret* operation for terminal symbols (leaves of the abstract syntax tree), while *NonTerminalExpressions* component are used to define complex grammar rules (nodes with one or more children). A non-terminal expression can consist of several terminal and/or non-terminal expressions. The use of non-terminal expressions makes it possible to break down grammar rules into smaller parts, which facilitates the interpretation of the expressions.

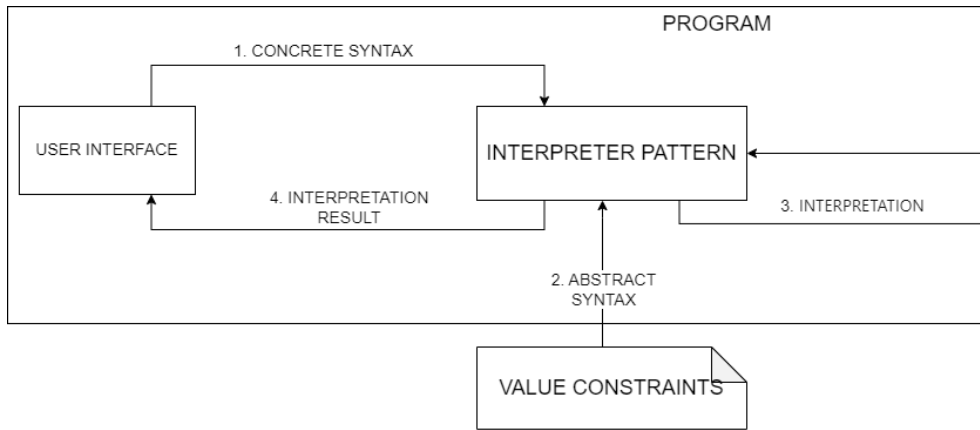
The general structure of the Interpreter pattern also includes the client class, which creates the abstract syntax tree that represents a particular sentence in the language defined by the grammar (Vlajić, 2014). The tree is composed of occurrences of non-terminal and terminal expressions, and the client is responsible for initiating the interpretation operation (*Interpret*) on the input data. All elements of the general structure of this pattern together enable the interpretation of language sentences using the defined grammar.

The Interpreter pattern provides numerous advantages in software system design. It enables flexible addition of new grammatical rules without the need to modify existing code (Gamma et al., 1995). For example, in a software system designed for organizing exams at a faculty, where the Interpreter pattern checks the condition for exam registration (for instance, whether the student has registered for the course), adding new (more complex) rules to the software system is straightforward. New constraints are added by implementing the *AbstractExpression* interface, while the rest of the system structure remains unchanged. For instance, we can add rules that consider the student's average grade, the status of their student account, and the number of exams passed.

In addition to the advantages mentioned, the Interpreter pattern also has some disadvantages. The complexity of the grammar can be a challenge for the programmer, especially in the case of complex expressions. For example, consider a software system that interprets mathematical expressions involving both basic operations (addition, subtraction, multiplication and division) and more complex operations such as exponential functions, roots and trigonometric functions. In such a system, each mathematical operation requires a corresponding interpreter that defines rules for its interpretation. For example, if we have a mathematical expression with nested operations (both simple and complex), each part of the expression must be interpreted separately according to the grammar of the language. This can lead to complex and convoluted code and interpretation algorithms, especially if the grammar is constantly changing or expanding.

#### 4. DESIGNING VALUE CONSTRAINTS USING THE INTERPRETER PATTERN

Further in the text, the process of data interpretation will be explained, which occurs in several phases (Vlajić, 2023). Figure 2 illustrates the process of interpretation at a conceptual level.



**Figure 2:** Data interpretation process

The first step of the data interpretation process involves accepting data from the user interface (in general, the user interface can be any other software component in the software system architecture). The data from the user interface represents a concrete syntax, i.e. the input data to be interpreted. Once the data has been received from the user interface, it is forwarded to the interpreter. The Interpreter pattern interprets the data according to the defined value constraints from the file. The file contains an abstract syntax that defines the value constraints that the data must fulfil.

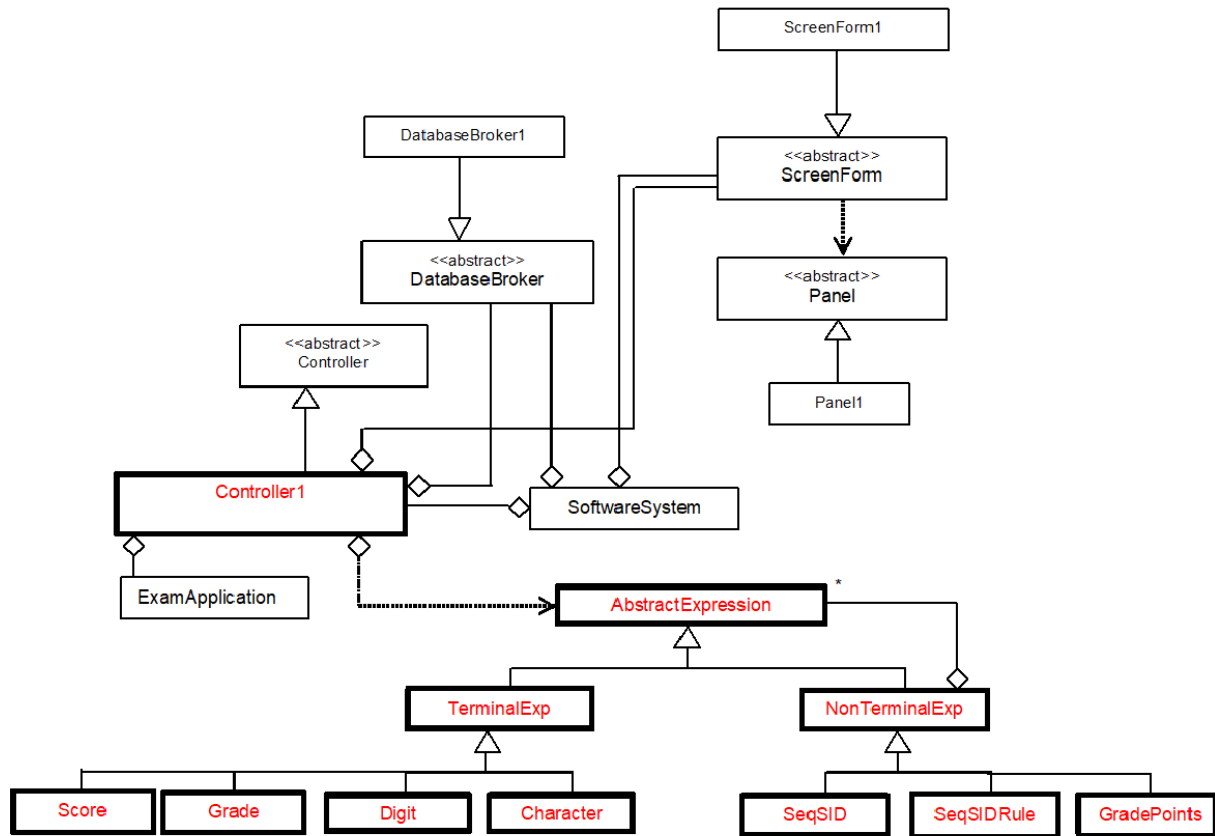
After loading the value constraints from the file, the data from the user interface is interpreted. The system checks whether the concrete syntax matches the abstract syntax. If the data matches the defined constraints, the interpretation is successfully completed. Otherwise, the system reports that the interpretation process was not successful. The feedback about the failed interpretation process enables the user to correct errors in the data and thus ensure the consistency of the system.

## 5. CASE STUDY

Within the case study of this paper, a software system implemented in the Java programming language will be discussed. The problem domain of the system is the processing of student exam applications, where it is imperative for the data within the system to comply with defined value constraints (Vlajić, 2023). An exam application object comprises the following attributes: application code, student ID number, subject code, exam date, grade and score. The basic requirements of the software system include performing operations such as inserting, deleting, searching, and updating exam applications in the system. Additionally, there are requirements to validate the correctness of the value constraints for attributes student ID number and grade before saving the exam application in the system. In addition, it is necessary to allow value constraints to be changed during program execution and to ensure that the system interprets data in accordance with these value constraints.

To overcome the challenges mentioned above, the Interpreter pattern is used, which enables the interpretation and application of new (changed) value constraints in runtime. The interpretation is performed according to certain rules defined in a file with the value constraints. By applying the general structure of the Interpreter pattern, the system is enabled to flexibly interpret and apply new validation rules, ensuring that the data within the system remains compliant with changing user requirements.

Based on the general structure of the Interpreter pattern and user requirements, a software system has been implemented. The class diagram of software system is shown in Figure 3.



**Figure 3:** Class diagram of a part of the software system (Vlajić, 2023)

In the class diagram of a part of the software system (Figure 3), the classes *Controller1*, *AbstractExpression*, *TerminalExp*, *NonTerminalExp*, *Score*, *Grade*, *Digit*, *Character*, *SeqSID*, *SeqSIDRule* and *GradePoints* form the structure of the Interpreter pattern. Their role is to verify value constraints before the domain object of the *ExamApplication* class is saved. These classes are necessary to maintain data consistency and ensure the correctness of the data within the system. Other classes are involved in the creation and operation of the software system. The abstract classes *ScreenForm*, *DatabaseBroker* and *Controller* together form a software system (*SoftwareSystem*). *ScreenForm*, *ScreenForm1*, *Panel* and *Panel1* determine the appearance of the screen form, while *DatabaseBroker* defines the operations with the database. The *Controller* responds to user requests and invokes system operations on the database (creating, editing, searching and deleting exam applications), which are defined in the *DatabaseBroker1*.

According to the general structure of the Interpreter pattern, *Controller1* acts as a client that initiates the interpretation of the input data with the help of the *AbstractExpression* abstraction. *Controller1* checks whether the values of the attributes student ID number and grade match the specified constraints. The rules that are applied when interpreting the attribute values are defined in a file (Listing 1). The contents of the file can be changed while the program is running. The flexibility in changing these constraints allows the system to adapt to different situations and user requirements over time.

```

#Student ID number format
studentIDNumberFormat = CCCC/CC

#Minimum and maximum year of enrollment
minEnrollmentYear = 10
maxEnrollmentYear = 24

#Minimum and maximum student ID number
minStudentIDNumber = 1
maxStudentIDNumber = 1200

#Regular expression for the range of points
minPoints = 0
maxPoints = 100

#Regular expression for the range of grades
minGrade = 5
maxGrade = 10

#Points (in %) required for a passing grade
#Each subsequent grade has a threshold that is 10% higher
thresholdFor6 = 53

```

**Listing 1:** Example content of a file for defining value constraints

The abstract class *AbstractExpression* contains an abstract method *interpret(String context)*, which subclasses implement in different ways according to specific data validation requirements. For example, the class *Digit* checks if the passed String is a number between 1 and 9, while the class *SeqSID* verifies if the student ID number value is consistent with the defined constraints from the file.

The classes *Grade*, *Score*, *Digit* and *Character* represent terminal expressions or leaf nodes that are formed by applying the Interpreter pattern. The *Grade* class interprets the value of the grade attribute, while the *Score* class checks whether the value of the score attribute is within the permitted range. The *Character* class interprets whether the passed character corresponds to the defined format (the format is defined when the *Character* class is instantiated).

The classes *SeqSID*, *SeqSIDRule* and *GradePoints* are non-terminal expression classes. They can contain one or more terminal and/or non-terminal expressions, providing the possibility for a more complex interpretation of data within the system. The *SeqSID* class is responsible for checking whether the value of the student ID number corresponds to the format defined in the file (the format consists of a combination of numbers and letters). The interpretation within this class is performed using the interpretation of the terminal expressions *Digit* and *Character*. The *SeqSIDRule* class checks the constraints related to the maximum and minimum values of the student ID number and the year of enrolment, but only after the format of the student ID number has been checked in the *SeqSID* class. The *GradePoints* class contains two terminal expressions (*Grade* and *Score*) with which it checks whether the values of the grade and score attributes match the defined constraints. In addition to interpreting the terminal expressions, the *interpret* method of the *GradePoints* class checks if the entered grade corresponds to the achieved score. This interpretation involves the dependency of attributes within a single domain class and includes the following steps: Calculating the percentage of the score achieved in relation to the maximum score; Calculating the grade based on the percentage threshold for passing the grade (condition read from the file) and the percentage of the score achieved; Comparing the grade entered from the form with the calculated grade.

An example of interpreting the value of the student ID number is provided below. Value constraints are checked in the *Controller1* class before the exam application change operation is executed. The validation of value constraints is performed as follows:

1. The contents of the properties file are loaded.
2. Instances of terminal and non-terminal expressions are created based on the constraints defined in the file. First, the *SeqSID* class is instantiated, followed by the *SeqSIDRule* class, which contains a reference to *SeqSID*. In the constructor of the *SeqSID* class, the format for interpreting and validating the value constraint of the student ID number is defined (Listing 2). The format is stored in an array of *AbstractExpressions* objects, consisting of the classes *Character* and *Digit*.

```

public SeqSID(String format1) { // Abstract syntax
    format = format1;
}

```

```

        int length = format.length();
        ai = new AbstractExpression[length];
        for (int i = 0; i < length; i++) {
            if (format.charAt(i) == 'C') {
                ai[i] = new Digit();
            } else {ai[i] = new Character(format.charAt(i));}
        }
    }
}

```

**Listing 2:** The constructor of the SeqSID class

3. The interpretation method is applied to the object of the *SeqSIDRule* class. It first interprets whether the value of the student ID number matches the constraints defined in the *SeqSID* class. The *interpret* method of the *SeqSID* class is shown in Listing 3. The method iterates through each element (character/letter) of the student ID number and calls the *interpret* method of the corresponding element of the array of abstract expressions. If all elements have been successfully interpreted according to the specified rules, the *interpret* method returns true. After confirming that the format of the student ID number is satisfied, the range of values for the student ID number and the year of enrollment is checked within the *SeqSIDRule* class.

```

public boolean interpret(String seq) {
    String[] c = seq.split("");
    if (c.length != format.length()) {
        return false;
    }
    for (int i = 0; i < c.length; i++) {
        System.out.println("c[" + i + "]: " + c[i]);
        if (ai[i].interpret(c[i]) == false) {
            return false;
        }
    }
    return true;
}

```

**Listing 3:** Method interpret of the class SeqSID

## 6. CONCLUSION

The importance of the Interpreter pattern for the dynamic validation of value constraints was emphasized in the paper. Through its application, a flexible and adaptable software system was developed for the processing of student exam applications. The developed software system demonstrates the possibility of dynamic data interpretation by applying new rules to validate value constraints in runtime.

It is important to mention that the developed software system serves as a basis for further research. As part of further research, it is planned to extend the software system by implementing complex value constraints, as the current system only checks simple value constraints. In addition, the processing of structural constraints is planned in order to extend the functionality of the system and enable an appropriate response to more complex scenarios and user requirements.

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# IMPROVING ADDRESS RETRIEVAL IN GPS BASED SOFTWARE SYSTEMS

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**Abstract:** *This paper evaluates different methods for retrieving address data within a GPS tracking application. With the expanding use of GPS for various applications, the accuracy and efficiency of address retrieval are paramount. This study compares three principal approaches: the use of external APIs, such as Google Maps or HERE Maps, the utilization of a pre-existing location table created from past application usage, and a combined model integrating both methods. The advantages and limitations of each method are analyzed, considering factors such as response time, accuracy, data usage, and operational costs. A series of experiments were conducted to assess each method's performance under various conditions. The results suggest that while API-based solutions offer the most up-to-date information and scalability, they may incur significant costs and dependencies. Conversely, using a location table can enhance response times and reduce data usage but at the expense of accuracy and comprehensiveness. The combined model attempts to balance these aspects by leveraging the strengths of both strategies.*

**Keywords:** *gps, geolocation, performance evaluation, software system*

## 1. INTRODUCTION

GPS tracking applications are software solutions that rely on GPS data to provide real-time tracking of vehicles, people, or animals (Rasdorf et al., 2012). These applications utilize devices that are either built into the subjects being tracked or carried by them. As integral components of larger Fleet Management Systems (FMS), these applications allow businesses to oversee and optimize the operations of their vehicle fleets. Beyond fleet management, GPS tracking is also utilized in personal safety devices and public transportation management systems, enhancing service reliability and operational efficiency. By leveraging real-time location data, these applications offer critical functionalities such as route planning and logistics management, making them indispensable in both commercial and personal contexts.

These applications are underpinned by the Global Positioning System (GPS), a global navigation satellite system developed and maintained by the United States government (Leick et al., 2015). The system consists of 24 satellites in orbit approximately 20,000 kilometers above Earth's surface (United States Department of Defense, 2008). To compute an approximate location, including latitude, longitude, and altitude, a GPS device requires signals from at least four satellites (Chow, 2008). This setup includes three satellites for latitude and longitude determination and an additional satellite to assess altitude (Guier & Weiffenbach, 1997). GPS can also be highly precise, sometimes able to locate a device with 1 cm precision (Larsen, Nielsen, & Tyler, 1994). Initially developed for military applications, the GPS system was opened to civilian use in the 1990s. Due to its comprehensive availability and reliability, GPS has become a foundational technology for a wide range of applications across civilian, commercial, and military sectors.

One critical application that builds on the capabilities of GPS is reverse geocoding, which converts geographic coordinates into a readable address or place name (Curtis, Mills, & Leitner, 2006). This process is essential for making GPS data practical and understandable for everyday applications. For instance, when a GPS tracking system captures the coordinates of a vehicle, reverse geocoding can transform those coordinates into street addresses, thereby providing valuable context such as the nearest intersection or building. This is particularly useful in applications like emergency response, where rapid, accurate location identification can save lives, or in logistics, where precise delivery locations are crucial. Reverse geocoding not only enhances the functionality of GPS tracking applications by adding a layer of human-friendly information but also improves user interaction by allowing individuals to search and navigate based on commonly recognized address formats rather than obscure coordinate systems.

There are several ways to implement reverse geocoding. The most frequently used method is the use of an external API by providers such as Open Street Maps (OSM), HERE Maps, Google Maps and others. These services can be free, but are most commonly paid on a pay-per-use subscription model. Most often they provide a long list of geolocation services and have information about almost all locations on the globe (McKenzie & Janowicz, 2015). An alternative to this method is a local approach - storing geolocation data in

a local database, and using that database for geolocation queries. This approach can significantly reduce costs, increase speed and reduce dependencies on third-party services, but can also be very limited in terms of geocoding capabilities (Jarke & Koch, 1984). This can be a big drawback, especially in the case of applications that always require the most up-to-date data and total coverage.

The aim of this research is to compare different methods for retrieving address data (reverse geocoding) within the existing GPS tracking application. In this paper, three strategies are compared: using an external API (Google Maps API), using a local table with locations (Stored in the MongoDB database) obtained through the Google Maps API by applying the application's historical usage, and a hybrid approach that integrates both methods.

The rest of the paper is organized as follows. Section 2 describes the methodology used in the research – three tested methods. Section 3 presents an overview of the data the methods were tested on, different criteria used for evaluation as well as the obtained results, observing the method performance according to the given criteria. Section 4 discusses the limitations, implications, and advantages of each of these methods. Finally, in Section 5, the conclusions obtained in the study are drawn, the key insights are summarized and further directions of development are reviewed.

## 2. METHODOLOGY

The objective of the study is to compare different methods for acquiring detailed address data from GPS device information, specifically using latitude and longitude coordinates. The methodology of this study involves evaluating three primary approaches for retrieving reverse geocoding data within GPS tracking applications, with a focus on applications operating in Serbia. The methodology encompasses three primary approaches detailed in the sections that follow.

### 2.1. Basic reverse geocoding methods

Below are the two basic methods used:

- **External API:** This method involves using an external service (in this case, the Google Maps API) to convert location values (latitude-longitude) into a human-readable format. In this paper, a part of the Google Maps API service, called Geocoding API, was used. This service contains the required functionality - Reverse Geocoding. Geocoding API charges \$5 per 1.000 requests sent, which equates to \$0.005 per request. Results are obtained using GET requests with URL parameters representing latitude and longitude (Svennerberg, 2010). The response to this request is a JSON with detailed location information corresponding to the given latitude-longitude pair.
- **Pre-existing Location Table:** This approach utilizes a collection of addresses that have been accumulated from historical use of the application and interactions with an external API (Ong et al., 2015). The premise is that the majority of locations traversed by vehicles have already been logged in the first year of the application's operation, negating the need for continual reliance on an external API. Instead, the application leverages a pre-existing database of saved addresses and their corresponding latitude-longitude pairs. This database is managed using MongoDB, chosen for its robust handling of large data volumes and its built-in support for geographic data queries. The "existing-address" collection in this database houses approximately 200,000 entries, each containing "lat", "lng", and "address" data. To reduce data-fetch latency, the database is hosted on the same server as the backend application. The process for retrieving an address from a given latitude and longitude involves querying this MongoDB database. Instead of standard queries, MongoDB Geospatial Queries are employed—these are specifically optimized for spatial data requests (Yuliang, Xiangwei, & Bo, 2015). An address is considered successfully retrieved if there is a recorded latitude and longitude in the database that is within 10 meters of the requested coordinates. This 10-meter threshold was selected based on the average proximity of addresses in the historical data.

Distances are calculated using the Haversine formula, which accounts for Earth's curvature and calculates the great-circle distance between two points on a sphere (Winarno, Hadikurniawati, & Rosso, 2017). Unlike Euclidean distance, which measures the shortest straight-line distance in a flat plane, the Haversine formula provides a more accurate measure by considering the spherical shape of the Earth (Ikasari et al., 2021). The formula is defined as follows:

$$d = 2r \arcsin \left( \sqrt{\sin^2 \left( \frac{\Delta\phi}{2} \right) + \cos\phi_1 * \cos\phi_2 * \sin^2 \left( \frac{\Delta\lambda}{2} \right)} \right) \quad (1)$$

## 2.2. Combined model approach

The Combined Model approach aims to leverage the speed and cost-effectiveness of the local location database search approach while ensuring that there are no gaps in the data by also leveraging an external API. This hybrid approach works in the following way - first it tries to find the requested location in the local location database using MongoDB Geospatial query, and then, if the query does not return a result, that same latitude-longitude pair is sent to an External API (Google Maps API) (Chow, 2008). In cases where the external API is called, a record of that address is subsequently saved in the MongoDB database for further use. For most queries, this method should be slower than only searching the local database, because for some locations it also searches both the database and calls an external API. However, this method should also always retrieve location data.

The Combined Model provides a balance between a solution that uses local resources to minimize costs and optimize speed, and a model that always returns the desired data. The best way to represent sequence of steps with conditions and branching is by utilizing a algorithmic flowchart (Cormen, Leiserson, Rivest, & Stein, 2009).

Flowchart of the combined model is shown in Figure 1.

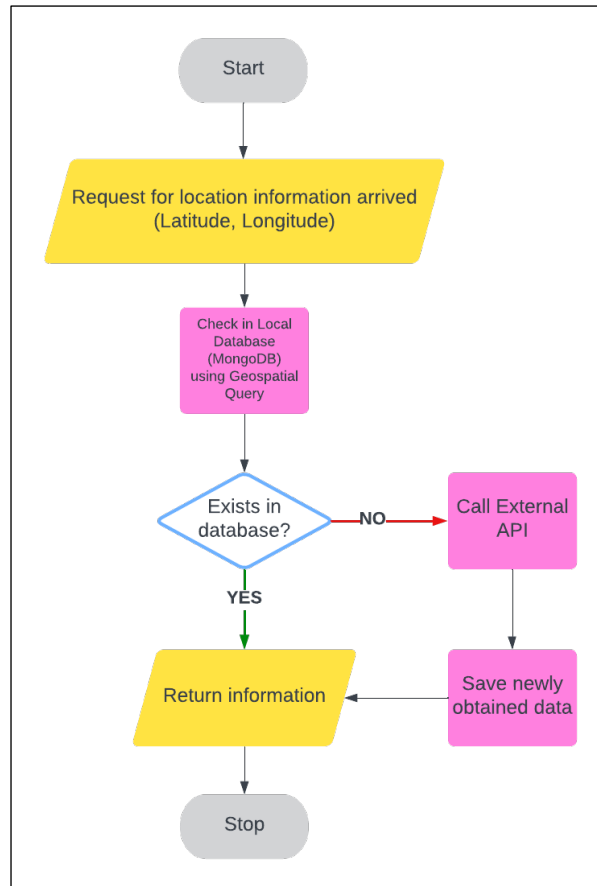


Figure 1: Combined model algorithm.

## 3. EVALUATION

This section delves deeper into a comprehensive evaluation of the three methods used for reverse geocoding mentioned in Section 2. Each of these methods was rigorously tested using over 200 cases spanning different conditions, times of day, and vehicle loads. The evaluation was based on three main criteria: data reliability, response time and operational costs. These criteria were chosen to assess the effectiveness and efficiency of each method in real-world scenarios. The results obtained by conducting the tests were then quantified and presented.

### 3.1. Evaluation Criteria

Each of the three approaches presented in Section 2 will be evaluated based on the following criteria:

- **Data reliability:** This criterion assesses how reliably address information is obtained from latitude and longitude pairs. Specifically, it measures the percentage of these pairs for which an address result is successfully found (Meeker, Escobar, & Pascual, 2022).
- **Response time:** This criterion indicates the speed at which the report is completed, i.e., how quickly all address data for a series of latitude and longitude values is obtained (Levesque & Wagenbreth, 2010).
- **Operational costs:** This refers to the average cost incurred to generate a report for a single vehicle (Peterson, 2019).

To ensure that the evaluation is thorough, a test was conducted on over 200 cases (segments of daily vehicle movements, lasting 12 hours each) including 20 randomly selected vehicles. These vehicles were tested under different loads, conditions, parts of the days, weeks, and months. It is assumed that it is necessary to find the address data for each vehicle report. This approach is designed to ensure that the result data is not biased. After completing the tests, average and median values were calculated for each of the mentioned criteria to provide a fair evaluation for each of the mentioned approaches (Basili & Weiss, 1984).

### 3.2. Results

During the evaluation period, reports were made with an average (mean) frequency of 291 reports per hour, while the median frequency was slightly higher (310 reports per hour). Slight difference between mean and median value indicates a skew in the data towards some vehicles with a high number of reports, pulling the mean value up (Nijs & Klausen, 2013). This information highlights the active reporting of vehicles and the continuous communication of the vehicle and the tracking system providing a thorough dataset for reverse geocoding approach performance assessment.

Additionally, it was observed that over 61% of the locations (latitude-longitude pairs) sent by vehicles during one period were repeated. This indicates that in one test period the vehicle sends only 39% of unique locations, reflecting the recurrent nature of the routes and stops encountered (Avrutov, Ryzhkov, & Sushchenko, 2020).

The table below summarizes the performance of each reverse geocoding method across the evaluation criteria:

**Table 1:** Summary of Reverse Geocoding Method Performance

Method	Data Reliability (%)	Response Time (ms)	Operational Cost (\$)
External API	100%	~980000ms	\$17.2
Location Table	95.3%	~507500ms	\$0
Combined Model	100%	~570800ms	\$0.89

## 4. DISCUSSION

Observing the results from the point of view of data reliability, it can be noted that the External API approach as well as the Combined Model provide equal results. This is the expected behavior because, in the Combined Model every latitude-longitude pair that is not found in the location table is obtained by calling an external API (In this example Google Maps API). Approach based solely on the use of the location table retrieves address information in about 95% of cases.

It is important to note that just getting a result does not necessarily mean that the result is completely correct. Combined Model, due to the prioritization of data from the location table, is prone to the problem of outdated information, where a street, place or some other geo location has been given a new name, or the enumeration has been changed.

As far as response time is considered as a criterion, the following conclusion is reached: Using a local location table in combination with a MongoDB Geospatial Queries is an approach which gives the best results. It is 11.10% faster than the Combined Model and 48.20% faster than the approach using an External API. This result was expected due to MongoDB-s optimization for geospatial queries as well as a minimum latency cost (Li & Yang, 2014). It is interesting to note that the Combined Model searches some locations twice - the first time in the local location database, and when it does not find them there, it calls an external API. In this example this scenario happens in only about 5% of cases.

The last criterion is the operational cost based. If the costs of hosting the database are ignored (since it is certainly necessary for the operation of the application in terms of reports, movement history, etc.), the approach using the local table of locations does not create any additional costs. Approach using only the external API resulted in an average cost of \$17.2 for a 12-hour interval (about 3500 vehicle reports). When observing this approach Internet traffic prices (bandwidth) of the server on which the application is hosted were ignored, and only billing by the API provider was observed. It is interesting to note that due to the recurrent nature of vehicle movement, about 61% of addresses were repeated several times during one interval, so many of these API calls were repeated - returned the same result. From that point of view, solely external API approach is economically inefficient. The Combined Model found about 95% of locations in the local location table. In view of that, only 5% of locations were requested from the external API, so the cost in the comparison period was slightly lower than \$1. Further optimization of this approach could be in saving these new addresses obtained from the external API in the location database itself.

## 5. CONCLUSION

Analyzing the results, one cannot arrive at single “best” approach. Each of these approaches has its own advantages.

*The Local Location Table approach* provides a time efficient and zero-cost way of obtaining address data, with the downside of not always providing the address.

*External API approach* is the best choice in situations where it is necessary to always get the most up-to-date information, regardless of the price. When using this approach, it is necessary to pay attention to the number of redundant queries - that is, low efficiency in situations where the route is often repeated.

*The Combined Model approach* strikes a balance between these two approaches. It is slower than the approach using only the location table, but it also has better data completeness. The operational cost of this approach depends on the quality of filling the location table but should always be more cost-efficient than using solely external API.

Further research could focus on improving existing models, such as testing different thresholds for location sensitivity (10 meters is used in this research), experimenting with a smaller or larger number of records in the database, testing different distance formulas, or switching to different API providers (Here Maps, OSM, etc.). Additionally, integrating machine learning algorithms could enhance the accuracy and efficiency of address retrieval. Exploring real-time data processing techniques and the use of alternative data sources, such as satellite imagery and sensor networks, could provide valuable insights and new opportunities for innovation (Xiong, 2021). Future studies should also investigate the scalability and robustness of these systems in diverse geographical and operational contexts.

Moreover, incorporating advanced caching strategies based on vehicle history could significantly improve performance and reduce costs. Predictive caching using historical data patterns can minimize redundant API calls and enhance the efficiency of address retrieval (Javed & Zeadally, 2021).

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# **BLOCKCHAIN TECHNOLOGY IN BUSINESS AND INFORMATION SYSTEMS**

# DEVELOPMENT OF PERSONAL HEALTH RECORD BASED ON BLOCKCHAIN

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**Abstract:** *Patients face challenges such as the inability to track their all-health activities through a single application. The paper provides a detailed overview of the design and development of a decentralized PHR application based on blockchain. The application design encompasses main interactions between patients and key stakeholders in a healthcare ecosystem. Design of the developed PHR application prioritizes simplicity, intuitiveness, and accessibility, fostering seamless interaction for healthcare providers and patients. B2C transactions can be conducted using developed smart contract in Solidity. Developed application enables patients to track their medical reports, analysis, medical treatments and to track their health parameters in real time. This is a unique application that enables storing all medical records and medical data history in one place with possibility to share this data in the request.*

**Keywords:** *Blockchain, Personal Healthcare Record, Ethereum based application*

## 1. INTRODUCTION

The problem faced by many patients stems from the fact that they have numerous documents and findings from various healthcare providers that are not located in one place, making it difficult to manage all documents, analyses, results, and similar items. All of this affects efficiency and accuracy during medical examinations. Additionally, the existence of various standards for health data complicates consistency and uniformity. In an era marked by digital innovation and the democratization of healthcare, the integration of blockchain technology has emerged as a transformative force (Agbo et al., 2019). As individuals increasingly seek personalized solutions for managing their health and wellness, the development of personal healthcare applications leveraging blockchain stands at the forefront of this revolution (A. Labus et al., 2022).

The main aim of this paper is to develop a decentralized PHR application based on blockchain technology, which will solve the problem of storing all data in one place, provide the ability to choose healthcare provider services, and manage the entire patient health record. Furthermore, the paper will feature a description of smart B2C contracts programmed in the Solidity programming language. These smart B2C contracts' transactions will be tested on the Sepolia test net, with the aim of addressing the challenges faced by patients mentioned above. By leveraging blockchain technology, the main goal of application is to ensure the security and integrity of health information, allowing users to consolidate their medical records from various sources into one comprehensive application. The application empowers users with unparalleled control over their health data. Users can selectively share their health metrics with chosen individuals or healthcare providers, thereby maintaining their privacy while facilitating a collaborative healthcare environment. Additionally, the application extends its utility by incorporating information on donations and insurance, providing a complete overview of the user's health profile. By offering a centralized platform for all medical data, PHR application aims to revolutionize the way patients interact with their health records and engage with the healthcare system.

## 2. IMPORTANCE OF BLOCKCHAIN IN HEALTHCARE SYSTEMS

The encyclopedic usage of the internet is one of its main functionalities. The internet has big impact on education and empowering the health consumers, by giving them necessary information on healthcare and health services. Interactivity of the internet probably has the biggest profound impact on health and healthcare, because it is changing the way of communication between patient and doctor such as communication through e-mail (Powell et al., 2003).

With the fast growth of Internet of Medical Things (hereinafter: IoMT) with focus on personal health, personal health data are collected by IoMT and stored as Personal Healthcare records (hereinafter: PHRs). PHRs are



highly private, and process of sharing data can lead to leaking and concerns that privacy and security will be violated, especially in centralized systems (Wang et al., 2021). Blockchain could be one of the solutions as this technology has big focus on areas of electronic health Records and Personal Health Records (Attaran, 2022).

Practitioners in healthcare systems as well as patients come across difficulties with accessing, managing, and sharing health records with secure. Patients should be able to share and keep track of their data and to manage their personal healthcare records anywhere in the world, but current technologies don't meet requirements for this due to the limited possibilities of privacy, security, and ecosystem interoperability (Attaran, 2022).

There are many benefits of IoMT, but there are challenges when it comes to its usage in real world due to its centralized client/server model. Moving the IoMT system into decentralized platform such as blockchain can solve many problems, especially the problem of security (Atlam et al., 2018). One typically usage of blockchain applies to drug supply chain management and data management purposes to avoid frauds and to encourage patients in their way of looking on data. Blockchain is resolving the problems by making the drug supply chain trustworthy, transparent, traceable, and resistant to intrusion of counterfeit medicines (Adere, 2022).

Decentralized systems are great for keeping digital assets organized, that were created by various institutions. This is attractive for applications where users do not prefer to relay on central authority, and in private healthcare systems there are many institutions for patients. (Jafri & Singh, 2022) Blockchain have big advantage when it comes to recordings of data provenance, because it creates an erasable track of transactions, so critical records are always available for all in network to inspect (Kuo et al., 2019).

Due to the need for a more patient-centric approach to healthcare systems and needs for connection of different health systems to increase accuracy of electronic healthcare records (EHRs), blockchain has a huge potential in providing necessary resources (Hölbl et al., 2018). Therefore, blockchain has many potentials and in the next part of the document is example of implementing it in healthcare application which could be used in real world.

Electronic Health Records (hereinafter: EHR) are digital systems that connect different healthcare providers, offering benefits like better prescription management and disease control. However, they face issues with interoperability (for example, when health organizations adopt international but diverse standards) and security of shared data (Bhartiya et al., 2016) .

Blockchain interoperability is representing one of the crucial features of blockchain technology (Belchior et al., 2022). It is considered that there is no way of reaching interoperability without a trusted third party, because clients would need to convert one cryptocurrency into another to use different blockchain (Lafourcade & Lombard-Platet, 2020), but the complex landscape of blockchain underscores the need for interoperability mechanisms to ensure widespread acceptance of this technology. (Bhatia, 2020) One way to get over the third party is using the benefits of interchain interoperability and its seamless exchange of cryptocurrencies through automatic swapping (Mohanty et al., 2022). This technology can't meet the needs of current world if different ledgers don't communicate with each other and old systems. Therefore, blockchain platforms should be able to interact with each other and provide services one to another (Khan et al., 2023).

Based on the nature of data that is used in PHRs and EHRs it is necessary to consider private blockchains. Private blockchain systems are designed with strong security and performance requirements. Target of this systems are applications that have sensitive data like banking, finance and health (Dinh et al., 2017). The issue of current private blockchains is that they limit the data, assets and processes within closed boundary witch limits secure service providing to the customers. Therefore, there are solutions that propose using architectures that combine public and private blockchains (Ghosh et al., 2021).

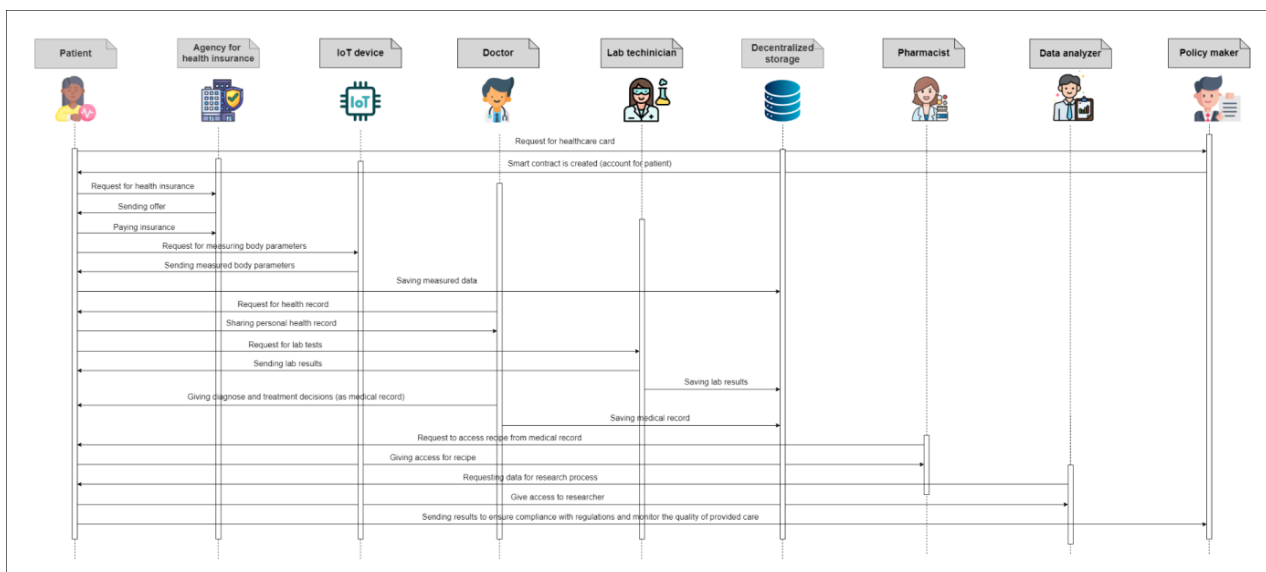
### **3. DESIGNING DECENTRALIZED PHR APPLICATION**

The focus of this paper is on one aspect, which is the patient's perspective through a personalized healthcare application. Patients are at the core of the healthcare ecosystem, owning and controlling their health data. They use the PHR application to enter, manage, and share their health information, granting access to their records to healthcare providers, researchers, or other parties as needed. This empowers patients to take an active role in their health management and decision-making processes. Beside patients there are also.

In the blockchain-based Personal Health Records (PHR) ecosystem, patients are at the forefront, controlling their health data through a PHR application. They can share their records with healthcare providers, researchers, and others as needed. Healthcare providers, such as hospitals and clinics, integrate the PHR system into their workflows to access and update patient records, enhancing personalized care. Medical laboratories and pharmacies contribute by uploading test results and prescription information, ensuring up-to-date records. Research institutes access anonymized data for medical studies, advancing science and healthcare outcomes. Insurance companies transfer policy data to the PHR application, streamlining the claims process. IoT device manufacturers ensure compatibility with the PHR system for real-time health monitoring. Data processing and analytics companies provide insights from health data to inform decisions. IT infrastructure partners support the technological backbone of the system. Blockchain providers secure health records on a decentralized ledger, enhancing privacy and security. Lastly, government agencies set standards and guidelines to ensure compliance and protect patient rights in this integrated, interoperable, and secure healthcare ecosystem.

Establishing interoperability is indeed one of the most crucial aspects of the PHR application. By ensuring that all stakeholders, including patients, healthcare providers, and other partners, use a standardized data model and are on the same Ethereum blockchain, seamless data exchange and communication can be achieved. However, in scenarios where other partners' applications are on a different blockchain, mechanisms to achieve interoperability become essential. Some mechanisms can include cross-chain protocols enabling communication and data exchange between different blockchain networks. To ensure interoperability with off-chain or legacy systems, we will implement decentralized oracles in our PHR application. These oracles will act as bridges, enabling the blockchain-based PHR system to securely and reliably communicate with external data sources and systems that are not on the blockchain.

Figure 1 shows the sequence diagram for the healthcare ecosystem based on blockchain. A sequence diagram is a type of interaction diagram in UML (Unified Modeling Language) that illustrates the flow of messages and interactions between objects or components within a system. In this paper sequence diagram shows the main functionalities which are developed via PHR application and the business logic behind patient's interaction with other key partners in healthcare system.



**Figure 1:** The sequence diagram for the healthcare ecosystem based on blockchain

The sequence diagram illustrates how a patient and various stakeholders communicate through an application seamlessly integrated with the blockchain. The process starts when a patient initially requests the issuance of a healthcare card. Subsequently, a responsible person at the healthcare facility creates an account for the patient, entering key information such as name, surname, social security number, unique ID, etc. This transaction is recorded on blockchain. Doctors may request access to a patient's health record. Patients, on the other hand, possess the ability to selectively share information from their health records with specific doctors by adding them to their access list. This action is recorded on the blockchain. Subsequently, doctors gain access to view the medical information of the designated patient from the blockchain. In case laboratory test are needed, the patient can request them. When then the results are done, they are stored on the blockchain. The patient has the option to later share these results with their doctor. The doctor can make a specific diagnosis or write a report, and then request to save it in the patient's medical history. Once the

patient approves the recording, it is securely saved on the blockchain. Pharmacists have the right to request access and review the prescription that the patient has received. Patient adds pharmacists with whom they can share prescriptions, on the blockchain. Then, pharmacists can retrieve prescription information from the blockchain and view prescriptions. Additionally, patients have the option to share their data with analytical companies, enabling further processing and analysis of health information. IoT wearable devices can request access to record a patient's health parameters, including heart rate, blood pressure, and activity levels. Once the patient approves the recording, it is securely logged on the blockchain. The patient can request coverage from the health insurance company. When the insurance company accepts the request and funds are transferred to the account, the transaction is recorded on the blockchain. The patient can schedule an appointment with the doctor, and this transaction is recorded on the blockchain. All patient's information will be stored on the blockchain, providing immutable and decentralized storage. Integration with IoT devices will enable the input of patient information obtained through these devices. Partnerships with key partners, such as healthcare providers, employers, and government, are crucial to promote the adoption of the PHR platform and integrate it into existing healthcare workflows. Maintaining data security and privacy is essential, especially in compliance with healthcare privacy regulations such as GDPR (in the European Union) to protect the confidentiality and security of patients' health information.

#### 4. DEVELOPMENT OF A B2C SMART CONTRACT

In this chapter, we will showcase some of the key functions provided by smart contracts for the PHR (Personal Health Record) application called "Medchain" and speak about main technologies used for development of PHR applications. Smart contracts are developed in Solidity, they are based on Ethereum platform, which will regulate interactions between patients and healthcare providers, ensuring data integrity and access control by users of the PHR application through various transactions. On the Figure 2 we can see example of our smart contract for Medical Persons. It defines some basic data of any medical person like first name, last name, role name and main functions for managing medical persons data. Role name indicates position of the doctor, for example role can be surgent, lab technician, general specialist etc. This contract is then used in the Patient.sol smart contract, which is represented on the Figure 3, to specify main doctor for patient and also list of doctors with access to patient's medical records.

```
contract MedicalPerson {
    address private medicalPersonAccount; //address of medical person
    string private first_name; //first name of doctor
    string private last_name; //last name of doctor
    string private roleName; //position of the doctor

    constructor(address _medicalPersonAccount, string _first_name, string _last_name, string _roleName) { @ infinite gas
        medicalPersonAccount = _medicalPersonAccount;
        first_name = _first_name;
        last_name = _last_name;
        roleName = _roleName;
    }

    function getMedicalPersonAccount() public view returns (address) { @ 2000 gas
        return medicalPersonAccount;
    }

    function setMedicalPersonAccount(address _medicalPersonAccount) public { @ 2000 gas
        medicalPersonAccount = _medicalPersonAccount;
    }

    function getMedicalPersonFirstname() public view returns (string memory) { @ infinite gas
        return first_name;
    }

    function setMedicalPersonFirstname(string _first_name) public { @ infinite gas
        first_name = _first_name;
    }

    function getMedicalPersonLastname() public view returns (string memory) { @ infinite gas
        return last_name;
    }

    function setMedicalPersonLastname(string _last_name) public { @ infinite gas
        last_name = _last_name;
    }

    function getMedicalPersonRole() public view returns (string memory) { @ infinite gas
        return roleName;
    }

    function setMedicalPersonRole(string _roleName) public { @ infinite gas
        roleName = _roleName;
    }
}
```

Figure 2: MedicalPerson.sol smart contract

```
contract Patient {
    address private id_account; //address of patient
    string private first_name; //first name of patient
    string private last_name; //last name of patient
    string private password; //password
    string private gender; //gender (male, female)
    string private year_of_birth; //in format (YYYY)
    string private unique_id; //2000
    string private blood_type; // (A+, A-, B+, B-, AB+, AB-, O+, O-)
    string private height; //in format (mm) (measure will be cm)
    string private weight; //in format (kg) (measure will be kg)
    address private mainDoctor; //address of the patient's main doctor
    address[] private medicalPersonsWithAccess; //list of the medical persons which can see patient's medical records
    EmergencyPerson private emergencyPerson; //a person who will be contacted if it is necessary to make a decision instead of patient
    Insurance[] private insurances; //list of insurances which patient takes
    Immunisation[] private immunisations; //list of immunisations which patient got
    bool private donor; //is patient is donor (true, false)
    string[] private donations; //list of organs which patient will donate
    MedicalRecord[] private medicalRecords; //list of insurances which patient takes
    HeartRate[] private heartRateList; //list of heart rate records
    BloodPressure[] private bloodPressureList; //list of blood pressure records
    uint256 counterMedicalRecord = 0;

    struct EmergencyPerson {
        address emergencyPerson;
    }

    struct HeartRate {
        uint256 heartRate;
    }

    struct BloodPressure {
        uint256 bloodPressure;
    }

    struct Insurance {
        string insuranceName;
    }

    struct Immunisation {
        string immunisationName;
    }

    struct MedicalRecord {
        uint256 id; //unique identification number of medical record
        string typeOfRecord; //da li je operacija, alergija, vakcinacija, bolest, poremećaj
        string description; //doktorova napomena
        address doctorSignature; //adresa doktora koji je napravio record
        uint256 date_time_of_record; //datum kada je napravljen record
        string recdes; //recet
        address patient; //address of patient
    }
}
```

Figure 3: Patient.sol smart contract

The development of an application for end-users (patients) will throughout modern design and friend-user interface allow patients to manage their health records, track their lab results, measure health and body pressure, provide patient an ability to give and revoke access to their data etc. The interface will provide a secure view into a patient's health data and history. This end-user interface was built using the React framework, because it has all needed web3 libraries for communication with blockchain.

On the Figure 4 we can see the user interface where patient can assign his main doctor, grant access to a doctor who can access patient's medical records and exclude doctor from the list of those doctors with access. The primary objective of this functionalities is to ensure that the patient data is always accessible to the relevant medical staff. By granting access to patient records, these authorized personnel can view past medical history, medications, and other critical information, which can help them make informed decisions

about patient care. On the Figure 5 we can see also how patient can exclude doctor from the list of those doctors with access to patient's medical records. Patient needs just to select doctor from the drop-down list and then by clicking on the “Exclude” button transaction will be generated in the background on the blockchain side. The Figure 6 represents result of successful transaction.

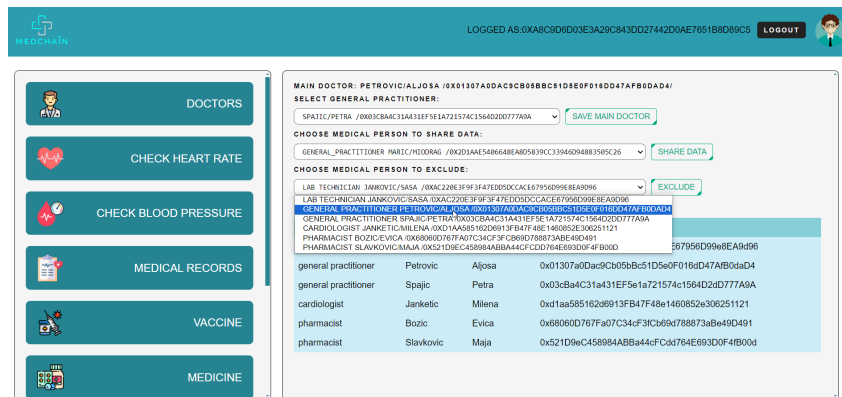


Figure 4: The view of patient's user interface for doctor's tab

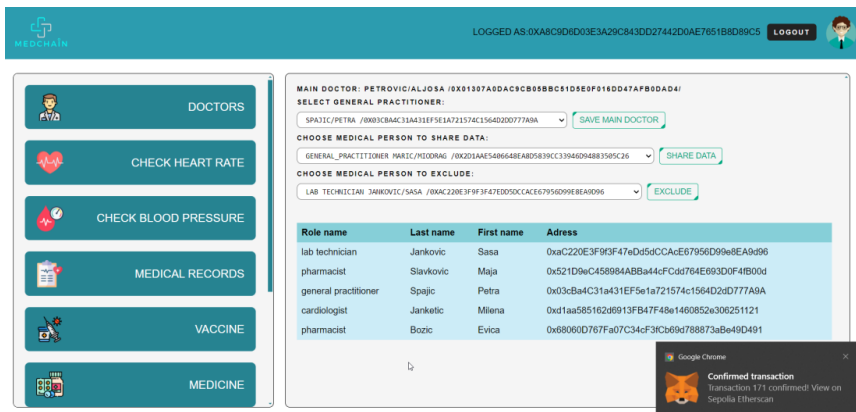


Figure 5: The view of successful transaction

For our application we chose Meta Mask wallet as a digital wallet, as it is the leading self-custodial wallet and it represent the safe and simple way to access blockchain applications. (MetaMask, 2024) It is considered one of the best crypto wallets for several reasons (some of them are User-Friendly Interface, Ethereum Ecosystem Support, Open-Source and Active Community etc.) and its compatibility with React is indeed an advantage. MetaMask is available as a browser extension for various web browsers and as a mobile app for iOS and Android devices. This cross-platform compatibility ensures that React developers can use MetaMask across different platforms and devices without restrictions.

```
const excludeMedicalPersonWithAccess = async () => {
  if (excludedMedicalPerson == null) {
    alert(
      "Choose medical person who u want to exclude from the list with access"
    );
    return;
  }

  try {
    const patientContract = new web3.eth.Contract(PatientABI.abi, patient);

    const transactionParameters = {
      to: patient,
      from: patient_account, // must match user's active address
      data: patientContract.methods
        .throwMedicalPersonFromTheListWithAccess(excludedMedicalPerson)
        .encodeABI({ from: patient_account }),
    }; // call to contract method

    // txhash is a hex string
    const txhash = await window.ethereum.request({
      method: "eth_sendTransaction",
      params: [transactionParameters],
    });

    console.log("Transaction Hash:", txhash);

    alert("Medical person excluded!");
  } catch (error) {
    console.error("Error during changing medical record", error);
  }
}
```

Figure 6: The view of functionality for excluding medical person on the React side

The Figure 7 shows function on the blockchain side. On the Figure 6 we can see how we call this function on the React side via web3 library.

```
//this function throws doctor from the list of doctors who can see patient's medical record.
function throwMedicalPersonFromTheListWithAccess(address medicalPerson)public{
    uint arrayLength = medical_persons_with_access.length;

    for(uint i = 0; i < arrayLength; i++) {
        if(medical_persons_with_access[i] == medicalPerson) {
            // Remove the medical person from the array
            // Move the last element to the position to be deleted
            medical_persons_with_access[i] = medical_persons_with_access[arrayLength - 1];
            // Remove the last element
            medical_persons_with_access.pop();
            return; // Exit the function once the doctor is removed
        }
    }
}
```

**Figure 7:** The view of functionality for excluding medical person on the Blockchain side

## 5. Conclusion

The development of a personal healthcare application based on blockchain technology represents a significant leap forward in the realm of healthcare innovation. By leveraging the inherent features of blockchain, such as decentralization, immutability, and transparency, these applications offer unparalleled opportunities to revolutionize personal healthcare management. Through secure and tamper-resistant storage of health data, users gain greater control over their sensitive information while ensuring privacy and confidentiality.

The Medchain application serves as a comprehensive solution to the challenge of centralizing and securing all of a patient's medical records in one accessible place. By leveraging advanced technology, it empowers users to maintain their medical data and files in an organized manner, ensuring ease of access and retrieval. This seamless accessibility enables patients to conveniently review their health information, including laboratory reports, prescribed medications, treatment histories, and more, at any given moment. Through its user-friendly interface and robust security measures, Medchain has a great efficiency of managing medical records and it also fosters greater patient engagement and empowerment in their healthcare. By offering a decentralized platform for storing and accessing vital health data, Medchain contributes to improved healthcare outcomes and patient satisfaction. By using blockchain technology, the Medchain application ensures high-level security for users' sensitive data. Every transaction is tracked and stored securely, minimizing the risk of fraud. Additionally, the decentralized nature of blockchain reduces the chance of data breaches. This provides users with confidence that their medical records are protected and private.

The future of the Medchain application involves embracing modern technology trends for continuous improvement. One key aspect of this plan is integrating with the Internet of Things (IoT), allowing seamless connection with devices like blood pressure gauges and heart rate counters. This integration enhances the user experience by enabling automatic and real-time tracking of vital health metrics, providing valuable insights for both patients and healthcare providers. One of the main goals in the future will be to enable seamless integration with various healthcare systems, electronic health records (EHRs), and medical devices to ensure comprehensive data aggregation and interoperability.

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# DEVELOPMENT OF AN NFT FASHION PLATFORM

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**Abstract:** *This research revolves around designing and implementing an NFT fashion platform to enhance community engagement among fashion enthusiasts, designers, and NFT collectors. The platform exclusively offers fashion items as non-fungible tokens (NFTs), suitable for use in the Metaverse, video games, or traditional NFTs. Key components include developing the platform using React, creating a peer-to-peer (C2C) smart contract using Solidity for secure transactions, integrating with a digital wallet for minting, and utilizing Ethereum (ETH) on the Testnet Sepolia for transactions. The project aims to establish a functional and inclusive NFT fashion platform.*

**Keywords:** *Digital fashion, NFT, Solidity, Smart Contracts, Minting*

## 1. INTRODUCTION

The fashion industry is undergoing a digital revolution, embracing innovative technologies to redefine garment creation, distribution, and ownership. Blockchain technology, particularly Non-Fungible Tokens, has catalyzed this transformation by introducing novel possibilities in the realm of digital fashion. Digital fashion bridges physical and virtual experiences, offering consumers unique engagement opportunities in immersive digital environments (Baek et al., 2022). NFTs, as blockchain-based digital assets, enable the creation of verifiable and scarce fashion items, empowering creators and collectors.

This paper presents the development of an NFT fashion platform using React and Solidity technologies to facilitate peer-to-peer (C2C) transactions through smart contracts. The platform allows users to mint, buy, and sell NFT fashion items, fostering a decentralized marketplace for fashion enthusiasts to interact and trade within the virtual fashion ecosystem. The integration of NFTs in digital fashion expands creative and trade opportunities while enhancing sustainability and authenticity. Blockchain ensures transparent and immutable records of fashion item origins and ownership, combating counterfeit goods and enhancing supply chain transparency (Davies et al., 2024). Fashion brands use NFTs to promote circular economies through resale markets and reduce material waste, with blockchain's immutability ensuring authenticity and consumer confidence in digital fashion assets.

The primary goal is to explore the technical implementation and user experience of the NFT fashion platform, highlighting the integration of blockchain with fashion design and e-commerce. By developing a functional prototype and evaluating its usability, this study contributes to the evolving field of digital fashion platforms, driving innovation at the intersection of fashion and blockchain technology. Through this exploration, the researchers aim to harness the transformative power of blockchain and NFTs to foster innovation, transparency, and sustainability within the fashion industry, shaping the future of fashion design, distribution, and ownership in the digital age.

## 2. NFT AND DIGITAL FASHION

The intersection of non-fungible tokens and digital fashion represents a dynamic frontier in the evolution of the fashion industry. NFTs are unique and irreplaceable digital entities, distinguished from easily replicable traditional digital objects, with each NFT possessing an authenticity attribute tracked via blockchain technology to ensure uniqueness and ownership rights (Chandra, 2022). This characteristic of NFTs has significant implications for digital fashion. This chapter explores emerging trends and transformative technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) in the context of digital fashion. It also discusses the application of NFTs within the fashion industry, highlighting how non-fungible tokens are revolutionizing ownership, authenticity, and trading of digital fashion assets. Additionally,



key NFT fashion platforms are featured, showcasing their innovative contributions to this rapidly evolving landscape.

## 2.1. Digital Fashion

The term "digital" takes on varied meanings when applied to fashion. It can refer to intangible aspects like digital design and virtual prototyping, or it may denote physical devices that facilitate digital interactions within the fashion industry, such as digital marketing strategies or smart wearable technology. Digital fashion signifies the integration of digital technologies into every aspect of the fashion lifecycle, from design and production to marketing and consumption, transforming traditional practices and enhancing creative possibilities (Sayem et al., 2023). Technological advancements like augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) are also contributing to the transformation of the fashion landscape, introducing new possibilities and perspectives.

The application of AI technology in the fashion industry is significant for advancing design, manufacturing, and retail processes. AI enables predictive design, personalized recommendations, real-time defect detection, and trend analysis, ultimately enhancing efficiency, sustainability, and customer experience in fashion (Sayem et al., 2023). Its integration transforms traditional workflows and drives innovation across various facets of the fashion supply chain. AR has become a revolutionary tool in the fashion industry, seamlessly blending online and offline shopping experiences. Virtual try-on apps and AR mirrors allow consumers to visualize clothing items in real time, improving the online shopping experience by reducing uncertainty and enhancing customer satisfaction. Additionally, AR is transforming fashion marketing with interactive campaigns, where brands use AR to create immersive experiences like virtual fashion shows or dynamic in-store displays that captivate viewers through their smartphones, ultimately boosting brand engagement and leaving a lasting impression on consumers. Gucci pioneered virtual sneaker fitting with embedded AR in their app, enabling customers to try on 19 different sneakers by swiping, while Burberry uses AR in Google Search to display products like the Arthur Check sneaker and bag in customers' environments, offering a simulated in-store experience (Hilpert & Zumstein, 2023). Virtual Reality is elevating fashion retail by providing virtual shopping experiences and immersive fashion shows, allowing consumers to browse products and attend runway events from anywhere (Ahn, Bae, & Kim, 2023). This technology transcends physical boundaries, granting a global audience access to prestigious fashion events. Additionally, VR is transforming the design process by enabling designers to create and refine virtual prototypes in a three-dimensional space, speeding up design iterations and reducing environmental impact compared to traditional physical prototypes.

## 2.2. Application of NFT in fashion

Luxury goods companies are continually exploring new revenue streams through digital innovation, with NFTs as a notable example. Louis Vuitton's launch of a mobile game featuring NFT fashion in August 2021, which attracted widespread attention and exposure due to its popularity in app stores, exemplifies this trend. Similarly, brands such as Burberry and Gucci are adopting similar strategies to improve online customer experiences, demonstrating how luxury companies are embracing innovation in the digital space amid increasing interest in virtual products (Wang et al., 2022).

Non-fungible tokens have emerged as a transformative technology in the fashion industry, offering innovative solutions for authenticity, ownership, and digital representation of fashion items (Buriak, 2022). Fashion brands and designers are leveraging NFTs to create unique digital fashion pieces that can be owned, traded, and displayed in virtual environments, particularly in the realm of digital collectibles and virtual fashion. Italian fashion house Dolce & Gabbana creatively merged physical fashion with the metaphysical world of NFTs through their "Genesi" collection, offering buyers both a physical item and its animated digital NFT version. In contrast, other luxury brands like Givenchy, Gucci, and Louis Vuitton took a more conventional approach to NFTs, either selling NFTs based on graphic designs or showcasing their fashion in a film format (Ferrini, Huber & Batt, 2023). By converting physical fashion items into tokens or recording their digital equivalents on the blockchain, brands are improving transparency and traceability throughout the fashion supply chain while combating counterfeiting. NFTs also enable new forms of customer engagement through experiences like virtual fashion shows, digital try-on sessions, and limited-edition NFT collaborations with artists. Moreover, NFTs are reshaping ownership and creativity in fashion by empowering individual designers to monetize their digital designs directly through blockchain-enabled marketplaces, bypassing traditional gatekeepers. Additionally, fashion NFTs, along with associated digital wearables, can attract gamers familiar with in-game purchases like 'skins', offering more customization and interoperability across platforms compared to traditional gaming items (Lapatoura, 2023). This allows buyers to express themselves through virtual avatars and even resell their digital wearables.



### 2.3. NFT fashion platforms

The convergence of fashion and blockchain technology has catalyzed the emergence of innovative platforms known as NFT fashion platforms. These platforms enable designers to create, tokenize, and trade digital fashion items as NFTs, reshaping the fashion landscape in the digital era. By leveraging blockchain technology, these platforms introduce novel ways for designers and consumers to interact with and appreciate fashion as a digital art form. Digital-first websites and AI-generated fashion projects, like DressX, Dematerialised, and The Fabricant, offer innovative digital outfits designed with 3D software (Särmäkar, 2023), promoted as stylish choices for avatars across online platforms. These platforms also provide sustainable shopping options with on-demand garments made from conventional or advanced biomaterials, showcasing unexpected fashion designs generated by AI programs like DALL-E (Ornati, 2023).

In Table 1, an overview of prominent NFT fashion platforms along with their descriptions is presented.

**Table 1:** NFT fashion platforms

Platform	Description
The Fabricant	The Fabricant is a Netherlands-based digital design studio pioneering a new market for digital-only clothing by enabling designers to create, tokenize, and exchange digital fashion items as NFTs using blockchain technology. Their innovative approach fosters fluid, genderless collections known for their versatile possibilities (The Fabricant, n.d.).
DressX	DressX is a digital fashion platform that merges luxury clothing with NFT technology. Customers on DressX can purchase clothing items and receive digital versions of those items that they can wear in their photos or virtual environments (Shilina, 2022).
RTFKT	RTFKT, originally focused on virtual fashion and digital artifacts, transitioned to offering physical counterparts alongside its virtual designs, leveraging Nike's production capabilities following its acquisition (Weiking et al., 2023). This evolution reflects a shift from purely virtual goods to a hybrid model, mirroring a broader trend of digital ventures expanding into physical products.
The Dematerialised	The Dematerialised is a Web3 digital fashion marketplace enabling the purchase, sale, and experience of authenticated virtual goods. Their platform, powered by NFTs on the LUKSO blockchain, offers transparent product journeys and immersive interactions with digital garments (The Dematerialised, n.d.).

## 3. DEVELOPMENT OF A NFT FASHION PLATFORM

The integration of NFTs within the fashion industry represents a groundbreaking opportunity to address issues of authenticity, ownership, and sustainability in the digital realm. By tokenizing digital fashion assets, the aim is to empower creators with a novel way to showcase and monetize their designs, while offering consumers a unique and verifiable ownership experience. This chapter delves into the development journey of an NFT Fashion Platform—an innovative ecosystem where digital fashion creations are authenticated, owned, and traded using blockchain technology. Exploring the convergence of creativity, blockchain, and consumer engagement, we uncover the potential impact of NFTs on reshaping traditional fashion paradigms and fostering new forms of artistic expression in the digital era.

### 3.1. Project Description

This project aims to develop an NFT fashion platform that unites fashion lovers, independent designers, and NFT enthusiasts, creating a vibrant community. The platform will offer fashion items exclusively as NFTs, which can be used in the Metaverse, video games, or traditional NFTs. Using the React framework, the platform will provide a user-friendly interface for designers to mint and sell their fashion collections as NFTs. Additionally, a customer-to-customer (C2C) smart contract will be implemented using Solidity, enabling secure buying and selling of NFT fashion items. Integration with a digital wallet will further enhance the user experience, allowing for seamless management of NFT collections. Transactions will be conducted using ETH on Testnet Sepolia, ensuring a secure and efficient platform for the fashion community.

### 3.2. Project solution

In order to bring the platform to life and enable its core functionality, a robust backend logic is implemented through a Solidity smart contract. A smart contract is a program that runs on the blockchain and can be

accurately executed by a network of mutually untrusted nodes without the need for an external trusted authority (Zou et al., 2019). The Solidity smart contract that is made serves as the foundation for a Customer-to-Customer (C2C) NFT marketplace within the Ethereum ecosystem, facilitating the creation, listing, purchase, and resale of non-fungible tokens (NFTs). It leverages the ERC-721 standard for NFTs, ensuring compatibility and interoperability within the broader Ethereum ecosystem. The contract is designed to operate seamlessly on the Ethereum blockchain, incorporating essential functionalities for managing marketplace operations while ensuring security, transparency, and integrity throughout the process.

At its core, the contract revolves around the `MarketItem` struct, which represents an item listed on the marketplace. This structure contains crucial information such as the token ID, seller, owner, price, and whether the item has been sold. The contract also includes a mapping (`idToMarketItem`) that maps token IDs to their corresponding `MarketItem` struct, enabling efficient retrieval and management of marketplace items. The contract's key functions are meticulously crafted to ensure the smooth operation of the marketplace. Functions like `updateListingPrice` and `getListingPrice` enable the owner of the marketplace to update and retrieve the listing price for creating new market items, respectively. The `createToken` function is responsible for minting a new token and listing it in the marketplace, while the `createMarketItem` function, labeled as Figure 1, creates a new market item for a given token ID with the specified price. The `resellToken` function allows a token owner to resell a token they have purchased, updating the market item with the new price and seller information. Finally, the `createMarketSale` function, shown in Figure 2, completes the sale of a marketplace item, transferring ownership of the item to the buyer and handling the transfer of funds to the seller and marketplace owner.

```
function createMarketItem(uint256 tokenId, uint256 price) private {
    require(price > 0, "Price must be at least 1 wei");
    require(
        msg.value == listingPrice,
        "Price must be equal to listing price"
    );
    idToMarketItem[tokenId] = MarketItem(
        tokenId,
        payable(msg.sender),
        payable(address(this)),
        price,
        false
    );
    transfer(msg.sender, address(this), tokenId);
    emit MarketItemCreated(
        tokenId,
        msg.sender,
        address(this),
        price,
        false
    );
}
```

**Figure 1:** Function `createMarketItem`

```
function createMarketSale(uint256 tokenId) public payable {
    uint256 price = idToMarketItem[tokenId].price;
    require(
        msg.value == price,
        "Please submit the asking price in order to complete the purchase"
    );
    idToMarketItem[tokenId].owner = payable(msg.sender);
    idToMarketItem[tokenId].sold = true;
    _itemsSold.increment();
    _transfer(address(this), msg.sender, tokenId);
    payable(owner).transfer(listingPrice);
    payable(idToMarketItem[tokenId].seller).transfer(msg.value);
    idToMarketItem[tokenId].seller = payable(address(0));
}
```

**Figure 2:** Function `createMarketSale`

In addition to these core functions, the contract includes helper functions like `fetchMarketItems` for retrieving market items, `fetchMyNFTs` to access a user's owned NFTs, and `fetchItemsListed` to retrieve a user's listed items. These functions enhance the usability and accessibility of the marketplace, providing users with the necessary tools to interact with the platform efficiently.

Upon visiting the platform, users are greeted by the homepage, represented in Figure 3, which features an introductory banner. The user-friendly navigation bar at the top provides easy access to different sections of the platform. Visitors can explore collections, learn about the brand, find contact details, and more. Located in the bottom right corner is a button allowing users to switch between light and dark mode. Additionally, the homepage includes an NFT slider section, identified as Figure 4, where each slide provides details about featured NFTs, including the creator, collection, and current price, serving as a promotional tool.

The platform also offers a dedicated page for creating NFTs, shown in Figure 5, empowering users to add a new NFT by entering its title, description, price, and specifying the collection it belongs to. With a simple click on the "Upload" button, NFTs will be seamlessly uploaded to the platform, instantly available for display and discovery within the store. The store page, labeled as Figure 6, showcases a list of aggregated NFTs, allowing users to browse and explore a variety of options, make selections, and complete purchases. Additionally, within the store, users can filter NFTs to easily find desired items. On the NFT product page, marked as Figure 7, users can view detailed information about each NFT, including its description, price, and creator, and directly make purchases. The profile editing section, represented in Figure 8, allows users to update their information, such as avatar, name, and other details, ensuring their profiles are kept up to date. Users can also navigate to the My Items page to view a list of owned NFTs, which offers an organized display of digital assets for convenient management and tracking of collections.

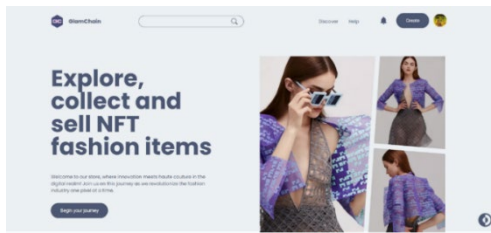


Figure 3: Homepage

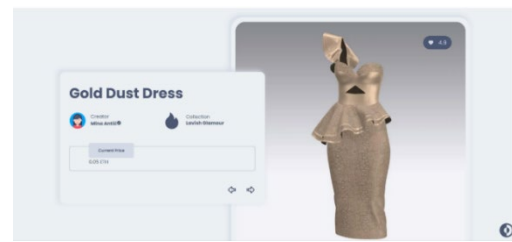


Figure 4: Promo NFT slider

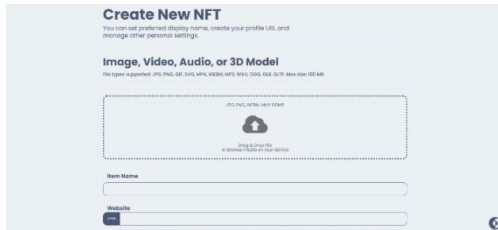


Figure 5: Create New NFT page

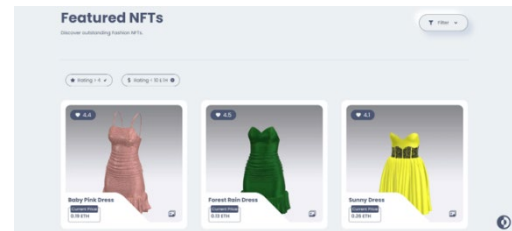


Figure 6: Store page

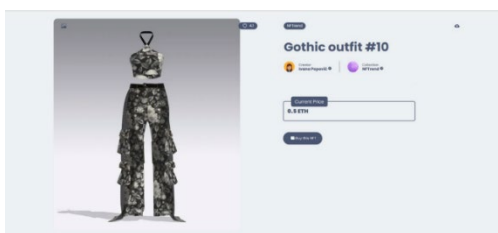


Figure 7: Product page

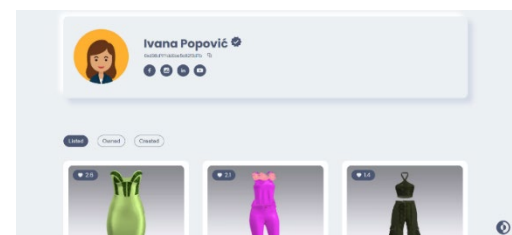


Figure 8: My Items page

The Metamask wallet was chosen as the primary wallet solution for the platform due to its seamless integration with the Ethereum blockchain. To initiate the process of creating a new NFT, users must first access the "Create New NFT" page, as shown in Figure 9. Here, they are prompted to upload the digital file they intend to tokenize, which can be an image, video, audio file, or other digital content. Throughout this process, users have access to a constant preview of how their NFT will appear once it is published on the platform. This feature enables them to make any necessary adjustments or additions to ensure that the NFT is accurately presented. After filling out all the required details, creators can review and finalize the creation of their NFT. This finalization step involves paying a small fee, which covers the cost of minting the NFT on the blockchain, thereby ensuring its authenticity and uniqueness. Once the NFT is successfully minted, it is added to the marketplace.

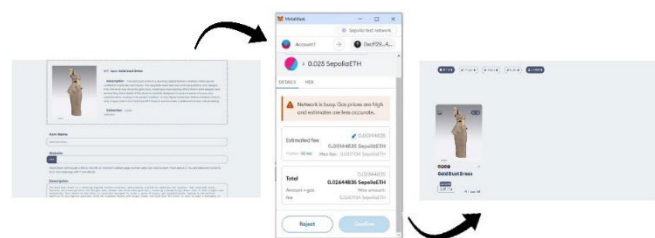


Figure 9: Creation of new NFT

Upon identifying the desired NFT, users can access its detailed information and pricing by selecting the respective item. The purchase process is initiated by clicking the "Buy this NFT" button. A MetaMask window will be triggered, presenting transaction specifics. Following confirmation, the transaction is propagated across the Ethereum network for processing. Once the transaction is integrated into a block and appended to the blockchain, ownership of the NFT is transferred from the seller's account to the buyer's account, as shown in Figure 10.

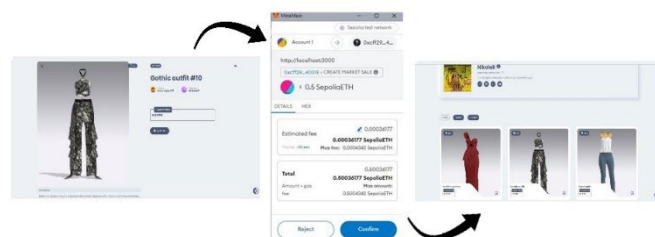


Figure 10: Purchase on NFT

## 4. CONCLUSION

This paper introduces a groundbreaking NFT fashion platform that enhances community engagement among fashion enthusiasts, designers, and NFT collectors. Leveraging React and Solidity technologies, the platform facilitates peer-to-peer transactions through smart contracts, enabling users to mint, buy, and sell fashion items as non-fungible tokens (NFTs). Beyond technical innovation, this project contributes to the evolving landscape of digital fashion and blockchain technology by promoting authenticity, ownership, and sustainability within the industry. By establishing a decentralized marketplace for digital fashion, this platform fosters creativity while addressing critical issues such as transparency and supply chain integrity. Through this initiative, the convergence of fashion and blockchain technologies shapes a more ethical and inclusive future for fashion design and e-commerce. In the future, it is planned to enhance the platform with AR/VR integration to offer an immersive user experience. Furthermore, broadening collaborations with designers will expand product ranges, introducing more innovative and diverse digital fashion items to the marketplace.

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# BLOCKCHAIN-ENABLED REPUTATION SYSTEM FOR C2C PLATFORMS

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**Abstract:** *In existing online reputation systems, one of the key problems is the isolation of reputation data within individual platforms. Users cannot transfer earned reputations from one platform to another, limiting their ability to leverage positive reputations across multiple markets. A centralized approach to data storage leads to potential security risks and privacy issues. Blockchain technology offers a solution to these challenges through its decentralized, transparent and immutable architecture, allowing users to maintain a single reputation that is applicable across platforms. This paper presents a reputation management system based on the blockchain network. The proposed system can be common to several online platforms and increases transparency and trust between all participants in the chain. The paper also refers to previous scientific research in this area. It describes the potential challenges of such a system and suggests future research directions.*

**Keywords:** *blockchain, reputation, C2C platforms*

## 1. INTRODUCTION

In the digital age, it is difficult to establish trust between distant individuals. Lack of trust is present in most online business models, where there is usually no previous relationship between the participants. Reputation systems play a key role in building trust and transparency in online markets. However, existing systems often face challenges such as lack of transparency, data protection, manipulation of ratings, as well as lack of interoperability (Gonçalves et al., 2022).

The problem we addressed is that in the existing systems the user does not have the possibility to transfer his reputation to another platform. Also, if he loses access to his account and creates a new profile on the same platform, he starts building his reputation from scratch, and that can require a lot of time and money. It is a real challenge to make the user's reputation reliable, permanent and transparent for different platforms.

This paper presents a possible way of applying blockchain technology to create a decentralized, secure and transparent reputation system. We propose a reputation system that would be common to multiple C2C platforms. The platform would use a decentralized database to record and verify user ratings, thus ensuring data immutability and transparency. With this approach, the user would have a unique reputation profile that would be applicable and relevant on all platforms participating in this system. The proposed system would not only improve reliability in online markets, but would also significantly reduce opportunities for manipulation and fraud, enabling everyone in the chain to trace back step by step how the user built his reputation by doing business on different platforms.

The rest of the paper is divided into a part on the theoretical basis where the importance of reputation systems and blockchain technology is discussed. In section 3 we described the identified problems. Section 4 provides a detailed system proposal, while Section 5 presents a discussion of the proposed system. Section 6 contains the conclusion. Referenced literature is listed in section 7.

## 2. THEORETICAL BASIS

### 2.1. The importance of reputation systems in the digital world

In online markets, we cannot fully rely on protection mechanisms such as the law and a reliable third party that guarantees us something. Anyone can easily and "cheaply" enter the online market and thus offer their services and products (Swamynathan et al., 2010). Doing business with unknown and remote individuals has

benefits and can be profitable, but comes with risks due to malicious individuals and potential fraud. Reputation systems are there to reduce that risk and recommend reliable partners to users (Resnick et al., 2000).

Many platforms have developed their own reputation management systems that allow users to rate the other party when doing business and that rating is available to all site visitors. Different models for calculating user ratings are present. There are those that follow only one business criterion, as well as those that are multidimensional and more complex (Gonçalves et al., 2022). When a user has a profile on a C2C trading platform, he builds his reputation there. After each transaction, the other party evaluates it and in this way collects ratings and comments. This rating is proof of his reliability, experience and satisfaction of other users with their cooperation. It adds value to him as a merchant, service provider, ie. his profile on that platform.

In our work, the focus will be on C2C trading platforms, where users rate each other. Also, we took into account one rating, whether it was derived from several criteria or received as such from the user. The paper proposes a new way of collecting, aggregating and distributing user data that is used to assess their reputation, relying on blockchain technology. The immutability, transparency and security of data is ensured, which allows users to maintain a reliable reputation across different C2C platforms, as well as that it remains permanently recorded and easily accessible to all interested parties.

Below are described the basic concepts of blockchain technology, which, due to its characteristics, is an excellent support for reputation systems.

## 2.2. About blockchain technology

Blockchain technology is a digital ledger of transactions that is distributed or decentralized, meaning that a copy of the chain is present with every user of the network. This system allows transactions to be recorded in a way that is secure, transparent and impossible to change without the consensus of the network. This allows two parties to complete a transaction without the need for an intermediary such as a bank.

Each block in the blockchain contains a set of transactions, a digital signature or hash of the previous block, which creates a chain link, and a timestamp. The hash is unique and each change in the block results in a different hash, which signals to the network that manipulation has occurred.

When a user wants to make a transaction, it is broadcast to the network and verified using cryptographic algorithms. After verification, the transaction is included in the block that is connected to the previous one in the chain. This process is known as mining and involves solving complex mathematical problems to add a new block (Zhou et al., 2021).

**Consensus mechanisms** are crucial to the operation of the blockchain because they allow agreement among all members of the network on the current state of the digital ledger. The most famous consensus mechanism is Proof of Work (PoW), which is used by Bitcoin. PoW requires miners to invest large amounts of processing power to "mine" new blocks (Lashkari & Musilek, 2021). Other mechanisms include Proof of Stake (PoS), Delegated Proof of Stake (DPoS), and Practical Byzantine Fault Tolerance (PBFT), each with their own specifics that address different needs and challenges in blockchain networks (Bashir, 2017).

Blockchain technology has wide applications in various industries and sectors, providing the opportunity for greater security, transparency and efficiency. **The financial sector** has recognized blockchain technology as innovative and it has found its application there. Blockchain enables fast, secure and low-cost international transactions without the need for traditional banking intermediaries. This reduces transaction costs and the time required to transfer money between accounts in different countries. By implementing blockchain, it is possible to digitize securities such as stocks and bonds, enabling faster and more transparent trading without the need for intermediaries such as brokerage houses (Panda et al., 2021).

**Supply chain management** has the challenge of ensuring transparency and traceability of information between all participants in the chain. Blockchain enables detailed product tracking from producer to consumer. Every step in the supply chain, including production, transportation and storage, can be recorded on the blockchain, allowing for complete transparency and making it easier to identify any problems in the chain. Particularly useful in the luxury goods and pharmaceutical industries, blockchain helps fight counterfeiting by ensuring that product information is authentic and unaltered (Mitrovic et al., 2022).

**Real estate ownership management** becomes more efficient with the use of blockchain technology. Blockchain enables the tokenization of real assets, including real estate, which simplifies transactions and reduces the need for paperwork and legal mediation. The implementation of blockchain in land records can

dramatically increase the efficiency and transparency of ownership records, reducing opportunities for fraud and corruption (Rouhani & Deters, 2019).

**Blockchain can help enhance reputation in higher education systems.** Some universities and higher education institutions have developed their own systems that they use to store and verify diplomas and other evidence of their education. One of the more famous examples is the **MIT Digital Diploma**: The Massachusetts Institute of Technology (MIT) issues digital diplomas to its graduates using blockchain technology. Graduates receive a secure and tamper-proof digital credential that can be easily verified by employers or other institutions (Camilleri, 2022).

### 3. DESCRIPTION OF IDENTIFIED PROBLEMS AND PROPOSED SOLUTIONS

Online reputation systems, crucial for trust between users on C2C platforms, face various problems. Based on the research of other authors, we have classified the problems of reputation models into several categories:

1. **Bias and Inaccuracy:** Bias can stem from user prejudices or manipulative behaviors, leading to inaccurate reputations. Users may give unfair ratings based on personal biases rather than the actual quality of service. This problem is exacerbated in centralized systems where the authority has control over rating data (Spitko, 2019). The central authority has the ability to change, add and delete ratings based on their preferences (Gonçalves et al., 2022).
2. **Scalability:** Many reputation systems face challenges in scaling effectively due to the large volume of data they need to process. Systems need to manage vast amounts of transactional data without centralized control to ensure trustworthiness (Aberer & Despotovic, 2001).
3. **Fraud:** Fraudulent activities, such as fake reviews and rating manipulation, undermine the effectiveness of reputation systems. Dealers may pay for good feedback to artificially enhance their ratings, which compromises the system's integrity (Rezvani & Rezvani, 2020).
4. **Interoperability problem:** Reputation interoperability allows users to transfer their reputation profile from one platform to another, improving their mobility and reducing the need to rebuild reputation on each new platform. Interoperability issues arise when different reputation systems use varied models and semantics, making it difficult to share and integrate reputation data across platforms. This problem is critical in multi-agent systems where agents rely on trust and reputation information from diverse sources (Nardin et al., 2011).

These papers highlight how reputation interoperability can improve flexibility and user experience on digital platforms, but also point to technical and regulatory challenges that need to be addressed to enable widespread adoption of such systems.

Of the problems mentioned above, which we have classified into several categories, we would highlight the problem of centralized authority, which can abuse its position through malicious behavior. Such systems make the reputation management process non-transparent and unreliable. In addition, our focus is on the problem of system interoperability, which is a logical continuation of this discussion. Isolated centralized systems do not benefit from each other. From the user's perspective, it is not fair that the reputation can be lost together with the profile on one platform. It should be permanent, transparent and able to be used on different platforms.

These problems are the focus of our work and we think that it is possible to overcome them by using blockchain technology. In the continuation of the paper, a system proposal is given that can bypass the problems we have highlighted. After that, we discussed the proposed system and highlighted the benefits, drawbacks, as well as possible directions for future research.

### 4. SYSTEM PROPOSAL

The user reputation platform based on Blockchain technology is designed to enable safe, transparent and decentralized storage of reputation data for C2C (customer-to-customer) online platforms. This platform uses blockchain technology to ensure the inviolability and durability of user reputation data.

After each transaction made on C2C platforms, users have the opportunity to rate each other. Ratings can include different parameters, but before sending to the blockchain platform, they must be reduced to one rating on a scale of 1-5 due to the unification of ratings from different platforms.

The platform is designed so that it can be connected to several different C2C platforms without the need for special adjustments. This allows users to transfer their reputation from one platform to another, thus enhancing their recognition and credibility regardless of the specific platform they are trading on.

#### 4.1. System architecture, participants and key elements

The architecture of the system relies on a decentralized blockchain network that, using smart contracts, enables secure and transparent recording and reading of grades. Key components are blockchain network, smart contracts, validation system, security mechanisms.

Participants in the system include users, C2C platforms, and validation nodes, whose interaction is crucial for the functionality of the platform.

**Consumers** - These are individuals or entities that use C2C platforms to buy, sell or barter services and products. They are the main grade generators. They rate other users based on their transaction experiences.

**C2C Platforms** - Online platforms that allow users to trade products and services with each other. Examples include online marketplaces like eBay, Etsy, or local trading apps. They can have their own rating system, multi-parameter and according to different criteria, but the rating recorded on the blockchain system must be reduced to one rating on a scale of 1-5.

**Blockchain Platform** - A central reputation management system.

**Blockchain Nodes** - These are servers or computers that maintain a copy of the blockchain and participate in the process of validating and confirming transactions and ratings. Nodes verify transactions using consensus algorithms, record valid transactions and ratings in the blockchain, and thereby maintain the integrity and availability of data on the network.

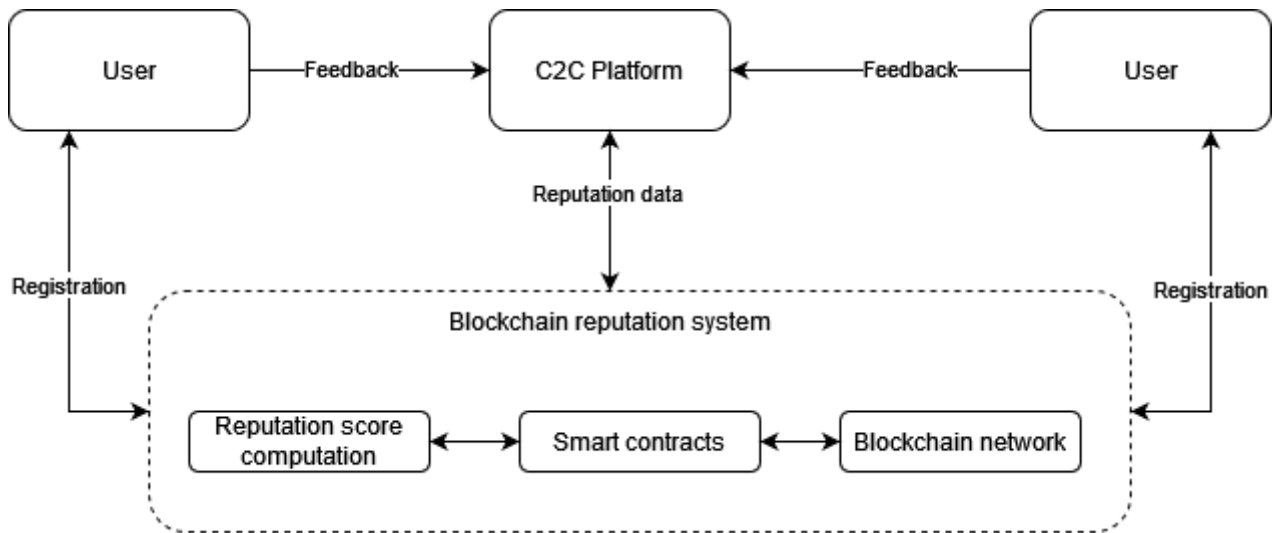
The proposed platform is simplified and represents an example that proves the benefits of this type of system in detected weaknesses. In addition to the above-mentioned elements and participants, it is important to note that even for an example in practice, an API for integration, a user interface, security protocols aligned with legal regulations are also necessary.

#### 4.2. Interaction between participants

A detailed description of the process shows how users create and link their profiles, how ratings are collected and verified, and how reputations are updated and used across platforms. This flow enables constant synchronization and validation of information, thus contributing to increasing the reliability and usefulness of the system. Further in the paper, the interaction between the participants is explained as well as the given diagram:

- **Registration on the Blockchain Platform:**
  - The user registers on the blockchain reputation platform.
  - Upon registration, the user is assigned a unique identifier (eg, public key).
- **Connecting to the C2C Platform**
- **Execution of the Transaction:**
  - Users perform a transaction on the C2C platform.
- **Submitting Ratings on Blockchain:**
  - After the transaction, the C2C platform collects ratings and feedback from users.
  - The C2C platform sends that data, including the unique identifier, rating, and transaction details to the blockchain
- **Verification and Recording on the Blockchain:**
  - Validation nodes on the blockchain verify the authenticity of the data.
  - The data is then written to the blockchain, updating the user's reputation profile.
- **Access to Reputation Data:**
  - Users and C2C platforms can access reputational data via blockchain at any time.
  - The C2C platform may use this data to display reputation on user profiles.
- **Feedback on the C2C Platform:**
  - The blockchain platform can send feedback on transaction status and ratings back to the C2C platform.
  - This information helps maintain the accuracy and transparency of the reputation on the C2C platform.





**Figure 1: Diagram of interactions between participants**

### 4.3. Smart contracts

Smart contracts are used to manage the rating and rating verification process, which minimizes the need for intermediaries and reduces the possibility of manipulation. Smart contracts automatically process transactions after pre-defined conditions are met, ensuring fast and efficient processing.

The table below provides a clear overview of each contract and its key functions, which is useful for understanding how each contract contributes to the overall reputation management system. This is followed by a part of the discussion, where we have listed the benefits of such a system, challenges, as well as potential directions for future research.

**Table 1: Smart contract functions**

Smart Contract	Functions
<b>User Registration Contract</b>	<code>registerUser(string _username)</code> <code>getUser(uint256 _userId)</code> <code>UserRegistered</code> event
<b>C2C Platform Connection Contract</b>	<code>verifyUserKey(address _userAddress)</code> <code>linkUserToPlatform(uint256 _userId, address _platformAddress)</code>
<b>Contract for Submitting and Verifying Grades</b>	<code>submitRating(uint256 _userId, uint256 _rating, string _feedback)</code> <code>verifyRatingData(uint256 _ratingId)</code> <code>RatingUpdated</code> event
<b>Contract for Access to Reputational Data</b>	<code>getReputation(uint256 _userId)</code> <code>getPlatformRatings(address _platformAddress)</code>
<b>Contract for feedback information</b>	<code>sendFeedbackToPlatform(uint256 _userId, string _feedback)</code> <code>FeedbackSent</code> event

## 5. DISCUSSION

Blockchain technology can improve reputation systems on online C2C platforms, as this paper has shown. It solves challenges related to security, transparency and trust. The decentralized nature of blockchain eliminates

the need for a central authority to manage reputation data, thereby reducing the risk of manipulation and fraud. In a blockchain-based reputation system, transactions and feedback are recorded on the blockchain, making them immutable and secure from unauthorized changes.

This interoperability can be particularly useful for users operating on multiple C2C platforms, allowing them to transfer their reputation from one platform to another. In addition, the reputation remains permanent, and if a platform stops working or the user loses access to the profile on that platform, he can link the old reputation to the new profile.

Due to the very nature of this technology, blockchain-based reputation systems are designed to be resilient to common reputation system attacks. Decentralized consensus mechanisms help validate the authenticity of transactions and user behavior, making it difficult for attackers to manipulate the system (Cai & Zhu, 2016).

Like other authors, we also recognized certain challenges and shortcomings of such systems. Below we have classified the challenges of using blockchain in reputation systems:

- **Scalability and cost issues:** Blockchain-based reputation systems can face scalability challenges due to limitations in transaction processing capacity. These limitations can lead to increased costs and slower transaction processing times. Additionally, the initial investment and ongoing costs of developing, implementing, and maintaining a blockchain platform can be significant (Yuan et al., 2021).
- **Privacy and Regulatory Issues:** Ensuring privacy while maintaining transparency in blockchain-based reputation systems remains a complex issue. It is necessary to develop strategies that balance these aspects without compromising security. Legal regulations related to user privacy and blockchain technology can be complex, with different laws in different regions (Bernal Bernabe et al., 2019).
- **Security Vulnerabilities:** Blockchain systems can be susceptible to various security risks, including a 51% attack, where an entity takes control of most of the network's computing power. Other security issues include vulnerabilities in smart contracts and the potential for collusion among network participants (Gupta et al., 2020).

## 6. CONCLUSION

In this paper, we explored how blockchain technology can redefine reputation systems in C2C environments, providing a solution that allows users to keep their reputations reliable and transparent across multiple platforms. The proposed platform uses blockchain to create a decentralized, secure and immutable system that could significantly improve trust and reduce opportunities for manipulation. Such a system would not only facilitate interoperability among different markets, but would also allow users to maintain and upgrade their reputation regardless of the platform on which they operate. Through the application of this model, we can see the way to a more transparent, reliable and user-oriented digital market space.

In future research, the focus would be on examining system performance under different market conditions, as well as developing methodologies to improve scalability. Also, it would be important to conduct security analyzes to identify and eliminate potential vulnerabilities, while considering how legal regulations may affect system operations.

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# DEVELOPMENT OF AN E-COMMERCE APPLICATION BASED ON BLOCKCHAIN

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**Abstract:** *The main aim of this paper is the development of an e-commerce application based on blockchain. The developed application aims to overcome traditional e-commerce challenges such as fraud, data breaches, and reliance on intermediaries by employing a decentralized and distributed ledger system. Key features of the application include using developed smart contracts for the automated realization of e-commerce transactions. For the smart contracts development Solidity programming language was used. For the front-end development, it used the React framework. The findings contribute to the advancement of decentralized solutions in e-commerce, paving the way for a more secure user-centric online shopping experience.*

**Keywords:** *E-commerce, Blockchain Technology, Smart Contracts, Solidity, React*

## 1. INTRODUCTION

Digital transformation in the business world has significantly changed how people buy and sell products and services. E-commerce has become a key segment of the global economic system, enabling companies to reach a wide range of consumers worldwide. However, this rapid evolution of e-commerce also brings certain challenges, including issues related to security, transparency, and the efficiency of transactions (Esfahbodi et al., 2022).

Blockchain technologies can significantly enhance the process of e-commerce. A blockchain-based e-marketplace enables efficient transaction execution among stakeholders in the trading process, ensuring privacy protection, transparency of customer information, and completed transactions (Subramanian, 2017). This innovation establishes a reliable and secure foundation for e-business, addressing challenges related to security and transparency, thereby improving the experience of participants in the trading process.

This paper aims to demonstrate the development of an e-commerce application based on blockchain, whose logic is based on smart contracts written in the Solidity programming language. The outcomes are related to providing consumers with more security during purchases and more transparency regarding the products' origin. The entire purchase process is based on blockchain, ensuring that customers are completely confident in what they are buying.

## 2. BLOCKCHAIN IN E-COMMERCE

E-commerce transactions, facilitated by internet-based platforms, have become increasingly prevalent (Shorman et al., 2019). Trust and privacy are paramount concerns in modern e-commerce (Duranović et al., 2023), necessitating transparent and secure transactional environments. Blockchain technology is pivotal in enhancing e-commerce payment systems, mitigating security risks associated with traditional methods (Swan, 2015). Its decentralized nature offers potential solutions to cross-border e-commerce challenges, leveraging features like decentralization and immutability (Wang et al., 2017). Furthermore, safeguarding consumer data is crucial in e-commerce, with blockchain offering additional security layers against cyber threats (Tapscott & Tapscott, 2016). Blockchain technology revolutionizes e-commerce by offering decentralization, transparency, security, and data immutability (Mougayar, 2016). Decentralization distributes data across nodes, enhancing availability and resilience while minimizing vulnerabilities (Smith, 2017). Transparency is achieved through a public ledger, fostering trust (Tapscott & Tapscott, 2016). Security relies on cryptographic techniques, making transactions resistant to fraud and data theft (Mougayar, 2016). Immutable data entry ensures integrity, providing essential trust (Swan, 2015). Synchronization is maintained through information exchange among nodes, ensuring consistency. Various techniques ensure data integrity. The network layer enables efficient communication between nodes. Implementing these principles reduces intermediaries, enhances payment security, and provides transparency in the supply chain, combating counterfeit products (Swan, 2015). Blockchain technology fosters more efficient and secure online transactions, diminishing reliance on intermediaries, and building consumer trust (Chang et al., 2019).

## **2.1. Blockchain-Based E-commerce Models**

E-commerce models are designed to tailor e-commerce processes to the specific dynamics among trading participants. E-commerce can be realized between sellers and buyers (B2C), business partners (B2B), and consumers (C2C). B2B represents an e-commerce model dedicated to facilitating business transactions between companies. Tracking B2B blockchain-based business can be implemented using e-commerce platforms, blockchain networks, smart contracts, and distributed databases. All participants in the B2B process can access all stored transaction documents made on the blockchain (Lahkani et al., 2020). B2C e-commerce facilitates business transactions between companies and consumers. Blockchain can be employed in online stores to monitor completed transactions between companies selling products and consumers. Additionally, it can be used to collect information about customers, including their product preferences, shopping habits, and expenditures (Jebamikyous et al., 2023). C2C e-commerce involves transactions between individuals or small businesses in a digital environment. This form is most commonly observed in the form of C2C websites or platforms through which interactions and transactions are conducted among participants in the trade (Duranović et al., 2023).

### **2.1.1. Blockchain in B2B E-commerce**

B2B e-commerce is evolving rapidly, with trends focusing on faster order processing, sales via independent marketplaces, personalized experiences, and enhanced supply chain management (Duranović et al., 2023). By implementing blockchain technology in B2B business models, a secure and reliable software interface for participants in business processes can be enabled (Sarwar et al., 2023). In the context of B2B transactions, blockchain can be used within organizations to:

- Create an accounting system that securely and reliably records all financial transactions from business in real time.
- Automate and verify business transactions between business partners without intermediaries.
- Optimize supply chains through greater data transparency of completed transactions between partners.
- More efficient management of business documentation. Blockchain addresses issues related to document duplication, reduces processing time for documentation, possibilities of misuse, and fraud.
- Reduce waiting times for the realization of international financial transactions and increase trust in international trade.

Tracking blockchain-based B2B transactions can be realized using e-commerce platforms, blockchain networks, smart contracts, and distributed databases. All participants in the B2B process can access all stored transaction documents made on the blockchain (Lahkani et al., 2020).

### **2.1.2. Blockchain in B2C E-commerce**

The implementation of blockchain technology has several positive impacts, including the reduction of transaction costs, enabling users access to all information, eliminating entry barriers to the market, as well as reducing the costs of creating and maintaining websites. In the context of B2C business, blockchain provides consumers (Gomber et al., 2018)(Grover, 2018):

- Reliable and user-friendly interface. The user easily conducts transactions using the appropriate application.
- Capability for instant digital payments without intermediaries.
- Users have the option of digital payments in various currencies, including cryptocurrencies.
- An incentivized revenue system that allows any profit or compensation earned by the consumer. Blockchain is suitable for tracking spending within an online store and implementing loyalty programs.
- Provides customers with insight into product information from production to delivery. Blockchain enables traceability and tracking of product origin.

### **2.1.3. Blockchain in C2C E-commerce**

C2C e-commerce represents transactions between individuals or small businesses in a digital environment (Swift et al., n.d.). This form most commonly appears in the form of C2C websites or platforms through which interactions and transactions between participants in trade are conducted. In the context of C2C transactions, blockchain enables (Shorman et al., 2019):

- Realization of peer-to-peer transactions between participants without intermediaries.
- Transactions are executed using smart contracts without paying commissions to banks or notaries. Contracts are valid without certification.
- Increased trust among buyers is achieved by signing smart contracts.

- Faster money exchange. Eliminating intermediaries reduces the time and money spent in the intermediary's account.

### 3. EXAMPLES OF BLOCKCHAIN APPLICATION IN E-COMMERCE

Blockchain technology has demonstrated immense potential in transforming how e-commerce operates. As one of the key applications where blockchain can be used in e-commerce, the ability to ensure transparency in every part of the supply chain stands out (Taherdoost & Madanchian, 2023). Smart contracts in blockchain technology enable the automation of the entire process of tracking and validating products, starting from the manufacturer to the end-user or consumer. It is precisely this transparency that provides consumers with reliable data and information about the origin, quality, and everything else related to the product being transacted (De Caria, 2018). Additionally, blockchain as a technological solution enables overcoming issues related to the authenticity of the product itself. By implementing a complete system to protect this authenticity within the blockchain, there is the possibility to track and confirm the complete authenticity of the product, reducing the risk of potential counterfeiting and fraud. Blockchain technology, through this application in e-commerce, would also enable faster and more secure transactions using cryptocurrencies. This would eliminate the need for any intermediaries through the decentralization of payments, reducing costs and speeding up the entire process (Tapscott & Tapscott, 2016). Blockchain technology brings numerous advantages and innovations to e-commerce. Secure transactions, supply chain tracking, microtransactions, smart contracts, and identity security are just some of the changes that blockchain introduces to e-commerce. Table 1 shows specific examples of blockchain technology applications in e-commerce.

**Table 1:** Examples of Blockchain Application in E-commerce

Example	Description	Benefits obtained
Origin of products	Using blockchain for tracking the origin of products enables customers to verify the authenticity of a product.	It increases customer trust and also reduces the risk of product counterfeiting.
Transaction security	Blockchain is used to ensure secure transactions in e-commerce, thereby reducing the risk of fraud and unauthorized access.	Protection against fraud and reduced transaction processing costs.
Improved transparency	Information about products, prices, and delivery is stored on the blockchain, enabling transparency for customers.	Customers can easily compare products and prices, reducing the risk of hidden fees or price changes.
Smart contracts	The use of smart contracts enables automatic verification and execution of contracts for payment and product delivery.	Reduced need for intermediaries, as well as faster and more accurate transaction execution.
Customer loyalty	Using tokens or cryptocurrencies to reward loyal customers increases customer loyalty.	It increases customer engagement and encourages repeat purchases.
Supply chain tracking	Blockchain enables the tracking of products throughout the supply chain, reducing the risk of loss or damage to products.	Improved inventory management and faster response to supply chain issues.

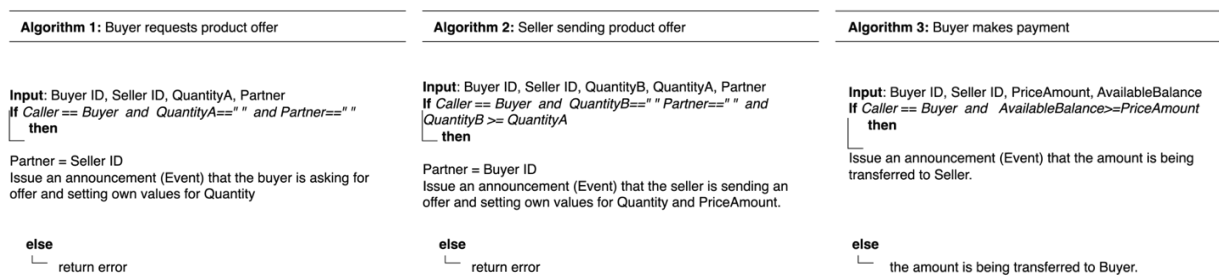
### 4. IMPLEMENTATION OF AN APPLICATION FOR E-COMMERCE BASED ON BLOCKCHAIN

Grounded in blockchain technology, our objective is to address and rectify the existing drawbacks and challenges within the current e-commerce landscape. Developed e-commerce application based on blockchain seeks to enhance the efficiency, security, and transparency of online transactions. This section will delve into the implementation of smart contracts in the e-commerce context, emphasizing their role in automating and securing transactions. Furthermore, the frontend visualization of the developed application will be shown.

#### 4.1. Development of Smart Contracts for E-Commerce

In this chapter, the development of a B2C smart contract for the fashion industry will be shown. The focus is on the interaction between buyers and sellers as the key participants. The smart contract, forged between a buyer and a seller, will be implemented on the blockchain platform using the Solidity programming language. This contract will empower buyers to initiate product requests, allowing sellers to receive and process these demands. The buyer can specify details about the desired items and quality criteria to be met. The buyer, based on their preferences and requirements, selects products that must meet specific criteria such as quality, design, size, and more. If all requirements are satisfied, a successful contract is formed. On the other hand, the seller is obligated to provide a product that aligns with the user's specifications, and upon meeting all conditions, the contract is executed, and the transaction is securely recorded on the blockchain. Every

transaction and contract state change will be recorded on the blockchain, ensuring security, transparency, and reliability throughout the collaboration process between the buyer and the seller. The following diagrams illustrate the algorithms utilized for implementing smart contracts using the Solidity programming language for backend development. In Figure 1, three algorithms are shown. In the first, the buyer sends a request for a product. The seller is sending an offer for the available product. The third algorithm shows transferring funds to the seller's account if all conditions are met.



**Figure 1:** The algorithms utilized for implementing smart contracts

Figure 2 depicts the primary function "makePayment" of our smart contract "BuyerSellerContract," initiating online purchases. This function facilitates the transfer of Ether from the buyer to the seller upon successful triggering and meeting all specified conditions. The function incorporates various checks and conditions to ensure transaction security and integrity. It utilizes the "onlyBuyer" modifier to restrict access solely to the buyer, preventing unauthorized entry. Additionally, it verifies sufficient Ether balance and confirms the order's placement and payment amount before execution. Confirmation of the buyer's order and payment amount further ensures error-free transactions. Upon passing these checks, the function executes the Ether transfer and marks the payment as completed by setting the "PaymentCompleted" variable to true. It also emits the "PaymentMade" event, providing details about the buyer, seller, and payment amount for external tracking and reaction. Overall, the "makePayment" function plays a pivotal role in enabling secure and efficient payment execution within the blockchain environment, with meticulous condition control and event emission.

```
function makePayment() external onlyBuyer paymentNotCompleted confirmedOrder payable {
    require(address(this).balance >= orderAmount, "Insufficient funds for transfer");
    require(orderSuccessfullyPlaced, "The order has not been placed yet");
    require(AmountSet, "The amount has not been set yet");
    require(confirmation, "You have not confirmed the order, check the set amount");
    require(contractAddress.balance >= orderAmount, "Insufficient funds for transfer");

    // Transfer ETH from buyer to seller
    (bool success, ) = seller.call{value: orderAmount}("");
    require(success, "Failed to transfer ETH");

    PaymentCompleted = true;

    // Emitting events
    emit PaymentMade(buyer, seller, orderAmount);
}
```

**Figure 2:** Key function "makePayment"

Transactions initiated through smart contracts are displayed on the Sepolia platform (Figure 3). We can keep track of whether a transaction was successfully executed or if it failed due to some conditions not being met.

Latest 19 from a total of 19 transactions									
Transaction Hash	Method	Block	Age	From	To	Value	Txn Fee		
0x8d7980921a...	Make Payment	5681979	29 secs ago	0x10c480Ae...332d5aDa8	0x767BBE8E_d01297C24	0 ETH	0.00007231		
0x2119d796f81...		5681976	1 min ago	0x10c480Ae...332d5aDa8	0x767BBE8E_d01297C24	0 ETH	0.00006656		
0x37e46021ab...	Place Order	5681970	2 mins ago	0x10c480Ae...332d5aDa8	0x767BBE8E_d01297C24	0 ETH	0.00010897		
0x5d142905f8a...	Place Order	5681960	4 mins ago	0x10c480Ae...332d5aDa8	0x767BBE8E_d01297C24	0 ETH	0.00003306		
0x32a3ce4d51...		5681954	5 mins ago	0x10c480Ae...332d5aDa8		0 ETH	0.00219368		
0x6e55045b12...	Place Order	5681905	15 mins ago	0x10c480Ae...332d5aDa8	0x299fbc44...815f45A46	0 ETH	0.00010897		
0x5fcd504c366...		5681896	17 mins ago	0x10c480Ae...332d5aDa8		0 ETH	0.00219379		

**Figure 3:** An example of a successful transaction by the Buyer

## 4.2. Development of the E-Commerce Application Frontend

The frontend application developed in React represents an e-commerce platform aimed at providing users with a seamless shopping experience. Upon accessing the platform, users are greeted with a "Login page", enabling new users to create accounts or existing users to log in. Once logged in, users are directed to their personalized "Profile page", as depicted in Figure 4. Users can view and manage their account information, including personal details, order history, and shipping preferences. Additionally, the profile page provides access to the user's shopping cart, allowing for the addition, modification, and removal of items.

Furthermore, the profile page features wishlist functionality, enabling users to save desired products for future reference. The frontend application offers an intuitive and user-friendly interface, designed to enhance the e-commerce experience for users while leveraging the benefits of blockchain technology to ensure security, efficiency, and transparency in online transactions.

Figure 5 showcases the "All Categories" section of the e-commerce front-end application. This section provides users with a comprehensive overview of the available product categories, enabling them to browse and explore a wide range of items conveniently. By organizing products into distinct categories such as blazers, t-shirts, jeans, and more, the platform enhances user navigation and facilitates targeted product searches. Figure 6 showcases the "Cart Page" a crucial component of our e-commerce application. Here, users can conveniently review the list of products they have selected for purchase before proceeding to checkout. The cart page provides users with a comprehensive overview of their shopping cart, displaying details such as product names, quantities, prices, and subtotal amounts.

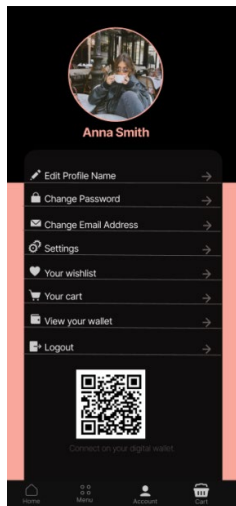


Figure 4: Profile page

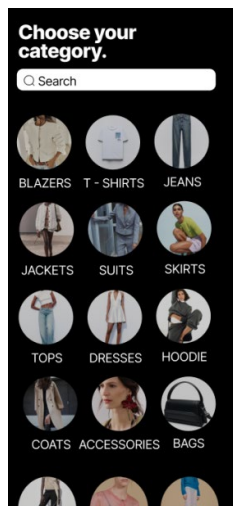


Figure 5: All categories

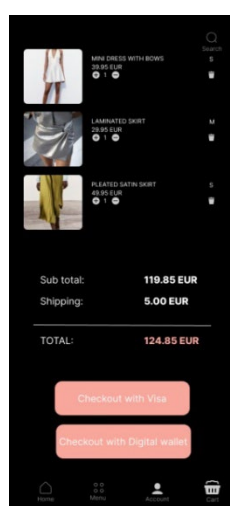


Figure 6: Cart page

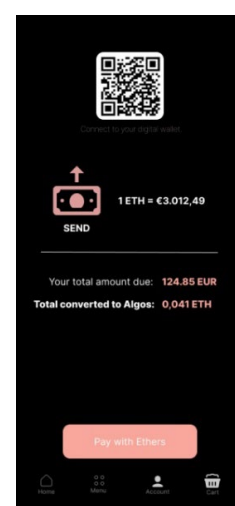


Figure 7: Checkout page

The application integrates with a smart wallet, providing users with a secure and convenient payment method for completing transactions (Figure 7). They can opt to pay using conventional methods like Visa cards, ensuring a seamless and familiar transaction experience. This familiar payment option offers users a seamless checkout experience, allowing them to securely enter their card details and complete the transaction. The checkout page provides fields for users to input their card information, including card number, expiration date, CVV code, and billing address. Once the necessary details are entered, users can proceed to confirm their order and finalize the payment, ensuring a straightforward and hassle-free checkout process. Alternatively, users can choose to leverage the power of blockchain technology by connecting to their digital wallet and completing the payment using Ether, a popular cryptocurrency. By selecting this payment method, users can connect their digital wallet to the e-commerce platform, enabling seamless integration with the blockchain network. Users can authorize the Ether payment and confirm the transaction, marking the completion of their purchase. Through this decentralized payment option, users have the benefits of secure, transparent, and efficient transactions facilitated by blockchain technology. Also, when paying with a digital wallet, the conversion from euros to Ether is displayed to provide users with a clear overview before completing the transaction.

## 5. CONCLUSION

In recent decades, there has been rapid development and widespread adoption of information technologies. This has led to a large number of people transitioning from traditional shopping methods to online shopping. However, alongside the many conveniences brought by online shopping, threats related to personal data security, product authenticity, transaction safety, and many others have started to emerge over time. Through transparency in the supply chain, process automation via smart contracts, and product authenticity protection, blockchain enables safer, faster, and more efficient transactions, eliminating the need for intermediaries and reducing the risk of fraud. This technology opens doors to innovative approaches in e-commerce, providing users with credible information and enhancing the overall shopping experience.

The paper shows the development of an e-commerce application based on blockchain. The application offers user registration, product selection for purchase and buying products. The purchasing process is regulated by a smart contract that contains the entire logic of online shopping and fund transfer. If all conditions within the smart contract are met, Ether will be transferred from the buyer's account to the seller's



account. The smart contract is developed using the Solidity programming language and tested on the Sepolia testnet to ensure the security and integrity of transactions, considering various scenarios and conditions that must be met before the payment is executed. Future work will be related to further development of the e-commerce application functionalities and introducing a loyalty program for the customers based on blockchain.

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# DEVELOPMENT OF A DAPP FOR AN EDUCATIONAL INSTITUTION BOOKSTORE

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**Abstract:** *The paper aims to develop a decentralized application for an educational institution's bookstore, utilizing Web3 technologies to integrate blockchain into the education system. It focuses on facilitating transparent transactions for learning materials, ensuring fair pricing and preserving authors' intellectual property rights. Additionally, it addresses issues of data accessibility, privacy, and trust within educational systems. Through the implementation of smart contracts and applications, the initiative seeks to streamline the purchase and exchange of educational materials, enhancing students' accessibility, privacy, and security.*

**Keywords:** *Blockchain, Education, Decentralized Application, Smart Contracts, PyTeal*

## 1. INTRODUCTION

In today's quickly changing digital landscape, the integration of blockchain technology into the educational sector has far-reaching consequences for the future of learning. This project focuses on creating a decentralized application designed specifically for libraries at educational institutions, leveraging blockchain's disruptive potential with the use of PyTeal Beaker and React. Blockchain, with its intrinsic properties of immutability, transparency, and security, provides a new opportunity to address basic obstacles in the educational system. Alongside data protection and transactional efficiency, blockchain technology provides solutions to the educational system's broader challenges. Blockchain-based solutions can efficiently address issues such as data accessibility, institutional trust, and academic credential integrity.

Additionally, the use of blockchain in education represents not only a technological improvement, but also a conceptual shift in how learning is facilitated and accessed. By decentralizing power and encouraging collaboration, blockchain has the potential to democratize education, making it more inclusive, transparent, and equitable for all stakeholders. This idea is essentially an innovative attempt to use blockchain technology to improve education. Decentralized applications and smart contracts are strategically used with the goal of empowering students, improving institutional efficiency, and creating a more favorable learning environment for the future.

The objective of this project is to develop an application that offers students and professors at the university insight into available literature and enables secure transactions for its sale, all recorded on the blockchain. The goal is to build a transparent and efficient system for handling university book information and student purchases of educational material using blockchain technology. The application aims to provide students with a transparent and efficient way to search for and obtain university literature through smart contracts.

Smart contracts automate and simplify transactions, improving student access to essential learning resources. For educational institutions, it offers a centralized system for managing book information, reducing administrative tasks, and enhancing efficiency. This system can also generate valuable insights into student purchasing behavior, aiding in inventory management and curriculum planning.

Furthermore, by using blockchain for digital rights management, the application protects authors' intellectual property rights, ensuring fair compensation. This not only encourages authors to produce high-quality educational content but also fosters a trusted relationship between authors and institutions.

## 2. BLOCKCHAIN IN EDUCATION

Blockchain technology offers vast potential in the field of education, providing enhanced support to students and various entities within educational institutions. Its applications extend to areas such as credentials and certification (Blockchain for Education & Research Webinar, 2016; Grech & Camilleri, 2017; Rooksby, 2017), promising significant improvements in these domains. Leveraging blockchain technology, educational institutions can enhance the transparency and security of their record-keeping systems, ensuring that once a record is created and accepted, it cannot be altered or disappear (Efanov & Roschin, 2018). This immutability feature is crucial for maintaining the integrity and trustworthiness of academic credentials and achievements. Blockchain technology also helps the recruitment process (Chen, Xu, Lu, & Chen, 2018). The scope of blockchain technology extends beyond the maintenance of records (Sharples & Domingue, 2016; Chen et al., 2018; Skiba, 2017) and ease of accessing these records (Turkanović et al., 2018). It also presents opportunities for university administration to streamline their finance and accounting departments.

Blockchain technology has emerged as a transformative force across various sectors, including education, where it revolutionizes record management and ensures interoperability. Research highlights its myriad benefits, including robust data security (El Koshiry et al., 2023; Radović-Marković, 2011), system reliability (Sharples & Domingue, 2016; Chen et al., 2018), and the facilitation of secure transactions through smart contracts (Sharples & Domingue, 2016; Skiba, 2017; Grech & Camilleri, 2017). By providing a unified view of student records and ensuring data integrity, blockchain enhances interoperability and security (Radović-Marković, 2011; Schinckus, 2020). The Blockchain Ecosystem for Education serves as a decentralized platform leveraging blockchain to securely manage, store, and share data. Its transparency and immutability enable transparent transactions while preventing unauthorized modifications (El Koshiry et al., 2023). This technology's potential spans across educational sectors, including universities, online platforms, government bodies, and academic publishing (El Koshiry et al., 2023; Alsobhi et al., 2023).

In education, integration with this technology promises to revolutionize the tracking and verification of academic achievements, empowering students to demonstrate their skills to potential employers (El Koshiry et al., 2023). Moreover, it can enhance sustainability education by increasing transparency and efficiency in sustainability efforts (El Koshiry et al., 2023; Chivu et al., 2022). Despite existing challenges, blockchain's transformative potential in reshaping education remains promising (El Koshiry et al., 2023; Shaikh et al., 2022).

Blockchain technology facilitates traceability of educational resources, enabling tracking from production to consumption and aiding informed sustainability decisions (Rusinek et al., 2018). It enhances data management by providing a secure and transparent ledger for sustainability-related data, promoting data-driven decision-making and transparency (Marjit & Kumar, 2020). Additionally, blockchain supports tracking sustainability initiatives like carbon credits and waste reduction, and facilitates crowdfunding for sustainability projects (Marjit & Kumar, 2020; Shaikh et al., 2022). By incentivizing sustainable behaviors and educating consumers about environmental and social impacts, blockchain promotes transparency and accountability (Chivu et al., 2022).

The integration of machine learning and blockchain in education offers enhanced security for student data, personalized learning experiences, and improved assessment of educational milestones (Shah et al., 2021; Shah et al., 2021; Shaikh et al., 2022). Notably, it enables the creation of digital identities for students, supporting continuous monitoring of their progress and providing secure access to academic records (Rahardja et al., 2021).

Blockchain technology offers transformative potential in education by streamlining processes and enhancing transparency and security. Notable applications include the creation and verification of digital credentials, enabling the issuance of tamper-proof certificates and badges. Furthermore, blockchain facilitates secure transactions for the procurement and distribution of educational materials, ensuring transparent pricing and preserving authors' rights. Moreover, blockchain enhances the security and privacy of student data by encrypting and storing it on a decentralized ledger, empowering students with greater control over their personal information. Overall, blockchain technology holds the promise of creating a more secure, transparent, and trustworthy educational environment, revolutionizing various aspects of the education sector.

### **3. DEVELOPMENT OF A DAPP FOR AN EDUCATIONAL INSTITUTION BOOKSTORE**

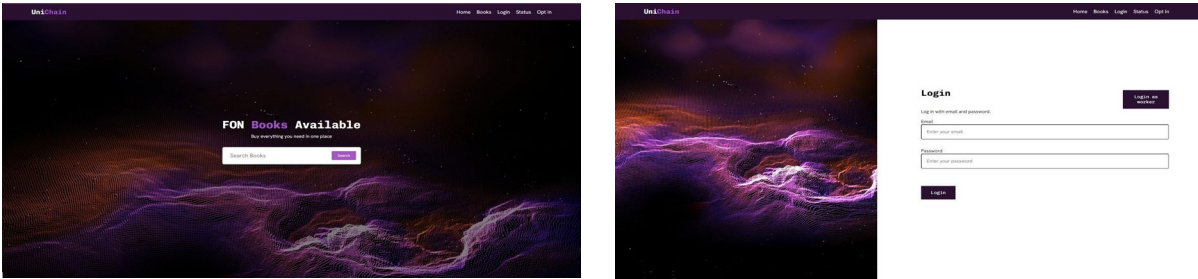
The main aim of the project is to develop a decentralized application for higher education institution libraries based on blockchain technology. Using revolutionary technologies of Web3 the authors aim to implement blockchain technologies in the education system and distribute learning materials throughout educational institutions.

The purchase of educational material is another example of how the blockchain could be used in the educational system. Students could be sure of the price they pay in exchange for the materials, such as books, and writers are assured that the work is viewed in its true form, unmodified, and that their intellectual property rights are preserved. By implementing a smart contract and an application that allows a student to effectively purchase educational materials the authors try to help solve this problem. The application would safely store

and manage student data, providing privacy, safety and simplicity in usage. Student data would be encrypted onto an immutable and decentralized platform, but a student would keep the right to modify their personal information and login information. The purchase process would be ensured and optimized by using a smart contract.

The student is the first who initiates the interaction and creates the smart contract. To obtain literature, students must first submit a request for access to scholarly materials directly to the faculty. As the gatekeeper, the faculty uses a Script Worker to confirm the student's eligibility, making sure that only those who are eligible can access the literature. After the student's status is verified, access is granted by the faculty, enabling the student to continue obtaining the resources they need for their study.

An application was developed using the React framework, which should allow the student to log in and choose the desired literature, after which the Worker checks the order address and the chosen book. If everything is correct, a transaction occurs. The front end of the application is shown in the figures 1 and 1.1.



Figures 1, 1.1: The Front Page of the Application

After successfully logging, the students can now browse the faculty library and find the books they are interested in ordering, which is depicted in the following figure.

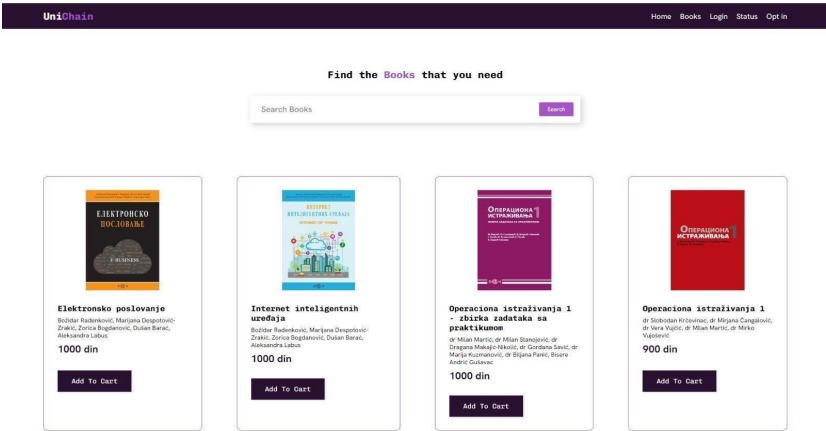


Figure 2: The Books Students can browse

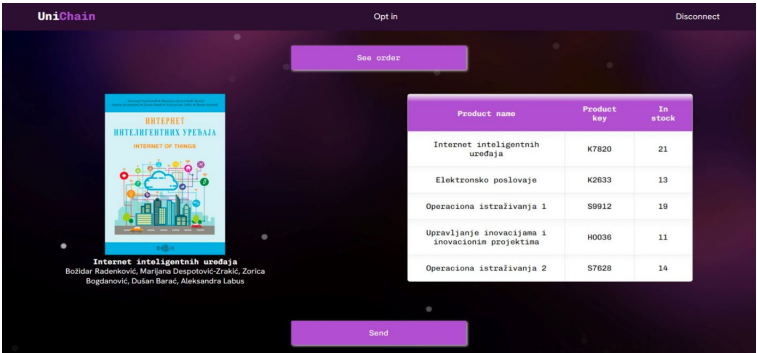
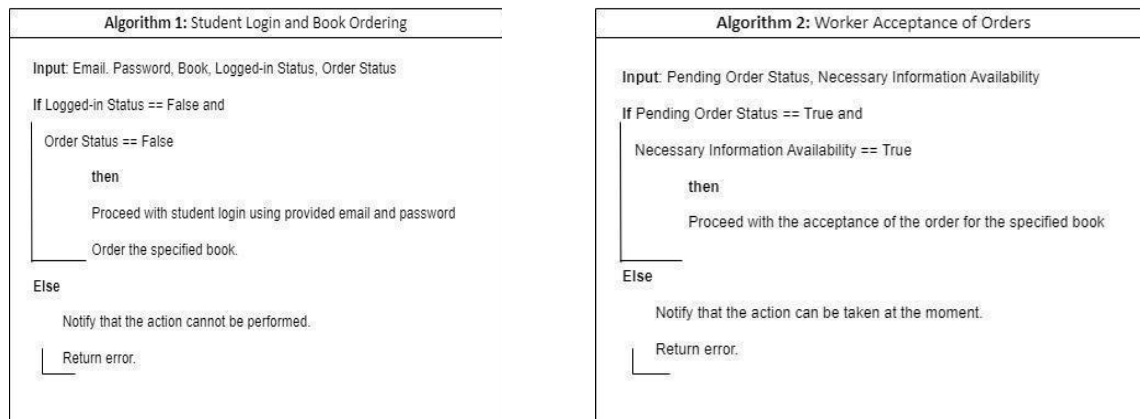


Figure 3: The Worker's Interface

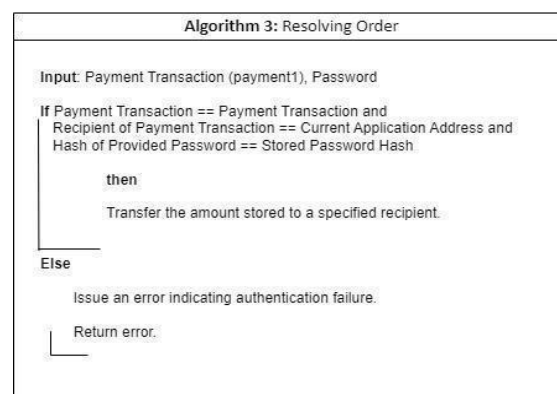
The screen that appears when a worker logs in where they can see orders is shown above. After that, confirmation with information about the order can be sent back to the student who has submitted the order. The three algorithms, which are shown in Figures 4, 5 and 6 present the smart contract created between two stakeholders.



**Figures 4, 5:** Algorithm for the operation of student login and book ordering and Algorithm for the operation of worker acceptance of orders







The first algorithm manages the student login and book ordering process within the smart contract. It checks whether the student is already logged in and whether they have already ordered a book. If the student is not logged in and has not yet ordered a book, the system proceeds with the login process using the provided email and password, and subsequently, orders the specified book. If the student is already logged in or has already ordered a book, the system notifies that the action cannot be performed.

The second algorithm handles the acceptance of orders by workers within the smart contract. It checks whether there is a pending order and whether the necessary information for processing the order is available. If there is a pending order and the required information is provided, the system proceeds with the acceptance of the order for the specified book. If there are no pending orders or if the necessary information is incomplete, the system notifies us that no action can be taken.



**Figure 6:** Algorithm for the operation of resolving order

The third algorithm presented in Figure 6, named "Resolving Order," verifies the authenticity of a payment transaction and a provided password within the smart contract. It ensures that the payment transaction is indeed a payment transaction, that the recipient of the transaction matches the current application address, and that the provided password's hash matches the stored password hash. If all conditions pass, it proceeds with setting the fee in the smart contract's state, storing it in a scratch variable, and performing a money transfer operation. If any of the authentication checks fail, it issues an error indicating authentication failure.

Transactions		Boxes		
Txn ID	Age	From	To	Fee
 UDCAG3BHCRC2C6OIOU5D3EBATQE...	1 hour, 48 minutes ago	LQGY6Z2HPPRJLXZXL5G372USU3I4CPP3...	→ Application: 628907507	▲ 0.001
 QR3QSMDFS6BGLNGBFOZNEZCBW...	1 hour, 43 minutes ago	LQGY6Z2HPPRJLXZXL5G372USU3I4CPP3...	→ Application: 628907507	▲ 0.001
 WFL5KT7N7IY5JVQX2TABRGGLR45...	1 hour, 40 minutes ago	E3673IENYLOQFFSTQ4RKUE5TG6RP6XK...	→ Application: 628907507	▲ 0.001
 XFZ3ZJAH3JM5W34QEPISL4NV5XK...	1 hour, 40 minutes ago	LQGY6Z2HPPRJLXZXL5G372USU3I4CPP3...	→ Application: 628907507	▲ 0.001
 XEG6R7N5DVBRHO3YQ7EROIA37YC...	1 hour, 40 minutes ago	E3673IENYLOQFFSTQ4RKUE5TG6RP6XK...	→ Application: 628907507	▲ 0.001
 QTT6HTT3V3GRXNXWMG73XLIU3...	1 hour, 30 minutes ago	LQGY6Z2HPPRJLXZXL5G372USU3I4CPP3...	→ Application: 628907507	▲ 0.001

**Figure 7:** Representation of all transactions after finishing all steps of the smart contract

All transactions are presented in Figure 7. The initial transaction denotes the student's active participation in the application, indicating their authentication by signing into their account within the smart contract framework. The second transaction is the first operation, "Student Login and Ordering." Different account can be seen in the following transaction and that is the ID of the worker who just opted in the application. The next transaction is characterized by the "Worker Acceptance of Orders" operation, signifying the worker's acknowledgment and acceptance of orders within the application interface. The following transaction is resolving order operation. Notably, an icon depicting a folder is discernible within this transaction, indicating its classification as a group transaction. A group transaction denotes the simultaneous execution of both transactional and payment processes. Within this context, the first transaction encompasses a payment of 0.001, while the subsequent transaction encompasses the distribution of literature.

## 4. CONCLUSION

The incorporation of blockchain technology into the educational scene has shown transformative potential, particularly in the context of decentralized library applications for higher education institutions. PyTeal, which harnesses the potential of blockchain and implements smart contracts, has begun to redefine how educational materials are accessed, shared, and controlled.

The decentralized application tackles immediate difficulties with secure and transparent book ordering while also highlighting blockchain's greater advantages in protecting student data and intellectual property rights. The use of smart contracts has streamlined the purchasing process, ensuring accuracy, transparency, and efficiency.

Furthermore, the inherent features of blockchain—transparency, immutability, and security—have laid a robust foundation for a trust-based educational ecosystem. This initiative sets the stage for a future where students have greater control over their educational journey, and institutions benefit from enhanced operational efficiency and data integrity. To conclude, this proposal encapsulates the potential of blockchain to revolutionize the educational ecosystem. Using smart contracts, a foundation deeply based in blockchain enables smooth interactions between workers and students.

The future work will focus on extending the application's reach to all universities nationwide, establishing a unified platform for securely accessing and purchasing educational literature, all meticulously recorded on the blockchain. This initiative strives to establish a secure and transparent ecosystem for transactions recorded on the blockchain, serving as a centralized platform where students and professors can easily access a comprehensive range of educational materials. Additionally, efforts will focus on refining data synchronization and management processes to boost overall efficiency. As the landscape continues to evolve, blockchain's role in reshaping education stands as an exciting frontier worth exploring and improving.

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# A PROPOSED DATA MODEL FOR THE ENHANCED PROCESS OF ACQUISITION TESTED ON FINGERPRINT READERS

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**Abstract:** *Today, biometrics are increasingly used in everyday life. More and more devices have at least one sensor through which biometric samples are collected. The influence of the environment when taking biometric samples can be an important factor in the process of using biometric sensors. Also, the quality of the biometric sample can be affected by the contamination of the sensor or the biometric modality on which the sensor works. Evaluation of the quality of the biometric sample is an important part of the acquisition process. A data model has been developed that tracks performance sensitivity during biometric sample acquisition. In this paper, we present a data model that we tested on a multisensor biometric system with multiple fingerprint readers during the acquisition process. During the experiment, fingerprints were taken with different finger contaminations while controlling the environmental conditions under which the acquisition took place.*

**Keywords:** *fingerprint, acquisition, data model, biometrics*

## 1. INTRODUCTION

Biometrics automates the user identification process using a person's physiological or behavioral characteristics [1,2]. There are many biometric modalities for determining a person's identity: face scan, hand geometry, signature, retina scan, voice, facial thermogram, hand geometry, palm print, signature, and the most used fingerprint. Precisely because it is widely used, there are also many problems that biometric systems face.

With the increase in user accounts on various systems and applications, the number of passwords that need to be remembered has also grown. Biometrics is trying to solve that problem on a global level. The fingerprint is mostly used in forensic research, but also in all applications where it is convenient to apply the system, such as access control or online authentication. During the acquisition of biometric samples, the way in which the sensor is used is of great importance, that is, the interaction between the user and the sensor must be intuitive. It often happens that the user is inexperienced and does not leave a quality sample [3]. The successful development of a biometric system also requires consideration of the interaction between the subject and the device. The acquisition is influenced by environmental conditions (lighting, temperature), demographic influences (age, gender, medical or physical impairments), device characteristics (e.g. feedback from the digitizer during dynamic signature verification), and the design of the device itself is also possible [4]. Biometric modalities where there is contact with a sensor (as in fingerprint) or alignment with a sensor (as in iris identification) for acquisition are highly dependent on human-computer interaction. Depending on the conditions under which the acquisition is performed, the level of print quality varies.

Three issues in biometrics that need attention are:

- Selection of an adequate sensor
- Selection of the appropriate algorithm
- Examining the possibility of integrating the biometric system into the existing computer system.

Nowadays, everyday life cannot be imagined without identity management techniques, and we are not even aware that we are using them. Research has shown that a large number, as much as 45% of the population who use user accounts, do not change their passwords after five years, which increases the rate of misuse. Even more than 70% of users use the same password for multiple systems or applications. The introduction of biometrics is the solution, because with the method of authentication, where the user is something, that is, by using some of his physical or behavioral characteristics, the identity is confirmed in order to be able to



access the desired resources or to approve some action, to give consent. Biometrics already occupies a significant part of the market, and forecasts are that in the coming period the market share will continue to move upward [5].

Fingerprint is the most widespread biometric modality, which is widely used primarily in unimodal biometric systems, but also in multibiometric approaches [6]. The quality of the biometric fingerprint sample has a great impact on the performance of the biometric recognition system and depends on the environmental conditions under which the acquisition is performed, as well as the sensor technologies and algorithms that are applied. The quality of the fingerprint can be defined as a measure of the clarity of the ridges and valleys, as well as the extracted minutiae, delta, core features necessary for identification [7,8].

## **2. ACQUISITION**

The first step in identifying a person based on a fingerprint is the acquisition of a fingerprint image and the process of digitizing the fingerprint for further processing. The traditional way of acquiring a fingerprint was using ink, and that is the so-called offline method, which dates back to the 19th century. The print was taken using ink on paper and further processed through special scanners. Another example of an offline method is the taking of latent, hidden fingerprints from objects on which subjects have unknowingly left them. Back in 1823, Purkinje published the classification of papillary lines in his work, and later Galton was the first to explain the concept of minutiae [9]. Henry contributed to the classification of fingerprints, which was initially used in the police, the so-called Henry's system.

Today's systems work in online mode, where a fingerprint is taken using one of the sensor technologies and immediately digitized.

The acquisition of a fingerprint, as the initial stage in the process of identification of the person performed on the sensor module, depends on the range of temperature, degree of air humidity, cleanliness of the finger, damage of the finger, humidity of the finger and other parameters [10,11]. All these parameters affect the performance of the biometric system, so that different environmental conditions lead to different results if performed on different sensor technologies. Based on the conducted research, it was concluded that it is necessary to conduct experimental research that would examine in more detail the possibilities and limitations of fingerprint acquisition in different circumstances on different sensor technologies. The designer of the biometric system would certainly have to keep these limitations in mind, because they can affect the performance of the biometric system. The sensor module is used for the acquisition of a person's biometric data. In fingerprint [12,13], a fingerprint reader is used for acquisition.

## **3. EXPERIMENT**

The goal of the experiment was to conduct measurements under standard and controlled conditions, focusing on different acquisition methods simulating real-life situations. The acquisition methods were performed on several sensor technologies, primarily optical and capacitive. The impact of sensor technologies, as well as various environmental conditions, training of subjects, on the sensitivity of the performance of the biometric system was investigated. The workspace of the Laboratory for Multimedia Communications at the Faculty of Organizational Sciences was utilized. During the experiment, fingerprint readers were connected to a computer, which stored all the samples whose quality was analyzed and which were statistically processed. For the purposes of the experiment, a software tool was implemented that realizes the acquisition process, as well as a software solution for the process of comparing samples during verification. The need to evaluate the performance of a unimodal biometric system in various usage scenarios was observed.

The main goal is to develop a model to improve the acquisition process with the aim of testing the performance sensitivity of fingerprint biometric systems. The test was repeated on several sensor technologies on multiple fingers of the left or right hand in different scenarios. The main goal is to find an answer to the question of how controlled environmental conditions, user training and other parameters affect the performance sensitivity of a fingerprint-based biometric system.

### **3.1 DESCRIPTION OF EXPERIMENT CONDITIONS**

The experiments were performed in accordance with predefined ambient conditions and appropriate equipment. The following states of finger soiling were monitored: normal, dirty, greasy, moist and shriveled.

The experiments were performed under two temperature ranges: a normal temperature of 20-24 degrees Celsius and an elevated temperature of 35-40 degrees Celsius. Two types of sensor technologies were used: optical readers (Digital Persona, HF-7000 [14,15]) and capacitive readers (Eikon UPEK) [16,17]. The acquisition of biometric fingerprints was realized at a resolution of 500 DPI. Two algorithms, NBIS and SourceAfis, have been used in the extraction of features from biometric fingerprints. Subjects left their left and right index fingers during the acquisition.

Based on the stated conditions under which the experiments were carried out in which 37 respondents participated, 2664 different measurements were made, that is, the creation of biometric samples.

In order to be successfully performed, the biometric sample acquisition process requires appropriate software. An application was developed that allows subjects to leave their fingerprints on different readers in different environmental conditions. Biometric templates are extracted from data obtained using biometric sensors. Templates, together with metadata about temperature, humidity, resolution, date of acquisition are placed in the database.

The Fedora operating system was used for the software solution for fingerprint acquisition, while the application was developed in the Java programming language. In order to achieve communication with fingerprint readers, the Libfprint library [18] was used for Digital Persona and Eikon UPEK devices, while for the HF-7000 the SDK that was supplied with the reader was used. As the application interfaces for both mentioned libraries are written in the C programming language, a corresponding JNI Wrapper was developed that allows the fingerprint acquisition to be integrated into the wide range of possibilities offered by the Java programming language. The architecture of the software solution for fingerprint acquisition and evaluation is shown in Figure 1.

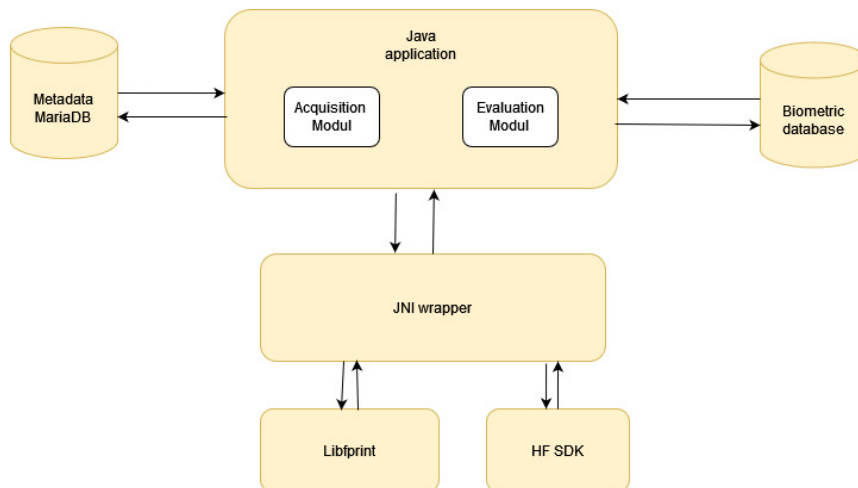


Figure 1: Architecture of the software solution for fingerprint acquisition

The application itself consists of two modules. These are the acquisition module and the evaluation module. The acquisition module is used for data collection and their storage, while the evaluation module uses the collected data and enables their textual and graphical display for the needs of further research.

Metadata contains data on respondents who provided biometric fingerprints, data on the type of fingerprint contamination, the hand on which the finger is located, the position of the finger on the hand, the type of biometric sensor, as well as data related to the ambient conditions in the environment that were recorded when the biometric fingerprint was taken on the sensor. They are stored in a relational database, and the implementation uses MariaDB as a relational database management system. The biometric database is a hierarchically structured set of directories where files containing biometric fingerprint images are stored. They carry with them data on image size, image resolution, number of image colors as well as the format of the binary record of the biometric fingerprint image.

#### 4. A DATA MODEL FOR THE FINGERPRINT ACQUISITION PROCESS

A data model for the biometric fingerprint acquisition process was developed [19]. Figure 2 shows a data model that monitors performance sensitivity in the fingerprint acquisition process.

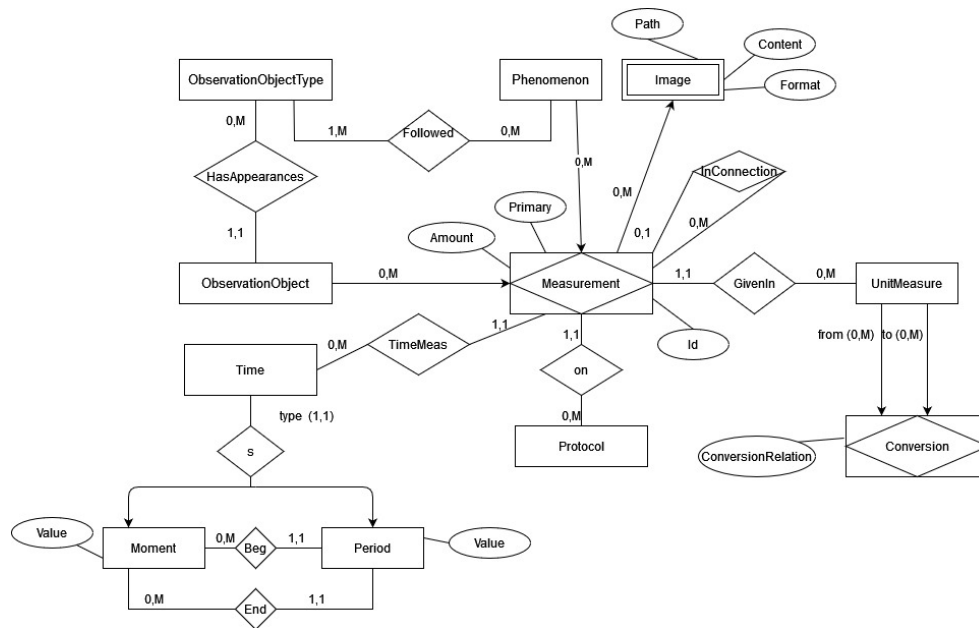


Figure 2: Data model for the fingerprint acquisition process

The result of the proposed methodological approach is a data model that monitors the behavior of various parameters (Fig. 2), the so-called Phenomenon, which was demonstrated through the program solution. The "Measurement" model of analysis was used as a basis for creating this data model [20]. A Phenomenon is an event that occurs during acquisition and can occur due to a change in ambient conditions such as temperature, air humidity, light intensity, etc., or due to the interaction of a sensor and a person's finger. The interaction between the sensor and the person's finger gives Phenomena like a biometric fingerprint or some of the events that can be detected by the sensor, such as: pressing the finger on the sensor plate, separating the finger from the plate before the scan is complete, etc.

Due to the fact that the values of the Phenomenon vary from one occurrence to another, a general data model is proposed for monitoring the sensitivity of fingerprint acquisition performance. It is of great importance to monitor and measure various phenomena over various objects of observation such as the working environment, sensors or individuals. For this reason, the integration of all measurements, both of ambient phenomena and others, was carried out.

In our case, for one ObservationObjectType, 1 to M Phenomena are monitored, while each ObservationObject has its own Observation Object Type. For example The Object of Observation can be a concrete sensor, and the Type of Object of Observation can be an optical or capacitive sensor. For them, measurement results are recorded through the aggregated object Measurement. A Protocol for each measurement is defined for that object in the form of a measurement method. On the Measurement object, there are two attributes Amount and Primary. In the Amount attribute, the results of all Phenomenon measurements are recorded (degrees Celsius, percentage of air humidity, number of minutes), and the unit of measurement is defined using the GivenIn link. Also, the data model allows defining the conversion of one unit of measure to another using the aggregate object Conversion and the attribute ConversionRelation.

The Primary attribute is of the boolean type, and if the occurrence of a measurement has a value of this attribute equal to True, it means that it is the root of a measurement procedure, to which the values of all other measured parameters in the procedure are later added. Individual measurements in one procedure are connected to the root measurement via the binary connection InConnection. Also, the weak Image object from the strong Measurement object is used to store the fingerprint image, and in this case it is the Observation Object of the individual. The weak object has a Content attribute that stores a blob (Binary Large Object) of the fingerprint image.

The proposed data model also enables monitoring of the moment in time or the period when the measurement was performed through the specialization of the Time object into the subtypes Moment and Period. This model presented in Figure 2 monitors the sensitivity of the system performance in the acquisition process depending on the change of parameter values over different observation objects that have a dominant influence on the quality of the fingerprint image.

#### 4.1 EXAMPLE OF A MEASUREMENT INSTANCE

The evaluation of the proposed data model will be demonstrated by presenting an example instance of the Measurement object in the proposed software solution in JSON format for better readability.

```
{
  "imprint": {
    "hand": "left",
    "finger": "index",
    "dirt": "normal",
    "fingerreader": {
      "name": "DigitalPersona",
      "technology": "optical",
      "maxdpi": 500
    }
  },
  "temperature": 24,
  "humidity": 50,
  "the picture": {
    "filepath": "Leva_Kaziprst_normalan_DigitalPersona_1555947468350.tif",
    "size": {
      "x": 481,
      "y": 364
    }
  },
  "dpi": 400,
  "quality": 1,
  "algorithm": {
    "name": "SourceAfis",
    "numberofminutia": 52,
  }
}
```

The displayed JSON object represents an instance of the Measurement object at time  $t$  for all Observation Objects. In accordance with the proposed data model, information is recorded on the fingerreader that represents the Fingerprint Phenomenon. The next step in the measurement is the information that the person is left-handed, as well as which finger he leaves on the sensor. If the Observation Object is ambient, then the temperature and humidity sensors read data about, for example, 24 degrees Celsius or 50% air humidity. Data on the normal condition of the finger's soiling are monitored, in the case when the Object of Observation is an individual.

#### 5. CONCLUSION

Some of the prediction models can be applied to the developed data model to observe the behavior of systems with larger biometric databases. With most systems, the question of the security of the biometric database is raised, so one of the directions of further research is the examination of the possibility of placing the biometric database in a cloud environment. An emerging area in the modern business environment is certainly the application of biometrics in blockchain technology. Of course, the directions of further research are the possibilities of applying the proposed methodology in various industrial activities.

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# BLOCKCHAIN INFRASTRUCTURE FOR MANAGING COMPETENCES IN HIGHER EDUCATION

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**Abstract:** *Recognizing the evolving demands of the labor market, universities are redefining education systems to emphasize practical skills and competences. The aim of this paper is to propose a solution for competence management in higher education that ensures the authenticity and accessibility of acquired credentials which represent competences. The paper outlines a blockchain-based ecosystem for managing competences in higher education, benefiting stakeholders such as educational institutions, employers, and students. Additionally, this paper proposes a system that enhances data integrity and accessibility, facilitating the transparent issuance and verification of academic credentials by leveraging blockchain, NFT, IPFS, and graph technologies. Implemented as a decentralized application, the system allows professors and students to securely assign and view competences. In summary, this paper presents a comprehensive solution for credential management in higher education, leveraging blockchain technology to address challenges in credential verification and ensure the long-term relevance and value of academic credentials in the job market.*

**Keywords:** *competence management, higher education, blockchain, NFTs*

## 1. INTRODUCTION

One of the main ways competences can be acquired is through the learning process (Berio & Harzallah, 2007). The labor market calls for changes. Recognizing the gap between the competences acquired at the university and those needed for the job, and after consultations with representatives of employers from various industries and students, universities worldwide are working on the development of innovative education systems based on skills and competences. The main conclusions are that universities need to enhance their existing curriculum and programs by improving competences related to communication, teamwork, technical expertise, customer satisfaction, multi-criteria decision-making, language, and multicultural work environments (Chiru et al., 2012). Universities should move away from traditional curricula, which provide non-specific, generalized education, towards managing the dynamics of students' knowledge acquisition based on specific and measurable descriptions of academic needs (García-Barriocanal et al., 2012). Competence frameworks are useful tools for teachers to identify and develop the knowledge, skills, and abilities needed for future leaders (Staškeviča, 2019; Shum et al., 2018; Sisson & Adams, 2013). Blockchain, due to its characteristics, has numerous applications, and one of them receiving special attention in this work is the application of this technology in competence management processes. Blockchain enables this process to occur in a transparent, efficient, precise, and secure manner. This paper presents a competence management system in higher education institutions aimed at leveraging the potential of blockchain in this area. The mentioned system emphasizes the accessibility and transparency of academic data, which stakeholders can access at any time from any location. Their storage on decentralized and distributed systems ensures their authenticity and immutability. A decentralized application called CompetenceBound, based on blockchain, NFT, IPFS and graph technologies, has been developed to avoid storing large files on the blockchain network itself. Additionally, for the purpose of this paper, a competence management model was created. The model is aligned with well respected industry standards such as ACM's Computing Curricula 2020 (CC2020) and Competence Model for Undergraduate Programs in Information Systems (IS2020), both of which incorporate Bloom's Cognitive Skill list and dispositions to precisely describe the acquired competence. The aim of this paper is the analysis and development of a blockchain-based solution for competence management in higher education institutions in an efficient and secure manner. This research is conducted to explore the possibilities of using blockchain technologies primarily in the field of higher education. The analytical part of the research provides an overview of concepts

such as competence model, blockchain, and its applications. The result of this research is a pathway to a community where academic credentials in the form of NFTs can be issued and verified in a transparent, secure, and straightforward manner by interested parties such as potential employers and higher education institutions.

In the second chapter, competence management and its correlation with effective role performance are explored. The broader concept of competences is discussed, along with the introduction of competence frameworks aimed at optimizing performance. This chapter also provides a brief overview of the blockchain applicability in higher education.

The third chapter proposes a blockchain-based ecosystem for managing competences in higher education, as well as a system architecture for the chosen part of that ecosystem and a competence management model used in the system. This chapter presents the main goal of this paper which is development of a part of the ecosystem, including the development of a smart contract for minting NFTs (that represent the attained competence and competence level) and decentralized application that allows users to easily assign and view competences. The smart contract is written in Solidity and deployed on Ethereum blockchain network. Decentralized app is developed using ReactJS and leverages IPFS to securely store vital competence data and utilizes GraphQL to seamlessly retrieve information stored on the blockchain. The implemented system currently focuses on a blockchain competence for decentralized app development named "DApp Development", with knowledge elements and detailed description presented in the Chapter 3.2. Chapter four provides the clear overview of the developed decentralized application called CompetenceBound.

## **2. LITERATURE REVIEW**

### **2.1 Competence management**

Competence management entails the identification of essential competences necessary for achieving targeted performance within a specific role (Hondeghem & Vandermeulen, 2000). This process involves analyzing the gap between required and existing competence levels, examining how learning technology can intersect with competence models, defining roles within organizations, and placing employees in positions where they can yield optimal results (García-Barriocanal et al., 2012). Since the 1980s, competence management has become integral to the business world, acknowledging that competences contribute to effective and superior organizational performance (Palan, 2003).

Competences represent proven abilities to responsibly and autonomously utilize one's knowledge, skills, and abilities (personal, social, and/or methodological) in various situations, such as work, study, professional, and personal development (Chiru et al., 2012). It's crucial to note that the concept of competences extends beyond technical knowledge and skills necessary for specific tasks, encompassing behavior, personal attributes, and how individuals apply their knowledge and skills (Chouhan & Srivastava, 2014). According to research, there are five main components of competence: Knowledge, Skills, Personal Concepts, Psychophysical Characteristics, and Motivation (Chouhan & Srivastava, 2014; Competency-based Pay on a Banding Platform: A - ProQuest, 1994).

A competence framework, also known as a competence model, consists of a group of key competences. It delineates a combination of specific knowledge, skills, and other personal qualities necessary for effectively performing designated tasks. The model should provide a clear definition of each competence, including measurable or visible performance indicators or standards. Developing competence models offers significant advantages across various domains - academic, private business sectors, or the public sector (Staškeviča, 2019).

### **2.2 Application of blockchain in higher education**

Due to its versatile nature and characteristics, blockchain has numerous applications (Shuaib et al., 2021). This paper primarily delves into its relevance within the educational sector, particularly focusing on its utilization within higher education institutions.

Blockchain technology in education is still a young discipline, but it has a lot of potential to be beneficial to the educational sector (Bhaskar et al., 2020). This paper suggests some potential uses of blockchain technology in various functions of the educational system, but it is important to note that there can be multiple applications in the educational system to fully utilize the potential of blockchain technology.

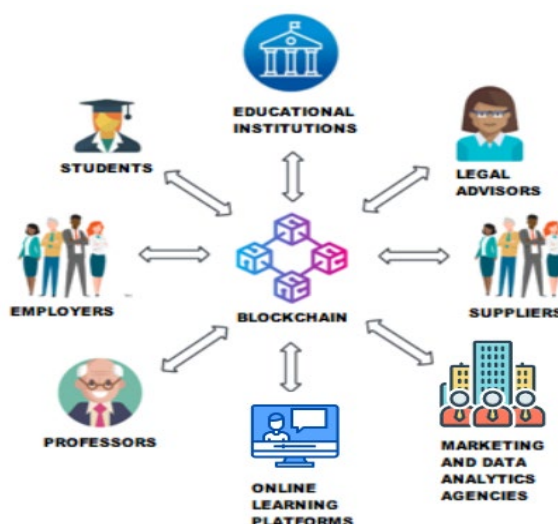
Blockchain could help educational institutions strengthen their ability to deliver knowledge to students through online education, knowledge evaluation, storage and verification of student profiles and documents, protection and publication of intellectual property of students and employees, and regulation of admission processes into institutions (Bhaskar et al., 2020; Averin et al., 2020; Liu et al., 2020).

Blockchain technology could be utilized in higher education to overcome various shortcomings of traditional methods of credential management and verification such as inefficiencies and mistrust in educational and employment sectors, by offering a transparent, decentralized, immutable way to manage student competences gained through the process of education and ensures the authenticity and validity of the obtained competences. According to (Alam, 2021), abilities that are highly desired in the employment sector such as software development competence, problem solving competence, project management competence, language proficiency competence, and many others, are invaluable yet difficult to prove. Blockchain offers the ability to validate students' competences and issue a credential or a badge in the form of Non-Fungible Tokens (NFTs) that will serve as a portable, future-proof, credential that maintains integrity over time.

### 3. BLOCKCHAIN-BASED ECOSYSTEM FOR MANAGING COMPETENCES IN HIGHER EDUCATION

Platform created utilizing blockchain technologies could be beneficial for different kinds of stakeholders such as educational institutions, employers, professors, students, online learning platforms, marketing and PR agencies, technology providers, data analytics agencies, legal advisors, government bodies and many more.

Figure 1 illustrates suggested ecosystem for educational sector based on blockchain technology:



**Figure 1:** Blockchain-based ecosystem in higher education

Educational institutions could keep track of students' progress and promote their commitment to innovation and student success. They could use the benefits of different online learning platforms to provide their students with extra learning material. Based on their students' preferences and engagement levels regarding those learning materials, educational institutions could easily identify areas of interests of their students and take them into consideration. Thanks to different statistics provided by the platform, educational institutions could spot the gaps in knowledge of their students. They could also benefit from getting insights into activities of various verifiers and talent acquisition specialists that visit the platform in search of students with certain competences and adjust their curriculum according to the competences that are recognized as most desirable. Online learning platforms benefit from proposed ecosystem is in the promotion and sales of their courses, bootcamps and other learning materials to the students and educational institutions that wish to provide certain learning materials to their students. Another important stakeholders are verifiers, such as employers and educational institutions, that benefit from the ecosystem by effortlessly validating credentials and spotting the students with exceptional capabilities and thereby making informed decisions about employment, admissions, etc. The value this ecosystem proposes to students is opportunity for continuous improvement and growth, by keeping track of their progress, and giving them access to various valuable learning materials that they can use to boost their knowledge and skills and acquire more competences. Another significant benefit is portability of the credentials which students can easily share with interested



parties. Credentials obtained through the use of this system retain their long-term relevance and value and are aligned with well respected industry standards. Expertise of legal advisors must be utilized in proposed ecosystem in order to ensure that there is law, regulations and industry standards compliance. Marketing and PR Agencies, data analytics companies, and suppliers are integral components of the proposed system, contributing significantly to its key activities. They provide essential support in areas such as marketing strategies, public relations efforts, data analysis, and the provision of necessary resources. Their involvement enhances the effectiveness and efficiency of the system, ensuring its success and sustainability. Fundamentally, this blockchain ecosystem is crafted to facilitate smooth interactions among diverse participants such as educational institutions, partners, verifiers, students, etc. Utilizing blockchain technology's capabilities empowers this system to deliver unparalleled transparency and security to these stakeholders and streamlining key processes. Within the context of this project, only a part of the proposed ecosystem for educational sector based on blockchain technology has been implemented. The developed system is being examined in the following section.

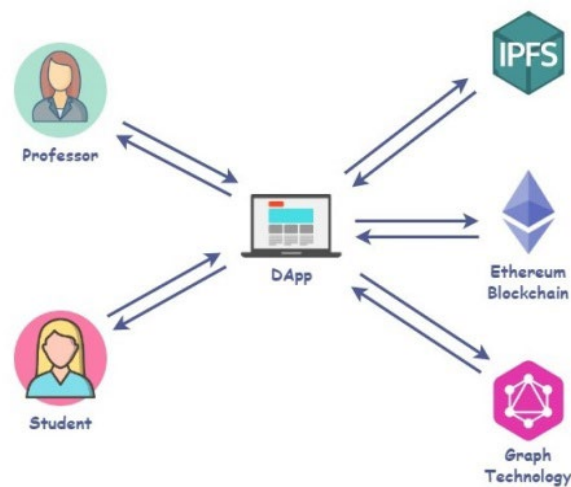
### 3.1. Designing system architecture

Decentralized application represents the core of the implemented system for credential management. The app enhances integrity, transparency, trust and efficiency by leveraging blockchain technology, graph technology and IPFS distributed data system. It also streamlines the credentialing process, empowers students, fosters continuous improvement, aligns with industry standards, and provides future-proof credentials compatible with emerging technologies and evolving industry standards, ensuring their long-term relevance and value in the job market.

Key users in the proposed system include:

- Professor(admin) – has the ability to assign competences to students, view and filter them
- Student – has the ability to view and filter the competences that are assigned to him

Figure 2 illustrates interactions between key components of the designed system:



**Figure 2:** Interactions between key components of the system

The functional requirements that the application must fulfill include:

1. Assigning competence credentials in the form of NFTs
2. Displaying assigned credentials
3. Filtering of assigned credentials

Sequence of system operations for assigning a competence is following:

4. Professor fills out the form for competence assignment which includes following data:
  - Student's first and last name
  - Student ID
  - Student's MetaMask account
  - Competence name
  - Competence knowledge elements and corresponding skill levels
5. General skill level (competence level) is being calculated based on the individual skill levels of each knowledge element

6. Appropriate image from the collection of the competence is being determined based on the general skill level
7. An object that will be stored on IPFS is derived from form data, general skill level and corresponding image representing that level
8. Object that represents the credential is stored on IPFS
9. Smart contract's function for minting NFTs is being called with following arguments: IPFS CID of the object, student's wallet address, competence ID and competence level
10. Query is executed to fetch the assigned competences (minted NFTs) from the contract's state

Sequence of system operations for viewing and filtering competences is following:

1. Choose a filter (optional):
  - Professor has the option to filter by competence name, student, or both
  - Student has the option to filter by competence name
2. Query is executed to fetch the assigned competences (minted NFTs) from the contract's state (by filter if it's selected)

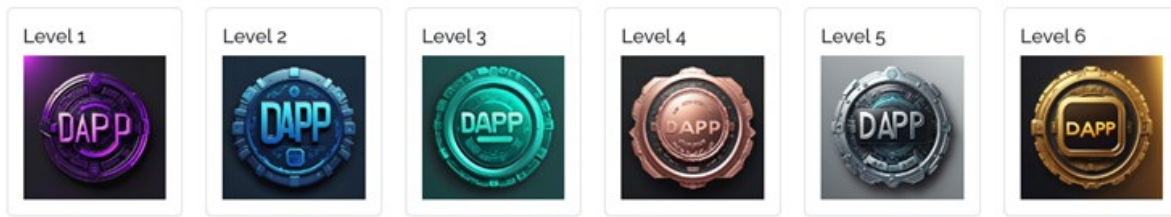
### 3.2. Proposed Competence Management Model

In order to establish a robust framework for assessing student competences, a competence management model, which follows acknowledged industry standards, was meticulously crafted for this project. This model draws inspiration from respected sources such as ACM's Computing Curricula 2020 (CC2020 Task Force, 2020) and the Competence Model for Undergraduate Programs in Information Systems (Leidig et al., 2021). These influential models integrate Bloom's Cognitive Skill list and dispositions, providing a comprehensive framework to accurately depict the acquired competence of students. Currently, the implemented system focuses on a specific blockchain competence that has been defined according to the best industry guidance and standards for the purpose of this project: **Decentralized application development**. The attributes and components of this competence are listed below.

**Table 1 - Decentralized application development competence**

<b>Competence area</b>	Blockchain proficiency
<b>Competence name</b>	DApp Development
<b>Competence description</b>	Proficiency in developing decentralized applications (dApps) on blockchain platforms, incorporating smart contracts, user interfaces, and backend infrastructure. DApp development involves understanding the principles of decentralized computing, designing user-friendly interfaces, implementing efficient smart contracts, and deploying decentralized applications that interact seamlessly with blockchain networks
<b>Knowledge elements of the competence</b>	
<b>Name</b>	<b>Description</b>
Smart Contract Development	Proficiency in designing, coding, and deploying smart contracts on blockchain platforms, ensuring security, efficiency, and functionality.
User Interface (UI) Design	Ability to design intuitive and user-friendly interfaces for decentralized applications, focusing on usability, accessibility, and user experience (UX) principles.
Backend Infrastructure Development	Competence in developing and managing the backend infrastructure required for dApps, including databases, servers, and APIs, while adhering to decentralized architecture principles.
Blockchain Platform Proficiency	Understanding of different blockchain platforms (e.g., Ethereum, Hyperledger, etc.) and their respective tools, languages, and development environments for dApp deployment.
Interoperability and Integration	Knowledge of integrating various components of dApps, including smart contracts, frontend interfaces, and backend systems, to ensure seamless interaction within blockchain networks.
Testing and Debugging	Ability to conduct thorough testing and debugging of dApps to ensure functionality, performance, and reliability, using tools such as automated testing frameworks and network simulators.
Deployment and Maintenance	Skills in deploying dApps on blockchain networks, managing version control, and performing maintenance tasks such as updates, patches, and scaling to accommodate increasing user demand

NFT collection representing different levels (correlated to Bloom's skill levels (CC2020 Task Force, 2020; Leidig et al., 2021; Anderson et al., 2001)) of this competence are shown in the image below:

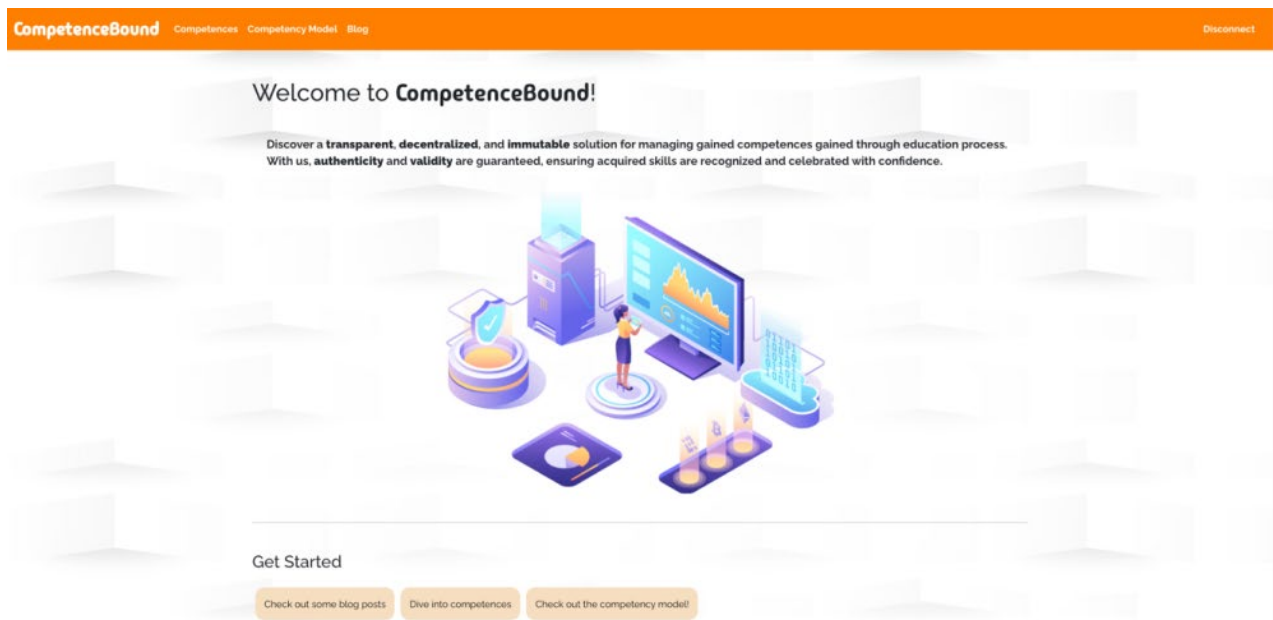


**Figure 2:** NFT collection of the competence

This competence model ensures that the platform is aligned with industry standards and equipped to effectively assess and validate students' skills in this specialized area.

#### 4. DEVELOPED DECENTRALIZED APPLICATION

Log in page is simple and clean. It consists of application name and "Connect" button. User can log in by clicking "Connect" button which will open MetaMask log in window extension. By connecting to the wallet, user can now access the application. He is welcomed by home page as shown in the Figure 4:

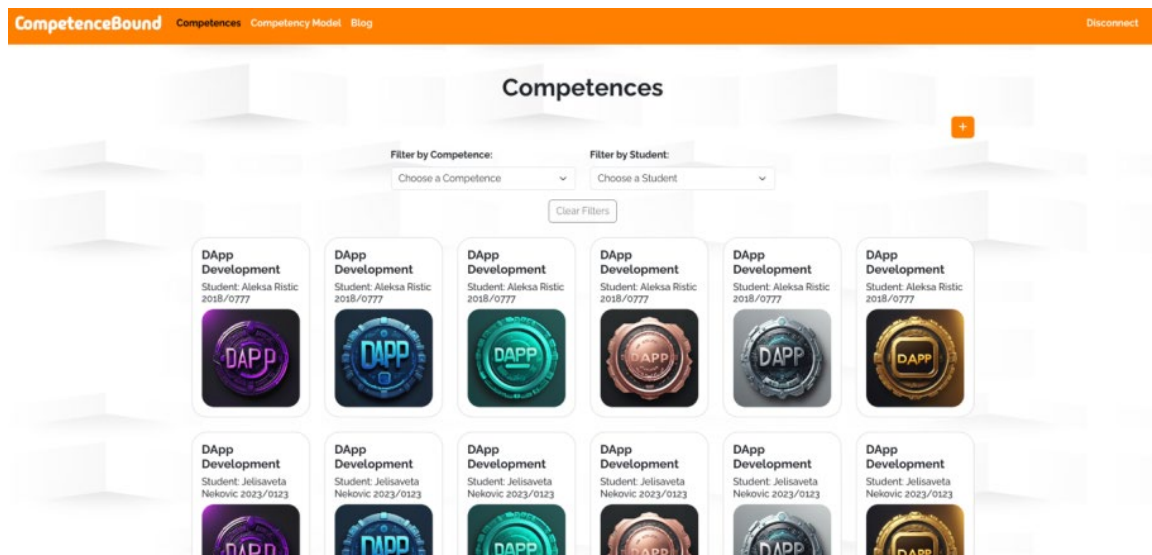


**Figure 4:** Home page

From this page, user can quickly navigate to other pages either by using navigation menu or by clicking "Get started" buttons. User can disconnect from the application by clicking "Disconnect" button in the top right-hand corner.

The "Competence Model" page provides the definition of competences and its components, and explains Bloom's Cognitive Skill list which is used for differentiating levels for each of the competence elements (CC2020 Task Force, 2020; Leidig et al., 2021; Anderson et al., 2001). This page also displays the algorithm used to calculate the general level of a competence. General level is calculated as an average value of all of the assigned levels of each knowledge element of the competence. The result of the calculation is rounded. At the end of the page, all of the available competences in the system are listed.

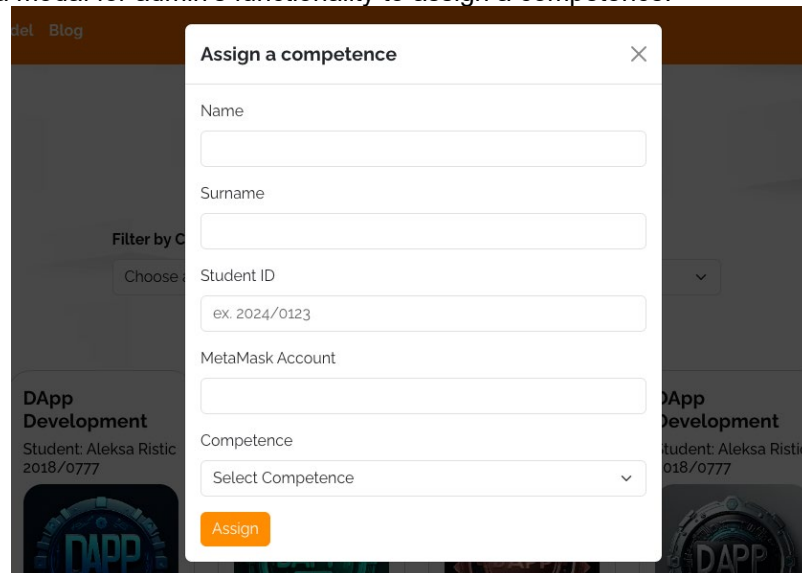
On the "Competences" page for admin user all of the students competences are displayed and he has the ability to filter them by competence name or student name as shown in the Figure 5:



**Figure 5:** Competences page from admin's point of view

This page doesn't offer functionalities to assign competence or filter by student when the logged in user has a student role. User with this role can only view his own competences.

Figure 6 illustrates a modal for admin's functionality to assign a competence:



**Figure 6:** Modal for assigning competences

The last page in the system is the "Blog" page where user is presented with some of the blogs related to competences and potential applications of blockchain and related technologies.

## 5. CONCLUSION

In summary, this paper presents a comprehensive solution to the challenges faced in credential management and verification. The implemented blockchain-based competence management system not only enhances trust, integrity and authenticity, but also streamlines the credentialing process, empowers students, fosters continuous improvement, aligns with industry standards, and provides future-proof credentials compatible with emerging technologies and evolving industry standards, ensuring their long-term relevance and value in the job market. Practitioners in higher education can benefit from adopting similar systems based on blockchain technology to ensure the authenticity of competences and improve employability for students. By prioritizing data security, promoting transparency, credential accessibility and embracing decentralized access, institutions can pave the way for a more efficient and trustworthy competence management process.

Future development will focus on adding more functionalities to the decentralized application that are represented in the proposed ecosystem.

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# BLOCKCHAIN AS A SERVICE: 5G OPERATORS PERSPECTIVE

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**Abstract:** *The Fifth Generation (5G) wireless networks and beyond are deployed in a heterogeneous environment with massive ubiquitous devices. The tremendous increase in the number of connected devices and exponential growth in data volumes pose severe security challenges in the 5G ecosystem. To meet these requirements, a redesign of the traditional centralized network architecture is needed. Blockchain is considered a promising solution that supports decentralization, transparency, security, and privacy for 5G operators. Recently, Blockchain-as-a-Service (BaaS) emerged as an improvement of blockchain applications. Cloud integration with blockchain provides a cost-effective and innovative approach for business activities in the 5G ecosystem. Nevertheless, it inherits challenges related to blockchain but also introduces novel BaaS-related issues. This paper addresses major incentives for 5G operators to use BaaS. Some notable use cases of BaaS in the 5G ecosystem are analyzed. Challenges and trade-offs that hinder the wider adoption of BaaS by 5G operators are highlighted.*

**Keywords:** *Blockchain, Blockchain-as-a-Service, smart contracts, 5G operators*

## 1. INTRODUCTION

Driven by the enormous growth in the number of connected devices and the rapid advancements in information and communication technologies, the Fifth Generation (5G) networks and beyond are expected to support a plethora of new innovative business opportunities and industrial applications (Tkachuk et al., 2022). The aim of 5G cellular networks is to provide a customized and advanced user-centric value, thus supporting ever-increasing demands for new services and, hence, revolutionizing global industries (Nguyen et al., 2020). To meet the diverse requirements in service provisioning, several technologies are integrated into 5G wireless communication networks, including Software-Defined Networking (SDN), Network Function Virtualization (NFV), multi-access edge computing, and cloud computing (Tahir et al., 2020). A wide range of technologies supporting 5G are needed to provide a flexible and scalable network. However, the integration of numerous technologies poses severe challenges for security, privacy, robustness, and resiliency. Blockchain technology is considered a promising solution to address the above-mentioned challenges in the evolving telecommunications ecosystem, thus enabling the continuous growth of the number of connected devices, data traffic, and diverse services. In essence, it is an immutable, transparent, and decentralized distributed ledger that relies on the Peer-to-Peer (P2P) network architecture. Smart contract is one of the major triggers for the development of blockchain-enabled applications due to their automatic control (Gai et al., 2020). Along with smart contracts, thanks to the recent advances in cryptography, distributed systems, and consensus algorithms, blockchain has become an effective and robust technology that can regulate interactions between numerous participants or devices in a secure, trusted, and decentralized manner (Deebak & AL-Turjman, 2022). Due to the inherent blockchain properties, including security, privacy, transparency, and immutability, blockchain can reveal its full potential in 5G and beyond networks that require autonomic resource management, security and fraud prevention, ubiquitous computing, and reliable data management (Moudoud et al., 2022).

Despite the diverse benefits of blockchain and 5G integration, the implementation of a blockchain is a complex, error-prone process that introduces significant costs in terms of redundant network and computational resources (Biswas & Gupta, 2019). To address the issue of complexity, the concept of Blockchain-as-a-Service (BaaS) is proposed (Song et al., 2022). In BaaS, blockchain applications are shifted from system development to service utilization, thus supporting the mass adoption of blockchain technology. BaaS can manage blockchain consensus, forking, node validity, and synchronization. Furthermore, BaaS can manage cloud-related services, including resource management, bandwidth allocation, and Internet connection. The main advantage that BaaS provides to enterprises is the flexibility to focus on the business goals and functional

needs of a blockchain. All blockchain-related applications are deployed on the cloud infrastructure, and the technical overhead is fully outsourced to the cloud service provider. The use of BaaS services requires little or no expertise in blockchain implementation. Blockchain participants can use a graphical interface to design the desired blockchain architecture, initialize pre-installed cloud virtual machines (VMs), and install smart contracts. Depending on the transaction rate, the resources allocated to blockchain components can easily scale up or down. Due to its centralized nature, BaaS is often criticized for undermining the main objective of the blockchain itself, i.e., decentralization. Besides, BaaS providers are usually general cloud service providers that offer blockchain-related services exclusively on their cloud, which leads to vendor lock-in situations. Therefore, the advantages of BaaS implementation in a 5G ecosystem should be thoroughly weighted against the disadvantages.

Currently, there are a number of research studies addressing the integration of blockchain and 5G networks. However, the literature lacks analysis of BaaS adoption by 5G operators. In this paper, we address the essential drivers and benefits of the BaaS implementation in the 5G ecosystem. The main contributions include the categorization of typical application areas and the systematization of the major trade-offs regarding the BaaS deployment in the 5G ecosystem.

The rest of the paper is organized as follows. The main drivers for wider deployment of BaaS in the 5G ecosystem are analyzed in Section 2. Some typical use cases of BaaS and blockchain by 5G operators are presented in Section 3. Section 4 observed major trade-offs in BaaS implementation in a 5G environment. Finally, concluding remarks are presented in Section 5.

## **2. DRIVERS FOR BAAS ADOPTION IN THE 5G ECOSYSTEM**

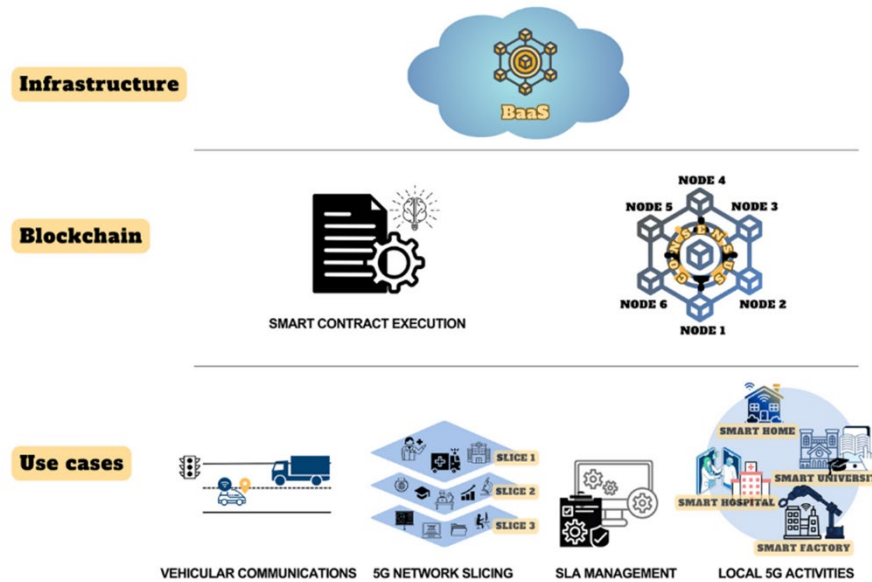
It is expected that 5G networks will provide a wide range of services in multiple vertical industries, including Internet of Things (IoT) applications (smart cities, smart grid, smart health, smart agriculture, etc.), Vehicle-to-Vehicle (V2V) communications, collaborative gaming, augmented reality, virtual reality, etc. These verticals have diverse and strict performance requirements in terms of bandwidth and latency. To meet these requirements, rapid resource allocation and network orchestration are needed. Additionally, a high degree of coordination and configurability should be achieved automatically in a secure and reliable manner. Due to the highly distributed network architecture, the synergy of several technologies, including cloud and edge computing, small-cells, SDN, NFV and D2D is needed in a 5G ecosystem (Tahir et al., 2020). It is likely that end-to-end service provisioning will surpass the capability of a single 5G operator from a cost and management perspective. Thus, several stakeholders need to share resources. These requirements pose severe challenges in the 5G ecosystem, such as security and privacy, service level agreements (SLA), interoperability, and resource management (Hewa et al., 2020). Blockchain, especially the consortium blockchain, appears as a convenient solution to address these issues. Both 5G and blockchain are decentralized networks. Since multiple stakeholders are involved, it is highly challenging to establish trust and, concurrently, to ensure security and privacy. The deployment of blockchain in a 5G network can release each party from control over the data. One of the most prominent drivers for the adoption of blockchain in a wide range of use cases in telecommunications is smart contract. Resource allocation and network orchestration are automated using smart contract based on the agreed SLA. Thus, all stakeholders can transparently monitor the entire process. This ensures a secure, trustworthy, and auditable trail of transactions on the blockchain.

Moreover, 5G networks enable smaller stakeholders to take part in a telecommunications ecosystem. Due to network virtualization technology, it is possible to dynamically allocate network resources to a small service provider, which can serve a wide base of users without its own physical infrastructure. A new entrant in the market, such as a small smart city service provider, can provide services forthwith by acquiring a virtual slice of the network from other operators who own physical infrastructure. These changes in the telecommunications ecosystem require new trust relationships, traditionally provided by a central trusted mediator (X. Li, Russell, et al., 2021). The trusted central mediator (trusted third party) aims to balance the power of the smaller operators since it cannot be guaranteed for the larger operators to act fairly. Since the new telecommunications infrastructure ownership models shift from a situation where a few network operators governed the entire ecosystem to a model with many small players that co-exist with larger players, the single source of trust (e.g., national regulatory agencies) is becoming less relevant (Afraz et al., 2023). Thus, distributed alternatives for ensuring trust are needed.

## **3. USE CASES OF BAAS IN THE 5G ECOSYSTEM**

There is a wide range of possibilities for BaaS application in the 5G ecosystem, including improvements in spectrum and infrastructure sharing, national and international roaming (Mafakheri et al., 2021), data management, offloading mechanisms, etc. (D. Li et al., 2022). Several typical use cases of BaaS in the 5G ecosystem are shown in Figure 1.





**Figure 1: Use cases of BaaS in the 5G ecosystem**

### 3.1. Network slicing

The advancements in information and communication technologies introduced some changes in network and infrastructure ownership models (Afraz et al., 2023). A wide variety of vertical stakeholders and over-the-top service providers can coexist as participants in the 5G ecosystem. In such a diverse environment, new levels of trust are needed. A typical example of change in ownership models in network slicing in a 5G environment (Gebraselase, 2021). A network slice in 5G is an instantiation of the physical infrastructure or the underlying network services and capabilities (Chaer et al., 2019). This technique allows an operator to provide numerous services and applications via the same network infrastructure. Concurrently, network slicing simplifies active infrastructure sharing and spectrum sharing. The smart contract can replace the role of a network broker, entirely or partly. Diverse parties can negotiate contract terms autonomously and dynamically, subject to predefined rules. Moreover, smart contracts can automate payment mechanisms. In this case, blockchain allows exclusively controlled access and prevents malicious entities from entering the network. It is crucial to protect the privacy of transactions between contracting parties. A promising solution for these challenges is permissioned blockchain (for example, Hyperledger Fabric), which enables the establishment of virtual channels between any number of organizations. In general, the requirements of network slicing in terms of scale and performance are moderate. The majority of common blockchain platforms can easily meet those requirements.

### 3.2. SLA management

SLA is an agreement between a service provider and parties using the service that comprises all detailed contractual terms, commitments, and the corresponding compensation mechanism in case of violation. Various Quality of Service (QoS) parameters can be embedded into the agreements. Blockchain-based SLA can be used in the neutral host small cell deployment. Third parties (for example, shopping malls or coffee shops) can participate in the cellular network market by installing small cells on their premises and serving users on behalf of the mobile operators. It is possible to establish contracts between the small-cell providers and multiple mobile operators or other service providers. In that case, all participants must monitor and comply with the multiple SLAs. Once the SLAs are established, the enforcement of those terms will rely on the compliance monitoring of the opposite party. Blockchain can assure transparent record-keeping of the measurements (Tahir et al., 2020). If measurements indicate a violation, a complaint will be raised. The provisions specified in the SLA (for example, penalties or termination) will be automatically enforced if all involved parties confirm the pending compliance, without the need for a third-party intermediary.

### 3.3. Vehicular communications

The advancements in Intelligent Transportation Systems (ITS) and Internet of Vehicles (IoV) are expected to reduce carbon emissions, improve traffic safety, and optimize traffic flows. These goals can be achieved through uninterrupted and reliable V2V and Vehicle-to-Infrastructure (V2I) communication. Such a vehicular network requires efficient and effective security mechanisms. The identification, authentication, and authorization processes of vehicles and other IoT devices have strict requirements in terms of latency. Additional important issues in vehicular networks that remain open are trust management, reliability, and data



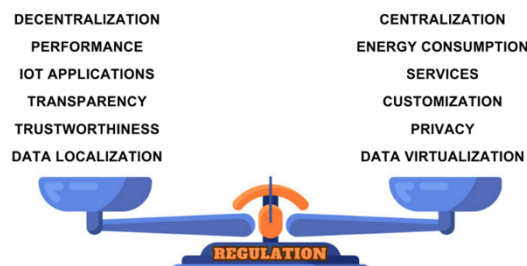
accuracy. Blockchain can solve these issues through decentralized data sharing and identity management as an alternative to conventional third-party reliance (Rasheed et al., 2022). However, designing a blockchain network that can meet the requirements of immense vehicular networks is highly challenging.

### 3.4. Local 5G operators' activities

Local 5G Operators (L5GO), often referred to as private 5G networks, emerged as a revolutionary application of 5G technology, able to cater to the diverse needs of various new applications. It operates as a small-scale mobile network within a limited geographical area, such as a university campus, hospital, shopping mall, etc. These operators have a decentralized and locally oriented design, thus supporting businesses to create their own 5G ecosystem. Furthermore, L5GO can ensure high reliability, manage privacy, and provide incentives for digital innovations. However, the deployment of L5GO poses some challenges, including lack of transparency in roaming and resource-sharing procedures, violation of pre-agreements by network operators, misuse of identity information, and poor adaptability to the extensive number of concurrent users in a 5G domain. To seize the full potential of L5GO, these challenges must be met. BaaS platforms are considered a suitable solution for spectrum and infrastructure sharing, roaming and offloading management, subscription management, NFV management, and IoT data management (Weerasinghe, Hewa, Liyanage, et al., 2021, Weerasinghe, Hewa, Dissanayake, et al., 2021).

## 4. POTENTIALS OF BAAS IN THE 5G ECOSYSTEM

The blockchain technology is expected to provide a new set of innovative solutions in the 5G ecosystem for improved security, privacy, decentralization, and to transform the network management architectures for improved performance. Despite the prominent benefits that blockchain enrolls in 5G networks and services, there are some drawbacks, including storage space, transaction throughput, accessibility, cost issues, and network congestion. On the other hand, BaaS builds a high-performance blockchain ecosystem to develop, deploy, and manipulate blockchain applications (Onik & Miraz, 2019). However, the development of BaaS platforms suitable for practical environments is at a very preliminary stage (Lu et al., 2019). BaaS inherits the unsolved issues of blockchain and also introduces its own challenges, which are covered in this section. The major trade-offs needed to exploit the potential of BaaS 5G operators are presented in Figure 2.



**Figure 2: Challenges and opportunities of BaaS in the 5G ecosystem**

Integration of a full blockchain framework into a 5G-IoT system is a complex process that requires completely separate architecture, specific technologies, protocols, and hardware components (X. Li, Zheng, et al., 2021). Providing IoT-based blockchain capabilities as services introduces additional challenges. Effective monitoring of transactions, blocks, users, and devices is needed. Each modification in the network topology, resource sharing, and computational offloading requires timely addressing. Concurrently, complex privacy issues should be properly managed.

BaaS can expand the transparency of blockchain deployment and runtime. This could remove some technical barriers to a blockchain. Additionally, BaaS can be more adaptable to diverse applications supported by 5G via customization. An issue closely related to transparency and customization is the granularity of the service interfaces, which enable users to use and customize the system. However, the finer granularity of service interfaces endorses customization but deteriorates transparency. In contrast, the coarse granularity of service interfaces increases transparency but disrupts the potential for system customization. A BaaS provider may use blockchain architecture as a source for transparency or may integrate transparency into its design based on the existing knowledge of cloud services. Customization can be improved by smart contracts. Embedding the SLA criteria and QoS considerations can help in achieving high-level customization.

BaaS re-introduces an intermediary in the form of a service provider that usually has some interactions with some entities in the 5G ecosystem. Thus, new trust-related issues emerge. Decentralized trust, as one of the pillars of the blockchain, becomes highly challenging to achieve. High BaaS trustworthiness deteriorates privacy. One possible solution is that BaaS providers enable users to offload parts of data and functions to

their trusted location. The trade-off between trust and privacy in BaaS requires comprehensive analysis. Likewise, the trade-offs concerning the adoption of cloud services should be properly addressed. An issue that arises from trust and privacy relations is data localization and virtualization. Both blockchain and BaaS are distributed systems and, thus, subject to data ownership and data privacy regulation. However, they differ in the block storage location. Blockchain stores blocks in a decentralized ledger (i.e., data is localized), while BaaS encourages block storage in a trusted cloud. The data is virtualized since users may own the data and manipulate the data through the service interfaces, but the data management is done in the cloud. Data localization in BaaS is highly challenging and requires a redesign of the system architecture.

Decentralization is often considered the essence of the blockchain. However, some centralized segments are also present in some blockchain platforms (for example, Hyperledger Fabric). On the other hand, the BaaS providers migrate the blockchain application to the cloud. These services are provided in a centralized manner, and potentially, vendor lock-in may be established and blockchain decentralization undermined. It should be noted that various 5G operators' business activities do not require decentralization itself. In the 5G ecosystem, centralized and decentralized collaboration are often joined for a user, and there is no difference whether the underlying blockchain is decentralized.

One of the major concerns regarding blockchain is energy consumption. Most blockchain consensus protocols require enormous power for execution. In BaaS, tasks related to consensus mechanisms are outsourced to the cloud that is already in use, so the extra power consumption can be saved (Cai et al., 2022). However, performance, resource utilization, and energy consumption are highly correlated and require comprehensive analysis. Several non-technical issues hinder the widespread development of BaaS, including intricate system configuration, high cost, and regulatory issues. Despite the fact that most BaaS platforms provide a whole life cycle of blockchain services, they generally offer only interfaces for creating blockchain applications. The complexity of the underlying infrastructure can discourage developers who need to acquire extensive blockchain knowledge. In addition, the incumbent blockchain systems introduce high costs for equipment and maintenance. Cost-effective BaaS solutions are still in the early stages of development. Furthermore, a lack of unified standards and regulatory issues are another barrier to the wider adoption of BaaS in the 5G ecosystem.

## 5. CONCLUSION

5G technologies aim to support diverse vertical applications by connecting heterogeneous devices and entities, with significant improvements in terms of bandwidth, network capacities, and high QoS provided. However, the number of connected devices shows tremendous expansion, thus raising several critical challenges for network architecture in the 5G ecosystem. A number of security challenges, including lack of transparency, interoperability, and network privacy vulnerabilities, are recognized by researchers. Traditional centralized network architectures cannot meet these requirements. 5G networks are expected to operate in a highly dynamic environment that requires a decentralized and distributed architecture. Such network architecture is crucial for numerous 5G applications and any use cases that require collaboration and cooperation. A blockchain-assisted 5G ecosystem can assure accountability, data provenance, and non-repudiation for every entity. Such network architecture provides self-maintaining, self-servicing, and self-managing capabilities. This can also foster a wider adoption of IoT applications. BaaS is a promising solution to further improve the productivity of blockchain application development. Easier deployment and simplified design are major benefits of BaaS. By deploying BaaS on cloud computing platforms, it is possible to leverage cloud-based solutions that can run on top of smart contracts and functions over blockchain networks. Thus, operators and service providers can simply employ BaaS to execute tasks and activities.

This paper addresses the potential and recent advances in BaaS application in the 5G ecosystem. We thoroughly observed the main drivers and incentives for BaaS adoption by 5G operators and presented some notable use cases where BaaS can be effectively applied. Moreover, we analyzed major trade-offs and the most critical challenges that need to be properly addressed in order to seize all the benefits of BaaS adoption by 5G operators. The development of BaaS platforms and their applications is still in the infant stage. Huge research efforts are needed to provide more convenient solutions for ever-increasing requirements.

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# VERIFYING AI MODEL INTEGRITY WITH BLOCKCHAIN TECHNOLOGY

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**Abstract:** *Analyzing current trends, the design and development of AI models has been the focus of modern machine learning for the last several years. Current AI model management solutions have limitations with features not fully encompassing model distribution, model security and model variants, such as specializations and new versions. We propose a complete solution using blockchain technology, specifically the ERC-721 standard and InterPlanetary File System (IPFS) as the distributed store. This approach secures AI models against model injection attacks due to its cryptographic design and provides hashes of verified AI models. Smart contract code that handles AI model integrity is provided, as well as the sample metadata file. The end goal is to enhance security, transparency, and version control, ultimately contributing to the trustworthiness of shared AI models.*

**Keywords:** *blockchain, artificial intelligence, AI model integrity*

## 1. INTRODUCTION

AI models can be defined as sets of weights, parameters, instructions, or other data that provides information on how the AI solution should operate to provide wanted performance across a set of problems (Kristensen, 2021). At the time of writing, HuggingFace (Hugging Face – The AI Community Building the Future., 2024), the platform most used for publishing and distribution of AI and ML models and datasets, contains more than one million published AI models (HuggingFace Statistics – Originality.AI, n.d.).

With constant improvements in the space of AI research and implementation and new technologies such as transformers (Vaswani et al., 2017), large language models (Brown et al., 2020) and spiking neural networks (Hazan et al., 2018) the need for secure and consistent AI models increases. With secure and consistent AI models we can guarantee that the AI models will perform similarly with expected results across all deployments, without unauthorized modifications. The advent of model poisoning attacks (Tomsett et al., 2019), where AI models can be affected during and after training to produce different results, further reinforces the need for AI model security.

So far, AI model poisoning has been used to prevent generative AI efforts in replicating art styles (Nightshade: Protecting Copyright, n.d.; This New Data Poisoning Tool Lets Artists Fight Back against Generative AI, n.d.). It is also worth mentioning that, after training, it can be difficult for AI models to roll-back to their previous uncorrupted state as well as determining the last good uncorrupted state. Having a hash-based system used for tagging AI models would allow the users to keep track of AI model integrity and its last good training data.

AI models are often specialized or evolved with optimizations for specific tasks or with new training data. One such example is the GPT large language model. First version of the GPT large language model was released in 2018. (Radford & Narasimhan, 2018) with several subsequent versions being released afterwards (Brown et al., 2020; Radford et al., n.d.). Besides general model improvements regarding training datasets and architecture, there are variants with different numbers of parameters, quantization, and context windows (Models - Overview, n.d.). Keeping track of models and its variants is something that should be thought of to maintain the resulting quality as well as security and safety of the AI model. Otherwise, it would be possible to use specialized models for general purpose tasks and vice versa, returning false information about model performance.

## 2. CURRENT WORK

Several keywords have been utilized to find the current work regarding the topic of AI model integrity with blockchain technologies. We used the combination of the base keyword “AI model” with the following keywords to determine the list of current work: “security”, “blockchain”, “distribution” and “sharing”. These keywords are chosen to describe the previously introduced problem. Keywords “blockchain” and “distribution” have been

combined to keep the discovered papers relevant to the context at hand. We narrowed our search for papers published in the period from 2019. to 2024.

The table below shows the number of relevant papers found for each keyword combination:

**Table 1** Comparison of keywords with number of relevant discovered publications

Keyword combination	Number of relevant discovered publications	Referenced publications
AI model blockchain distribution	6	(Boudguiga et al., 2017; Fan et al., 2022; Kim et al., 2020; Liang et al., 2023; Neisse et al., 2017; Xu et al., 2021)
AI model security	6	(Jiang et al., 2023; Kathikar et al., 2023; Khowaja et al., 2022; Pearce et al., 2022; Shevlane et al., 2023; Wu et al., 2023)
AI model sharing	5	(Lin et al., 2023; Moradi & Uta, 2021; Neyigapula, 2024; Pei et al., 2023; Zhou et al., 2021)

We have discovered a publication with the “AI model blockchain distribution” keyword combination that introduces an AI model trading mechanism based on the concept of blockchain and tokens (Fan et al., 2022). This publication defines a mechanism on how AI models can be copyrighted on the blockchain and traded between entities for a fee, as well as used to prevent AI model piracy. On the other hand, the provided solution does not handle the familiarity of different AI models such as generic or specialized variants.

Other works in this keyword combination handle the usage of blockchain technologies for legal contract data sharing (Neisse et al., 2017) which is an interesting approach since, like AI models, legal contract writeups need to be consistent across their implementations. Similar to that, we discovered publications that define methods to perform on-device model updates (Kim et al., 2020), which can be useful for specializing models for specific use cases, and solutions for accountability and algorithmic fairness of AI models (Boudguiga et al., 2017; Liang et al., 2023; Xu et al., 2021) which are distributed via blockchain.

General overview of identified papers in the “AI model security” keyword space confirms our suspicions on the need for traceable and accountable solutions for AI modelling (Jiang et al., 2023; Kathikar et al., 2023; Shevlane et al., 2023). We have also discovered several publications in AI models introducing security vulnerabilities and private data leaks in their day-to-day use (Khowaja et al., 2022; Pearce et al., 2022; Wu et al., 2023). Having an accountable system with an exact chain of model evolution would allow the auditor or the end user to pinpoint the exact model configuration which produced these issues.

Sharing AI models, to keep them secure from tampering and easily transferrable, represent another area where previous work has been performed. There have been ideas on utilizing encryption (Neyigapula, 2024) for secure model sharing and deep learning for model compression and transmission (Lin et al., 2023). Another aspect of sharing AI models are AI model marketplaces. AI model marketplaces are becoming a necessity (Moradi & Uta, 2021) with the amount of AI models increasing daily (Pei et al., 2023), as well as keeping them secure and private when shared between devices (Zhou et al., 2021).

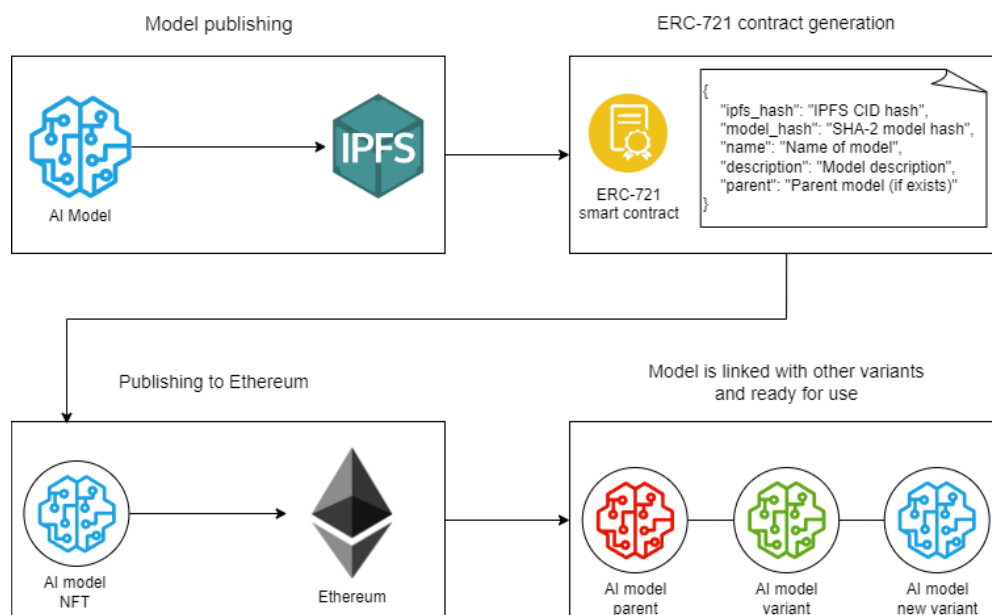
### 3. PROPOSED SOLUTION

We propose a solution based on the concept of non-fungible tokens (NFT’s) on top of the Ethereum blockchain as an AI model metadata exchange mechanism and the InterPlanetary File System (IPFS) as the underlying data store. The proposed solution can keep track of AI models as well as their history and ownership, while providing stable and distributed access points. Tracing AI models and their lifecycle allows easier discovery of new or improved models, easier distribution and easier verification of integrity and authenticity. This way we can be sure that the AI model in question will have correct and expected behavior.

Non-fungible tokens (NFT's) represent a unique data structure stored on the blockchain that cannot be further modified or duplicated. Non-fungible tokens are commonly used as ways to certify ownership of a specific asset and to confirm the authenticity of a specific asset. One of the more common NFT implementations are covered by the implementation of the Ethereum EIP-721 proposal (EIP-721, n.d.) which was ratified as the ERC-721 standard and published in 2017. This standard defines the existence of tokens on the Ethereum blockchain which are unique on the Ethereum blockchain, similar how the concept of Colored Coins (GitHub - Colored-Coins/Colored-Coins-Protocol-Specification: Colu Colored Coins Protocol, n.d.) exists on the Bitcoin blockchain and competing NFT standards running on different blockchains such as Solana (Metaplex, n.d.) or Cardano (CIP-68, n.d.). The ERC-721 non-fungible token standard contrasts with fungible tokens, defined in the Ethereum ERC-20 standard from 2015 (ERC-20, n.d.) which defines the API for fungible tokens and their implementation with smart contracts. Ethereum was chosen as a stable blockchain for our proposed solution with a mature ecosystem, but further research on different blockchains could improve the overall performance.

InterPlanetary File System (IPFS) "is a peer-to-peer distributed file system that seeks to connect all computing devices with the same system of files" (Benet, 2014). The goal is to have a decentralized file system based on content addressing instead of location addressing that is shared between all participants, allowing file access similar to local file system access. Key benefit of IPFS as the storage mechanism for our solution is the concept of immutability, where files added to the IPFS network cannot be modified afterwards. IPFS file immutability is a concept taken from immutable data structures which have the key feature of their state being unchangeable after creation (Cormen et al., 2022). Immutability on the IPFS is done by content identifier (CID) values which are analogue to cryptographic hashes.

When an AI model gets developed, it is first published using IPFS and by design, distributed. Afterwards an ERC-721 token gets minted with the resulting IPFS CID hash as part of the metadata. The metadata contains additional fields which track the history of the model as well as its children. Children in this case represent other AI models as ERC-721 tokens which are derived from the original one. This can be a specialized variant of the original model or an improvement of the model with different parameters.



**Figure 1** Conceptual overview of proposed solution

AI models need to be serializable to a file to be utilized by the proposed solution. There is no requirement for a specific serialization format for the proposed solution to work.

Since ERC-721 tokens are tradeable, it is possible for AI models to change ownership between entities. This can also facilitate the development of an "AI model marketplace" where it would be possible to sell or rent AI model ownership.

The operating cost of our proposed solution is largely based on the cost of storage devices used by the IPFS protocol. Utilizing IPFS pinning (IPFS Docs, n.d.) to keep IPFS distributed files local further increases the cost of storage by guaranteeing the files will be locally available. Besides the cost of a compute resource that will handle the orchestration of the proposed solution with IPFS and Ethereum, additional cost can be incurred by management of a dedicated Ethereum node.

The table below shows an estimate of costs for the proposed solution utilizing 1TB of storage space and a virtual machine that would handle the Ethereum node and the orchestrator of the proposed solution. The calculation is based on the current Oracle Cloud Infrastructure pricelist (Oracle Cloud, n.d.), per one 30-day month with 24 hours of active resources:

**Table 2** Estimated monthly cost for operating the proposed solution

Resource name	Cost of resource unit	Number of units	Total resource cost
Compute - Standard - E5 - OCPU	\$0.03 per OCPU per hour	2 OCPU (equivalent to 4 vCPU)	\$43.42
Compute - Standard - E5 - Memory	\$0.002 per GB per hour	16 GB	\$23.04
Block Volume Storage	\$0.0255 per GB per month	1024 GB	\$26.112
Total			\$92.572

## 4. IMPLEMENTATION

The entire solution is implemented as a single smart contract, `ai_model_verification.sol`, that can be deployed on the Ethereum blockchain. Smart contracts are computer programs running on the Ethereum virtual machine which publish to the Ethereum blockchain that manage digital assets according to defined rules and behavior (Buterin, 2014). The contract is available on GitHub (Mzdsv/Symorg-2024, n.d.) with a matching example of metadata that is used for minting ERC-721 tokens. Ethereum blockchain and ERC-721 standard were chosen for this use case due to the mature ecosystem, stable infrastructure, and possibility to provide rapid development and improvement of the smart contract, thus allowing evolution as the security landscape changes.

The smart contract utilizes OpenZeppelin Contracts library (OpenZeppelin/Openzeppelin-Contracts, 2016/2024) for simpler and more secure development. The included libraries provide implementations of Ethereum standards and implementations of commonly used code examples that have been securely audited and tested. This accelerates development and allows us to focus more on the logic behind the smart contract in question.

We are using the OpenZeppelin Contracts library `ERC721URIStorage.sol` (Openzeppelin-Contracts/Contracts/Token/ERC721/Extensions/ERC721URIStorage.Sol at Master · OpenZeppelin/Openzeppelin-Contracts, n.d.) to interface with the ERC-721 standard. It provides ERC-721 implementation and access to several methods regarding URI management on-chain. This allows the minted token to contain metadata both on-chain and off-chain, increasing redundancy and security. Usage of OpenZeppelin libraries is not a requirement for the implementation of ERC-721 standard. It is possible to use a bespoke implementation of the ERC-721 standard if it matches the EIP-721 proposal or some other libraries that are an alternative to OpenZeppelin, such as Solady (Vectorized, 2022/2024) or Snekmate (rm -rf --no-preserve-root, 2022/2024).

Our token is defined in the constructor with the ticker “AMV” and name “AI Model Verification.” They are optional names that we have chosen for this project. On-chain metadata belonging to our token is defined in the structure `TokenMetadata`. It contains the following fields: `ipfs_hash`, `model_hash`, `name`, `description`, and `parent`. Metadata contains the necessary information of the model that has been published. The location of the model inside IPFS is defined by `ipfs_hash`, while `model_hash` contains the SHA-2 hash of the model. Fields `name` and `description` contain the name of the model and its description, while `parent` is an address field in the metadata that links to the parent model. This allows inheritance and specialization of AI models published. Off-chain metadata has the same fields, but they have been serialized to JSON for easier communication.

Core functionality of the smart contract is defined in the `mintToken` function which handles the generation of the ERC-721 token and metadata publishing. It implements the `_mint` function defined by ERC-721 as well as extensions provided by `ERC721URIStorage.sol` by `_setTokenURI` and `_tokenMetadata`. The result is the identifier of the newly minted token which confirms it has been published on the Ethereum blockchain. Remaining two functions `tokenExists` and `getTokenMetadata` are wrappers around ERC-721 function `_exists` and structure `_tokenMetadata`. These wrappers provide additional safety and error handling for the smart contract.

## 5. CONCLUSION

The evolution of AI models demands robust solutions for security, consistency, and traceability. Our exploration of current research reveals a need for secure AI model distribution and sharing.

Our proposed solution utilizes non-fungible tokens (NFTs) on Ethereum and the InterPlanetary File System (IPFS) to create a metadata exchange system for AI models. By minting ERC-721 tokens linked to IPFS hashes, we enable tracking of model history and ownership, ensuring integrity and authenticity. We are also able to keep track of model history and its specific versions as model training evolves. Model metadata is kept on-chain and off-chain for redundancy and enhanced security.

Further research regarding the proposed solution would involve the development of the “AI Model marketplace” where AI model creators could be compensated for model usage. Deployment of the smart contract on different blockchains besides Ethereum, encompassing their features and benefits could further improve the presented AI model integrity solution. An additional area of research would be in fractional ownership of ERC-721 tokens (Stefanovic et al., 2023), allowing easier recognition of AI model development achievements

Business wise, the creation of monetization strategies for self-hosted and managed hosting services of the proposed solution, considering its cost of operation to be acceptable compared to the amount of data processed. Optimizing the provided cost numbers by utilizing different cloud providers or managed services can also be beneficial to further research and business development.

Considering off-chain improvements, to optimize smart contract transaction costs, the proposed solution should be formalized to provide new functionalities such as encryption before IPFS distribution and further optimizing models before distribution by compression.

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# USAGE OF BLOCKCHAIN IN HEALTHCARE

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**Abstract:** *Blockchain technology (BCT) has been widely discussed in the healthcare sector in recent times due to problems pertaining to EHRs. This report explores the use of blockchain technology in healthcare. It starts with an analysis of the background information about the blockchain, elaborating on the fundamental elements like distributed ledgers, cryptography, and smart contracts. This paves the way for the literature review with an emphasis on research areas of interest, such as the privacy of patients, integration, the security of data, and healthcare data integrity in blockchain systems. The report defines key application areas of blockchain in healthcare, including data protection with immutable records, optimization of organizational processes with fewer singularities, tracking counterfeit drugs and improving the transparency of supply chains, and clinical trial data sharing with better outcomes. These applications are, therefore, key to understanding the opportunities of blockchain in making healthcare more secure, efficient, and transparent.*

**Keywords:** *blockchain, healthcare, electronic health record, Internet of things*

## INTRODUCTION

Blockchain technology has become one of the most promising innovations that can revolutionize different industries, including healthcare, finance, and supply chain. A decentralized, distributed ledger resolves many issues affecting EHRs, including data security, patients' data privacy, and compatibility (Abu-Elezz et al., 2020). To address the needs of healthcare providers who are integrating digital solutions, the data management systems must be secure and efficient. Blockchain or distributed ledger refers to a chain of linked blocks of data units. These blocks digitally store the transactions in sequential sequence. Thus, this decentralized database continuously keeps track of data records created by participating nodes and grows. Data from each completed transaction is included in a public ledger containing the information (Chukwu & Garg, 2020). The entries that are added to the blockchain are decided upon via a variety of consensus methods in a peer-to-peer network. Due to the distributed ledger's numerous node storage, entries that have been accepted onto the blockchain are nearly impossible to remove. In addition, the potential for anonymity, or pseudonymity, is a desirable feature that is employed in numerous blockchains (Hasselgren et al., 2020). Another unique characteristic of blockchains is that they are unchangeable and do not require an intermediary. Since new information and data can only be added to blocks in the blockchain, the information is transparent and cannot be altered. Some of the real-world applications of blockchain technology in the healthcare industry include educating patients through monitoring them, management of medical records electronically, biomedical research, pharmaceutical supply chain, managing claims in health insurance, and data analytics in health, among others (Elangovan et al., 2021). The main objectives of implementing blockchain technology in this sector are due to its nonrepudiation, data versioning, data logging, access control, and data integrity. According to IBM, seventy percent of healthcare industry leaders believe that blockchain would have the most significant impact on improving clinical trials and compliance and creating a distributed sharing solution for EHRs. In addition, it is expected that in the coming years, the market for blockchain technology within the healthcare industry will reach over \$500 million (Azbeq et al., 2022). Health information systems have the potential to be expanded through blockchain technology. Still, the recent hype surrounding it has also given rise to several unrealistic ideas, as well as proposals. Current literature offers little overview of applications that have been created, tested, and implemented using this technology and this necessitates more research to be done in this field (Hasselgren et al., 2020). Blockchain technology transforms the healthcare sector by improving data protection, coordination, and the functioning of activities, which can be seen from its successful implementation in areas such as patient records, anti-counterfeit medicine traceability, and shared clinical trial information.

## THEORETICAL BACKGROUND - OUTLINING THE KEY CONCEPTS OF BLOCKCHAIN TECHNOLOGY

Blockchain technology is basically a distributed ledger that is used to store and manage transactions in a network. This, in turn, makes the blockchain decentralized so no one party has full control of the blockchain, making it secure and transparent.

Every transfer or data record is encrypted and arranged into blocks (Abu-Elezz et al., 2020). Each block is connected to the previous one to create a chain, hence the name 'blockchain.' Changing data in a block means having to alter data in all following blocks, which is almost impossible due to the copious amount of computational power required. In contrast to the centralized databases distributed in the blockchain network, all participants (nodes) have a full copy of the ledger. This eliminates third-party services, which minimizes the chances of a single point of failure and improves the system's stability (Chukwu & Garg, 2020). Therefore, blockchain provides protection, openness, and cost-efficiency in solving digital matters and transactions, which may be useful in connection with the healthcare industry.

## **BLOCKCHAIN TECHNOLOGY APPLICATION IN HEALTHCARE INDUSTRY**

Blockchain has been highlighted as having a potential solution to some of the issues regarding e-health records and data management in the healthcare sector. One of the most important application areas is in handling patient information (Chukwu & Garg, 2020). Due to the decentralized peer-to-peer ledger system of the blockchain, patient records can only be accessed or changed by permission individuals and are highly secure and resistant to alteration. This also regards data protection and the patient's privacy, which are values that are paramount in the health sector. Further, it allows for the integration of various healthcare organizations into the healthcare system, thus allowing easy transfer of patient details (Abu-Elezz et al., 2020). Thus, this makes sure that clinicians are able to obtain comprehensive and accurate information about patients, consequently enhancing patient care and diminishing medical mistakes. Besides, patient data management, blockchain is also finding application in the automation of other business processes of healthcare facilities. The use of smart contracts in the application of blockchain technology eliminates workload as well as risks of error on the side of automation. This can translate to a relatively higher possibility of feasible cost-cutting and improvement of economic returns. However, one of the direct uses can be identified in the drug distribution network (Tandon et al., 2020). This is so because, through a chain of blocks, it is possible to explain the process of supplying the drugs from the manufacturers to the patients. This assists in flushing out these fake drugs in the market and making sure that people get good and credible drugs. It also raises the efficacy of sharing clinical trial information. They offer a secure environment needed in documenting some clinical trials and the results thereby guaranteeing their authenticity. It can be beneficial for the search and improve the quality and relevance of clinical trials (Azbeq et al., 2022). Thus, blockchain technology is being used to address current challenges in the healthcare industry, improving patient experience and overall health sector management.

## **LITERATURE REVIEW**

Blockchain technology can be applied in healthcare in activities such as drug development, drug distribution, and patient treatment activities. This technology, being an extension of distributed ledger, provides better protection for data, enables secure data sharing of patient records, and deciphers the code of genes (Chukwu & Garg, 2020). It is also useful in operations connected to health records, clinical research, patient tracking, inventory management, and the preparation of balance sheets and income statements. Blockchain removes the need for a third party by offering data record immutability. This technology can assist in risk factor identification and improve decision-making, resulting in prompt and precise diagnosis. By tracking drugs' life cycles, blockchain technology can facilitate the detection and elimination of fake medications. Blockchain technology can also facilitate end-to-end traceability, which makes it simpler to locate and eliminate fake medications. Thus, blockchain can reduce the time and cost of data transformation while maintaining hospital financial statements. In the healthcare system, blockchain helps maintain and share patient records across hospitals, pharmacological companies, diagnostic centers, and doctors. The applications created through this technology can pinpoint severe mistakes that can negatively affect the medical industry and impair its normal function. This technology is useful to medical institutions to get more understanding and improve the evaluation of medical reports (Azbeq et al., 2022). Blockchain technology can improve data efficiency in healthcare since it is instrumental in the management of deception in clinical trials. It creates a unique pattern of data storage at the highest security level and can address the issues of data manipulation in the healthcare sector. It provides flexibility, integration, accountability, and data authorization (Haleem et al., 2020). There are several reasons why health records must be kept private and secure. Right application of blockchain, can eliminate certain risks and contribute to the decentralized protection of healthcare information. One of the main forces behind the advancement of treatment over the past ten years has been the implementation and design of EHR systems, which are intended to precisely capture a patient's condition throughout time and store the data (Abu-Elezz et al., 2020). Nevertheless, neither the concept of an integrated care plan that all members of the care team can read and participate in nor a model that goes beyond episodic encounters is supported by the HER (Ciampi et al., 2021). However, the notions of a "smart care plan" and a longitudinal record are crucial in advancing the field of preventive, predictive, participatory, and personalized medicine (P4-medicine), which is likely to be the only long-term, viable strategy for managing pandemics and "silent" chronic diseases. By

implementing blockchain technology on any platform and maintaining patient anonymity, health records may be trusted. For this reason, electronic health records are more efficient and trustworthy than paper-based ones. Based on research by Chukwu & Garg (2020), health records are a lucrative target for record breaches, putting providers at financial risk as well as raising the possibility of social isolation and psychological misery. The exchange of patient health records is challenging for businesses because of the need for a high level of interoperability. Millions of records are stored globally in EHRs. Thus, even a security breach might have a significant effect on the entire system. Because they are concerned about a security breach, about 25% of patients do not want to share their details with their doctors (Abu-Elezz et al., 2020). Enough security measures, such as periodically updating the password requirements and implementing secure code with security questions, should be included in EHRs. Electronic health reports are the next development in the progression of healthcare (Deshmukh et al., 2022). It's also important to have a thorough understanding of the cybersecurity procedures related to EHR adoption before moving further. Blockchain has limited dynamic network data jurisdiction; in some special applications related to health care, it does not accept any mediation, and it effectively safeguards data. Generally, any further modifications to data saved in a chained block are prohibited. By connecting hospitals and clinics, electronic healthcare systems make it possible to share electronic medical records by interoperability and regulatory requirements. Nevertheless, hospital-to-hospital healthcare record data silos exist, and data-sharing procedures fall short of ensuring a reliable audit of the data. Applications of blockchain technology to facilitate distributed data management have proven successful (Bittins et al., 2021). Thus, next-generation health data-sharing systems can be built on their decentralization and immutability properties. By transforming the traditional healthcare system into a digital one, the electronic health record (eHealth) improves patient care. These days, eHealthcare is receiving greater attention because of its advantages, which include easy record transfers, constant availability, and simple search and access. However, user privacy and security concerns impede the wider adoption of eHealthcare in different hospitals and nations. An electronic health record management system built on blockchain technology would help maximize the benefits of eHealthcare and safeguard the data from several threats. To guarantee data availability, integrity, and secrecy, the encrypted eHealth records are kept on the cloud or IPFS, and the blockchain data is kept on the meta-data of records (Venkatesan et al., 2021). Therefore, this new system provides immutable access information logging for regulatory compliance and audit. According to Gupta et al. (2021), the interchange of healthcare information is a critical component that helps both patients and healthcare practitioners. The monitoring of patient behavior is one way that the Internet of Things (IoT) is utilized to enhance traditional healthcare systems. Healthcare systems depend heavily on the data that sensors in the Internet of Things collect. Data must be shielded from unwanted alterations due to security and privacy concerns (Tandon et al., 2020). Conversely, Blockchain technology offers an extensive array of safeguards against modifications to data. As a result, blockchain-based IoT-based healthcare monitoring represents an innovative technological advancement that could allay worries about privacy and security regarding the data gathered for patient monitoring (Vahdati et al., 2021).

As highlighted by Saeed et al. (2022), BCT is increasingly being deployed to offer state-of-the-art and sustainable services to enhance the current management, distribution, and processing of clinical records in the healthcare sector. In the context of the healthcare industry, BCT is extending the conceptual progression by consolidating the core elements with enhanced and expanded efficiency, technical advancement, access management, data confidentiality, and protection (Saeed et al., 2022). Blockchain may be managed by a network of authorized users or nodes who possess blocks of fixed data that can be prudently exchanged without the interference of other people (Abou Jaoude & Saade 2019). Data is kept and stored by means of consensus techniques and cryptographic signatures which are used as enabling technologies for its application. Generally, another important reason for implementing BCT is data redundancy, particularly in the field of healthcare, which deals with the exchange and distribution of a vast amount of data. Driven by innovative technological attributes like immutable data, blockchain technology is undergoing a fourth generation of development with the advent of artificial intelligence. Because blockchain can provide decentralized and trustless transaction environments, it has a diverse range of applications (Kuo et al., 2019). Blockchain technology is ideally suited for the healthcare industry, as it can address critical problems like management of public health and automated claim authentication. With the help of technology, patients can regain ownership of their data and decide who has access to it, addressing data ownership and sharing issues. Concurrency controls allow the combination, alteration, sharing, and fast access of recorded data by some authorized personnel at the same time (Soltanisehat et al., 2020). Thus, this is a big advantage of using technology in the healthcare system because the current process of functioning needs third parties to hold the data. Blockchain can increase accountability to data management procedures, hence lowering the possibility of recorded data being handled improperly or misused due to human error. In light of the promising implications of blockchain technology for social and commercial transformation departure from preconceived notions- there is a debate over its inherent and secondary benefits (Cagigas et al., 2021). Even though public opinion is skeptical about whether blockchain technology will really deliver on its promises, corporations are expected to take a slow but strategic approach and spend a lot of money on the future (Pawczuk et al., 2019). Thus, this will cause blockchains to be adopted widely, especially through scrapping regulatory obstacles and other difficulties. The main concerns that modern healthcare facilities grapple with are high maintenance and administrative costs.

The healthcare system encompasses various sectors, which comprise several domains and stakeholders, including patients, clinicians, scientists, administrators, and support workers (Soltanisehat et al., 2023). Therefore, the regulation and categorization of patient information is a monumental challenge. This is aggravated by the fact that different areas of healthcare have distinct data formats and processes. These factors make it very challenging for the various fields of healthcare to share information on healthcare efficiently (Xing & Bei, 2020). It is essential to encounter health information records and interchange to develop, manage, and maintain a system. Traditional PHRs and EHR systems are created and managed by a third party; privacy, trust, and security concerns remain critical (Khan et al., 2022). However, the current third-party-based model cannot address clients' demands for privacy. However, the traditional e-health model is not transparent, mainly because of privacy and data security issues. Blockchain offers great potential to overcome existing security concerns and the tough task of storing large and highly diverse data in the healthcare sector. Blockchain is an example of a peer-to-peer network, a digital record-keeping system, and a decentralized database (Quadery et al., 2021). It allows the secure exchange of information between different parties by linking several computers through nodes, and no transaction is required to create a new block (Chanda et al., 2021). The client can leverage an encrypted blockchain to access all authorized and verified medical information. Someone can add a new chain to the block and choose the transactions. Therefore, a blockchain's master key is a hash, and by utilizing this hash function, it can add data for the cryptocurrencies and provide unique identifiers.

## CONCLUSION

Blockchain technology is a disruptive innovation that can address several issues associated with EHR and information management in the health sector. Hence, blockchain offers the necessary solutions for increasing the security and privacy of medical data while integrating various healthcare workers and organizations. These capabilities are so essential now that digital transformation of healthcare is not a luxury but a necessity. Applying blockchain technology to patient data guarantees that data can only be accessed by authorized individuals and are almost impossible to alter, therefore minimizing the risks of data leaks. This not only maintains the privacy of the patient but also ensures that comprehensive information regarding the patient is available to healthcare personnel to improve the quality of care. Also, smart contracts are free from bureaucratic aspects inherent in blockchain, and they are highly automated; thereby, they consume less amount of money and can go less wrong. This paper explores the application of blockchain technology in healthcare. It begins with a definition of what exactly blockchain consists of, how it differs from traditional systems in being a distributed ledger without a fixed point of reference, and the fact that the system is virtually immune to forgery. The paper goes further to analyze different healthcare applications such as electronic health record management, biomedical research, remote patient monitoring, and the supply chain of pharmaceuticals. Blockchain technology can be described as a promising technology in the health industry since it addresses the issues of security, decentralization, and transparency that are crucial for the management of health data and transactions. It is possible to identify several drawbacks of the literature overview, in particular, the scarcity of literature on this topic and the problem of updating documentation as technology advances in parallel. It means that when creating decentralized apps, the data transit pattern cannot be influenced by any outside entity using blockchain technology. In addition to a date, the data transactions of the entities are stored permanently, securely, and transparently in a decentralized database. In addition, there are many potential applications of blockchain in the healthcare sector, including log management, medicine administration and dispensing, data sharing, biomedical research and education, remote patient monitoring, and health data analysis. Thus, this research should act as an introduction to how blockchain can be used in medicine.

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# SECURING CRYPTOGRAPHIC SECRETS ON IOT DEVICES: A REVIEW

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**Abstract:** *Common attacks used to exploit vulnerabilities of IoT devices with the goal of exposing cryptographic secrets (keys, signatures, certificates) or bypassing verifications that use these secrets, include fault injection, side channel attacks and firmware extraction. Exposing cryptographic secrets in IoT can cause various problems from data breaches to malicious firmware flashing, leading to violation of data privacy and even substantial damage. The goal of this paper is to review methods for securing cryptographic secrets in IoT with some examples of microcontrollers and processors frequently used in IoT devices.*

**Keywords:** *IoT, security, cryptography*

## 1. INTRODUCTION

IoT devices collect data from their environment - pollution of air and water, power consumption, they can track goods in supply chains or a patient's wellbeing. Very often, the collected data is sensitive or the systems in question are integral components of critical urban infrastructure which are vital for the functioning of society. Systems such as those found in smart cities, encompassing smart traffic light control, autonomous vehicles, and smart electric grids, as well as IoT systems deployed in factories, pose significant risks when compromised or tampered with. Not only can such actions result in data breaches, but they also have the potential to cause substantial damage, including endangerment of people's health, and general security. Data collected by IoT devices is often sent to some central server using standards like WiFi, cellular network, Narrowband IoT, LoRa and others. The devices usually send HTTP requests, MQTT messages or communicate with the servers via Web Sockets and other similar technologies. During transmission, this data is susceptible to interception, tampering, and other security threats. For that reason, the transferred data is encrypted and the devices authenticate themselves using certificates. Cryptography in embedded systems plays other roles as well - it may be used for embedded software digital signature in secure boot process. Profentzas, Gunes, Nikolakopoulos, Landsiedel, and Almgren (2019) point out that in a secure boot process, a trusted, tamper-proof component starts the boot process and is referred to as the Root of Trust (RoT). RoT verifies the next-stage software and executes only authentic software (Profentzas et al., 2019). Secure boot prevents firmware modifications by, for example, flashing malicious code, or downloading malicious over-the-air update. Device's firmware and entire non-volatile memory are also often encrypted, so attackers who might extract the firmware are not able to analyze it and understand it. But even if communication protocols, memory and firmware are secured using cryptography, there are hardware vulnerabilities, found on IoT devices, that can lead to compromising cryptographic keys, certificates and signatures, and put the entire system in danger.

## 2. SECURITY THREATS IN IOT

An IoT system usually consists of devices that gather the data and send it over the network, edge devices that preprocess the data, central servers that further process and store the data, which is then presented to the end users via mobile, web and desktop applications. All these components are built using different technologies, so there are numerous possible vulnerabilities and methods to expose sensitive data. According to Zhang, Cho, Wang, Hsu, Chen, and Shieh (2014) heterogeneity and complexity of IoT systems, coming from large-scale objects and networks, make IoT security "much more difficult to deal with". OWASP IoT Top 10 listed the most common security threats in IoT, also including:

- Weak, guessable and hardcoded passwords that are publicly available or can be bruteforced easily
- Insecure network services that compromise information or allow unauthorized remote control
- Insecure ecosystem interfaces that include web, backend API, cloud and mobile interfaces outside of the devices
- Lack of secure update mechanism, meaning lack of secure delivery, but also lack of firmware validation
- Use of insecure or outdated components that could allow the device to be compromised (OWASP, n.d.).



Meng and Buchanan (2020) say that "while the conventional cryptography algorithms such as AES, RSA and Diffie Hellman are present on embedded systems with reasonable processing power, they don't scale well on more constrained microcontrollers and sensor networks". Because of that, effort has been put into development of so called lightweight cryptographic algorithms, such as PRESENT, SKINNY, SPECK and SIMON, XTEA. These algorithms take into account limited processing power, battery life and memory of constrained embedded systems.

Insecure hardware - microcontrollers and processors and unprotected debug or programming interfaces can make an IoT device vulnerable to attacks including fault injections, side channel attacks, firmware extraction and reverse engineering, and all of these can lead to exposing cryptographic secrets.

## 2.1. Fault Injection

Fault injection techniques can be used to exploit cryptographic algorithms such as DES, AES, and RSA by introducing errors into specific parts of these algorithms. There are three main methods for fault injection: injection by directly contacting the target device, contactless near-device injection and software-induced error (Chiu & Xiong, 2023). Usual representatives of the first method are clock and voltage glitching. Target of the clock glitching attack is the external clock on a CPU or microcontroller. The idea is to modify the instruction that is being executed by injecting another clock cycle. Voltage glitching targets the power supply of the system and the goal is to modify the instructions or memory of the system by cutting the power for short periods of time which will put the processor into an undefined state. Contactless injection is usually done through Electromagnetic Fault Injection (EMFI) which involves generation of a large electric field that can cause hardware fails, bit-flips and other undefined behaviour (Voidstar Security Research Blog [LLC], 2022). Rowhammer is an attack that falls under the software-induced error method and exploits physical characteristics of DRAM. The attacker can flip bits in nearby memory locations by repeatedly reading and writing to adjacent row of bits (Breier & Hou, 2022). One common fault attack on AES is the Bit-Fault Attack which injects faults on one bit of temporary cipher result before the final round to obtain the last round key. Rivest-Shamir-Adleman (RSA) is a Public Key Algorithm whose security relies on the mathematical challenge of factoring the product of large prime numbers. One common way to speed up the RSA calculation is to use Chinese Remainder Theorem which could make RSA susceptible to fault injection attacks. Examples of these attacks are DFA (Differential Fault Analysis) on RSA where the attacker injects the fault during the modulo reduction operation or storage attacks which cause memory access faults (Chiu & Xiong, 2023).

## 2.2. Side channel attacks

According to Woudenberg and O'Flynn (2022) a side channel is "some observable aspect of a system that reveals secrets held within that system" like power consumption and electromagnetic leaks. Power analysis is a side channel attack and represents a technique for exploitation of cryptographic algorithms by measuring power consumption at the time of the algorithm execution. Two main types of power analysis are: Simple Power Analysis (SPA) and Differential Power Analysis (DPA). According to Lea (2020), in SPA the attacker tries to gather cryptographic key from power consumption samples measured during execution of cryptographic operations. One of the prerequisites for successful SPA exploitation is that cryptographic operations should have significant impact on power consumption. Common types of SPA technique are: SPA over one sample, where analysis is conducted with a single measurement, and SPA over multiple samples, which is conducted with multiple measurements (measurements could be taken with the same or different plaintexts used).

DPA attacks are much more common in practice than SPA and the reason is that they don't require an excessive understanding of the targeted device and can reveal the key even in situations when there is a lot of noise in the recorded measurements, but at the cost of requiring much more measurements than SPA. Another important difference is that in SPA, the power consumption is analyzed along the time axis, while in DPA, it is observed at a fixed point in time for different data points being processed. In other words, DPA focuses on the dependence of power consumption on the data. DPA involves selecting intermediate results of a cryptographic algorithm, measuring power consumption for various inputs, calculating hypothetical intermediate results for different key values, mapping these to hypothetical power consumption values via simulation, and finally deriving the key by comparing these with measured power consumptions, often using correlation coefficients (Mangard, Oswald, & Popp, 2007).

## 2.3. Firmware extraction and reverse engineering

An access to device's firmware gives an insight into its inner workings, as well as the sensitive information stored inside of it, such as passwords and cryptographic keys (Vasile, Oswald, & Chothia, 2019). Reverse engineering of a device firmware is usually a black-box process that consists of several steps: physical inspection of the device, extraction of the device firmware image, firmware analysis and recovery of the sensitive information. During physical inspection of the device, reverse engineer tries to locate and identify non-volatile memory components, as well as any debugging interfaces left on the device. Common memory components include SPI or NAND Flash memory and EEPROM modules (Shwartz, Mathov, Bohadana, Elovici, & Oren, 2018). On the other hand, two of the most used debugging interfaces are UART and JTAG/SWD. UART interface can be identified through visual inspection and using a multimeter, and in order to determine pinout of JTAG interface, specialised tools, like JTAGulator, are used (Vasile et al., 2019). Obtaining the firmware can also be done in many ways, depending on the operating system (or lack thereof), and hardware components and interfaces that can be accessed - it can be sent over the network, dumped using interfaces like UART or JTAG or read directly from the memory by connecting logic analyzer to the module, extracting the communication of the memory bus, or by desoldering the memory chip and reading its content using compatible memory reader (Shwartz et al., 2018). Final step in reverse engineering of an embedded firmware is the firmware analysis. Static firmware analysis can be done using utilities like *binwalk* and *dd* for unpacking and extracting file system from the firmware image. Dynamic analysis of the firmware consists of running binaries or firmware image using tools like QEMU, *Firmadyne* and *Firmware Analysis Toolkit* for full firmware emulation of Linux-based embedded firmware (HackTricks, n.d.).

## 3. SECURING CRYPTOGRAPHY ON DIFFERENT MCUS AND PROCESSORS

### 3.1. Fault injection prevention

Securing IoT devices from above mentioned attacks starts with secure hardware, and vulnerabilities of chips used in IoT devices are often overlooked. Popular microcontrollers used in IoT, like Nordic Semiconductor nRF52840, Espressif Systems ESP32, Microchip/Atmel SAM L11 and STMicroelectronics STM32F2 are vulnerable to voltage glitching (Roth, Datko, & Nedospasov, 2019). SAM L11 is built with integrated security hardware features ("Sam L10 and Sam L11 Families of Microcontrollers | Microchip Technology," n.d.) and one of them is a brown-out detector that detects low voltage and triggers an interrupt or resets the device. STM32F2 is a microcontroller often used in cryptocurrency wallets, but as it is vulnerable to glitching, an attacker can obtain the access and read SRAM, exposing secrets. O'Flynn (2021) gives software writing techniques that can prevent fault injection attacks, especially when it comes to signature verifications during secure boot process, or password checks. If boot image is verified in an *if* statement that checks if the expression is equal to 1, it is easy to bypass the verification by fault injection if an attacker glitches the evaluation of the expression from 0 to 1. When random duration delays are added in code, voltage glitching should be much harder, since the attacker does not know the exact moment of image verification. Next, *if* statements should check against specific values rather than just against a value being non-zero, because it is more difficult to corrupt memory into a specific value. Lastly, more techniques are shown in the implementation of the function that verifies the firmware image, where image's calculated hash value is repeatedly checked against expected value, so if the value is changed at any point by glitching, the function will return an error value. During verification process, image bits are manipulated and flipped, and the image is gradually unmasked every time image's calculated hash and expected hash are compared and equal.

### 3.2. Side channel attacks prevention

Abdellatif, H'erveaux, and Thillard (2023) succeeded in obtaining flash encryption keys on ESP32 V3 microcontrollers performing a Correlation Power Analysis Attack and claim that the same attack can be performed on ESP32 S2, ESP32 S3 and ESP32 C3 microcontrollers. The ESP32 V3 is also used in Jade hardware wallet for Bitcoin. Widespread tools like ChipWhisperer (Chipwhisperer, n.d.) make side channel attacks easy to perform. Protection against power analysis attacks involves a set of methods aimed at making power consumption independent of the data processed in cryptographic devices, including uniform power consumption methods, with dual-rail pre-charge logic (DPL) being a representative. The idea of these methods is to consume the same amount of energy in each processor cycle, regardless of the data being processed (Soares, Lima, Lellis, Finkenauer Jr., & Camargo, 2021). The second group of methods is time-dimension randomization. In a differential power analysis attack, attackers analyze the power consumption at a particular time of an operation through numerous repetitions. The idea behind this method is to randomize the execution of cryptographic operations in the time dimension, which requires a much larger number of measurements for a successful attack. Shuffling is a randomization technique that involves randomizing the order of cryptographic operations whose execution order can be changed without changing the algorithm itself. Due to the limited number of such operations in cryptographic algorithms, the practicality of this technique is questionable. The

Random Delay Insertion (RDI) technique is based on inserting delays before or during the execution of cryptographic operations, resulting in their shifting in the time dimension. The RDI technique does not depend on the cryptographic algorithm itself and is therefore much more widely used than the shuffling technique (Yingxi Lu, O'Neill, & McCanny, 2008). Another method for preventing side channel attacks is masking technique - randomizing the intermediate values obtained by using a randomly generated bitmask. The goal is to perform all computations vulnerable to power analysis attacks on masked data (Soares et al., 2021).

### 3.3. Storing secrets

A big challenge for storing cryptographic secrets securely comes from the fact that IoT devices are built on a wide range of hardware platforms and architectures and because of that there is no universally accepted standard or best practices. For example, ARM-based devices offer TrustZone technology for creating trusted computing environment, ESP32 family of microcontrollers store some of the secrets in the eFuse memory, while more powerful systems offer dedicated TPM (Trusted Platform Module) modules on the board.

In order to ensure that the correct security mechanism has been applied, it is a good practice to check technical documentation and application notes of the device from the manufacturer's website. Other than the built in security, some platforms, such as Raspberry Pi, offer a TPM that can be connected through the GPIO pins. Another option is to use dedicated device or cloud service in form of Hardware Security Module (HSM) for cryptographic computation and storing secrets (Sommerhalder, 2023).

Even if memory is dumped from the device and an attacker has access to device's firmware, if flash and other parts of non-volatile memory are encrypted, it is difficult for the attacker to read it. Cryptographic keys and other secrets can be stored in eFuse (electrical fuse) memory. EFuses are a type of on-chip fuses that can be electrically programmed (Robson et al., 2007) and they provide one-time programmability through a physical process. Abhilasha (2023) claims that "once an eFuse is programmed, the change is permanent and cannot be undone, ensuring the security and integrity of stored data". An example of usage of eFuses is in secure boot process and secure key storage and "they play a pivotal role in verifying the authenticity of the software during device startup and storing cryptographic keys securely" (Abhilasha, 2023). Microcontrollers such as Espressif's ESP32 S3 (Espressif Systems, 2023) and Microchip's ATWINC15x0 IoT module (Microchip Technology Inc., n.d.) use eFuse technology. ESP32 S family of microcontrollers offers flash encryption and secure boot features. Flash encryption covers encryption of second stage bootloader, partition table, *NVS Key Partition*, *OTA data partition* (used to store information about the partition of currently used firmware update) and *app* partitions (used to store device's firmware and firmware updates) (Espressif Systems, 2023). The flash encryption key is stored in eFuses and, by default, is protected from further writes or software readout. SHA-256 digest of the public key for firmware signature needed for firmware verification during secure boot process is also stored in eFuse. By default, when Flash Encryption or Secure Boot is enabled, then JTAG debugging is disabled via eFuse and the device can no longer be programmed via UART - new firmware can be downloaded as OTA update (Espressif Systems, 2023).

Secrets can also be stored in a separated coprocessor - a TPM. According to Faisal et al., (2020), "TPM chip is mounted on a platform motherboard and provides hardware-based security to the user's cryptographic operations" and "it performs operations such as hardware encryption, signing, machine authentication, secure key storage, and attestation". TPM stores passwords, certificates, or encryption keys (Kumari, Singh, Singh, & Batth, 2019 as cited in Faisal et al., 2020) and guarantees that software running on the device is trustworthy and has not been compromised (Faisal et al., 2020). (Moghimi, Sunar, Eisenbarth, & Heninger, 2020) explored possible attack vectors on TPM and discovered that "elliptic curve signature operations on TPMs from various manufacturers are vulnerable to timing attacks". Through lattice techniques, they were able to recover 256-bit private keys for ECDSA and ECSchnorr signatures present on Intel fTPM and STMicroelectronics TPM, in a matter of minutes.

ARM developed TrustZone technology for ARM Cortex-A and ARM Cortex-M chips. ARM Ltd. (n.d.) states that "the typical use cases of TrustZone technology include the protection of authentication mechanisms, cryptography, mobile device management, payment, key material, and digital rights management". Many devices rely on Trusted Execution Environments (TEEs) built with TrustZone (Cerdeira, Santos, Fonseca, & Pinto, 2020). Cerdeira et al. (2020) also found vulnerabilities in major commercial TEE systems by Qualcomm, Trustonic, Huawei, and Nvidia. The vulnerabilities include information leakage from *secure world* to *normal world* via debugging logs, absent or weak ASLR (Address Space Layout Randomization) - trusted applications are loaded into the same fixed address in virtual address space implementation, and many other security flaws. Oliveira, Gomes, and Pinto (2022) developed uTango - an open-source TEE for IoT devices that aims at tackling the main architectural deficiencies prevailing on TrustZone-(M)-assisted TEE systems, presenting a multi-world security model.

## 4. CONCLUSION

In this paper common attacks on embedded hardware exposing cryptographic secrets are reviewed, as well as some of the methods of preventing such attacks. Keys, signatures and certificates can be obtained through side channel attacks or by accessing device's memory and firmware. Attackers can bypass verifications using fault injection techniques. Many security flaws are the consequences of microcontroller or microprocessor design. Manufacturers continuously make an effort to enhance the security features, but new vulnerabilities and threat vectors are also emerging. There is room for security improvements in this area, which will be a part of our further research, having in mind that IoT devices become increasingly integrated into our daily lives handling people's personal data and controlling subsystems in smart cities, factories and vehicles.

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# MODERN TOOLS FOR DIGITAL VISUALIZATION OF BUILT ENVIRONMENTS

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**Abstract:** *This paper investigates the role of digital visualization tools in improving the design and construction processes within the Architecture, Engineering and Construction (AEC) industry. It examines a spectrum of advanced technologies such as Building Information Modeling (BIM), Computer-Aided Design (CAD), 3D Modeling and Geographic Information Systems (GIS), along with immersive technologies like Virtual and Augmented Reality (VR/AR). These tools can be used separately or jointly in order to provide detailed visual representations and interactive simulations of built environments. Such representations and simulations can then support stakeholders with information needed for improved decision making and project efficiency. Having in mind different use cases of tools for digital visualization, the paper presents various technologies and specific tools used in urban planning, architecture design and development of built environments. The aim is to emphasize the impact of these digital tools in visualizing and shaping future built environments, at the same time encouraging their wider adoption in the industry.*

**Keywords:** *digital visualization, building information modeling (BIM), Virtual and Augmented Reality (VR and AR), Geographic Information Systems (GIS)*

## 1. INTRODUCTION

The Architecture, Engineering and Construction (AEC) field is of vast importance for shaping our physical and social environment. This is partially done through the design, engineering and construction of built environments. These environments include all spaces made by humans, including spaces intended for people to live in, work in and interact within. Built environments represent significant support to processes of urban planning and community development while promoting sustainability (Manzoor et al., 2021).

The concept of the built environment within the AEC sector does not include only construction. It represents a full integration of buildings and spaces that empowers interactions between human activities and the natural environment. Through different quality parameters, these environments directly impact public health, productivity and social connectivity in the real world (Manzoor et al., 2021). It is important to understand that improving the efficiency, aesthetic appeal and sustainability of built environments is highly important for advancing societal well-being. These improvements can be powered by innovative tools, methodologies and technology.

Recent years have seen a revolutionary adoption of digital tools in the AEC industry. In this way it is fostering significant advancements in the visualization and modeling of built environments. Technologies such as Building Information Modeling (BIM), 3D modeling, Computer-Aided Design (CAD) and augmented and virtual reality (AR/VR) are central to this transformation, enabling precise simulation and analysis of design and construction options (Wang et al., 2019). These digital tools facilitate better decision-making and project outcomes by providing a multi dimensional view of architectural projects and simulating their real-world performance.

The critical role of tools for digital visualization in the AEC field is enabling a shift towards more integrated and efficient practices. AEC professionals can improve their project accuracy, optimize resources and lower the costs by incorporating these technologies into standard workflows. Additionally, digital tools significantly contribute to the resilience and adaptability of built environments which enables more responsive design and construction strategies that align with emerging urban needs and real world conditions (Almusaed, 2023).

This paper aims to provide an overview of current techniques, technologies and tools for digital visualization of built environments.

## 2. LITERATURE REVIEW

The rapid advancement of digital technologies significantly impacts the Architecture, Engineering and Construction (AEC) sector, especially in digital visualization of built environments. This literature review explores various technologies for digital visualization, categorizes the types of tools used and details specific existing tools, highlighting their key features and primary use cases.

### 2.1. Digital Visualization technologies in Built Environments

Literature mentions several technologies used in the process of digital visualization. Each of the techniques supports digital visualization of built environments in one or several aspects. There are five emphasized approaches to digital visualization that are mentioned by respected authors:

- Building Information Modeling (BIM)
- Virtual and Augmented Reality (VR/AR)
- 3D Modeling
- Geographic Information Systems (GIS)
- Computer-Aided Design (CAD)

Table 1 shows the brief summary of these five technologies together with description, example of existing tools, as well as areas of potential application. In the following sections, each of the presented technologies is described and presented.

**Table 1:** Technologies used in Digital visualization of built environments

Technology	Description	Example tools	Application
Building Information Modeling (BIM)	Digital representation of physical and functional characteristics	Autodesk Revit, BIM 360	Lifecycle management, collaboration
Virtual and Augmented Reality (VR/AR)	Immersive technologies overlaying or creating digital environments	VR headsets, AR apps, Unity, Unreal Engine	Design validation, client presentations, training
3D Modeling	Creation of detailed three-dimensional models and their visual renderings	SketchUp, 3D Studio Max, Blender, Lumion	Architectural visualization, marketing
Geographic Information Systems (GIS)	Integration and analysis of spatial and geographic data	QGIS, Esri ArcGIS	Urban planning, site analysis
Computer-Aided Design (CAD)	Utilization of computer systems to assist in the creation, modification, analysis, or optimization of a design	AutoCAD, TurboCAD	Drafting detailed engineering plans, precision modeling

#### 2.1.1. Building Information Modeling (BIM)

BIM provides a collaborative framework for the lifecycle management of buildings. It emphasizes physical and functional characteristics (Sacks et al., 2018). Building Information Modeling (BIM) does not only provide simple visualization, but it also enables holistic management of architectural and construction projects by enabling information management. BIM integrates all relevant project data into one digital model that is improved through time. By creating such a model, it facilitates collaboration among project stakeholders. BIM's capacity to manage not only graphics but also data concerning the lifecycle of a building makes it invaluable for large-scale projects (Ding, 2014). Propelled by the advancements in the field of information technology, improved BIM solutions are arising. One of such improvements is the recent integration of cloud-based technologies with BIM which has enhanced its accessibility and collaborative potential (Zhao & Taib, 2022).

#### 2.1.2. Virtual and Augmented Reality (VR/AR)

Virtual Reality (VR) and Augmented Reality (AR), together with other similar immersive technologies, are commonly referred to as Extensive Reality (XR) (Balakrishnan & Hameed, 2021). These technologies are used

for interactive presentations and simulations. They allow stakeholders to experience built environments in immersive ways, facilitating better design validation and training (Milovanovic et al., 2017).

Virtual Reality in built environments offers an immersive experience that is unparalleled by other visualization tools. VR allows stakeholders to step into a virtual representation of a proposed space, understanding and interacting with the design in a way that traditional methods cannot match. According to (Ehab et al., 2023), VR significantly enhances client engagement and approval processes, as clients can visualize and “experience” a building or space before it is realized. Moreover, VR's role in architecture, engineering and construction highlights its potential to not only improve design understanding but also construction support, operations and management support and training (Delgado et al., 2020).

Augmented Reality overlays digital information onto the physical world. This way it offers dynamic insights and enhancements to real-time views of a project site. AR tools have been particularly transformative in site management and maintenance. For example, AR can superimpose a building's digital blueprints over its construction site to guide placement and installation processes accurately, reducing errors and speeding up the construction timeline (Gerger et al., 2023). There are many other use cases of AR in digital visualization of built environments. One of important utilizations of AR that should be emphasized is the possibility to visualize the 3D models of part of the building directly on the field in real-time (Schiavi et al., 2022).

### **2.1.3. 3D Modeling**

3D modeling is a technique in computer graphics for creating a three-dimensional digital representation of any object or surface (Concept Art Empire, 2018). An essential tool in various industries, including architecture, engineering and construction (AEC), 3D modeling facilitates the visualization, simulation and analysis of designs. The process involves constructing an object using dedicated software that creates a virtual three-dimensional model through layers of meshes or polygons, textures and digital sculpting (Cory & Bozell, 2001). Essential for visualizing design impacts before construction, 3D Modeling assists in decision-making and marketing by enabling visualization of design impacts before construction (Lopez et al., 2018; Sinha et al., 2008).

In regards to the built environment, 3D modeling serves multiple roles in enhancing the design process. One of the roles is in architectural visualization which empowers architects to create realistic and detailed presentations of projects. These models make it easier to understand complex architectural concepts and the spatial dynamics of a building. In the construction field, 3D models are used for simulation of the processes which is crucial for minimizing construction delays and optimizing resource allocation (Centofanti et al., 2014). 3D modeling is also frequently used in interior design. Interior designers are using 3D modeling to draft layouts and visualize interior spaces. Additionally, 3D modeling is utilized in the process of urban planning for visualization of entire urban landscapes. This technique is especially important in the preservation of cultural heritage, as it allows for the digital recreation of historical sites (Marques et al., 2017).

### **2.1.4. Geographic Information Systems (GIS)**

Geographic Information Systems (GIS) are frameworks for gathering, managing and analyzing data rooted in the science of geography (ESRI, 2018). GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships and situations helping users make smarter decisions.

3D GIS extends these capabilities by adding a third dimension, elevation, to the datasets. This allows for a more realistic and comprehensive representation of physical spaces. 3D GIS is particularly valuable in urban planning and natural resource management, where three-dimensional data provides a more accurate representation of the world (Abdul-Rahman & Pilouk, 2007).

GIS and 3D GIS integrate spatial data for urban planning and large-scale project management to provide a comprehensive analysis of geographic impacts on building designs (Batty et al., 1999; Gebur, 2021; Scholten et al., 2013). These technologies are commonly used in combination with other digital visualization techniques such as BIM and Heritage BIM for the purpose of site analysis and virtual reconstructions in heritage preservation (Dore & Murphy, 2012). GIS tools are not just about mapping and geographic analysis but rather they utilize the synthesis of various data layers, including environmental and economic datasets, to create a holistic view of the landscape and facilitate smarter decision making in the fields of urban planning, environmental and network and infrastructure management. Advanced GIS platforms provide capabilities for analyzing spatial relationships and patterns, which are crucial for urban planning and the management of natural resources (Scott & Janikas, 2009).



### 2.1.5. Computer-Aided Design (CAD)

Computer-Aided Design (CAD) has a crucial role in the field of digital visualization, particularly in the AEC industry (Aouad et al., 2013). CAD systems support precision and efficiency required in designing complex structures and components. These tools allow architects and engineers to create, modify, analyze and optimize their designs with a high level of accuracy. In that way compliance with specified standards and functional requirements can be ensured. The implementation of CAD not only speeds up the design process but also reduces errors through automated calculations and enhanced visualization capabilities. For instance, advancements in CAD technology have enabled the integration of simulation features that predict real-world performance, providing insights into mechanical stress, airflow and thermal properties. Such integrative capabilities ensure that the designs are not only feasible but also optimized for performance and cost-efficiency before the physical construction begins and additionally support more efficient education (Ibrahim & Rahimian, 2010).

## 2.2. Existing Tools and Their Applications

This section offers a comprehensive overview of contemporary digital visualization tools, highlighting their key features and primary use cases. Additionally, it delves into their significance within various industries and explores emerging trends in the field of digital visualization. In the group of CAD tools, Autodesk AutoCAD (Autodesk, 2024) undoubtedly holds the greatest significance. It is essential for drafting detailed 2D and 3D drawings and widely utilized across engineering disciplines. Additionally, this tool is extensively employed in data preparation for the construction of virtual reality models (Whyte et al., 2000). TurboCAD (TurboCAD, 2023) offers powerful 2D and 3D CAD capabilities with an economical price point, making it a viable option for smaller firms or individuals needing detailed architectural and mechanical design tools. In a study by (Nariman, 2016), TurboCAD is used for evaluation of e-learning systems for CAD drawing courses. On the other side, SolidWorks is primarily used in mechanical engineering and provides CAD and CAE capabilities, enabling designers to simulate physical behaviors, such as kinematics, dynamics, stress, deflection, vibration, temperatures, or fluid flow. Its advanced features and intuitive interface make it an ideal tool for creating highly detailed and accurate 3D models of architectural structures, infrastructure and landscapes (Sommer et al., 2023). Fusion 360 facilitates the visualization of the built environment by providing architects and urban planners with a comprehensive platform to design, simulate and iterate on architectural structures, infrastructure and landscapes in a collaborative, cloud-based environment (Fusion 360, 2024).

Revit software revolutionizes the visualization of the built environment by offering architects and designers advanced tools for creating detailed 3D models, facilitating collaborative design processes and enhancing project coordination and communication within the architecture, engineering and construction industries. (Tytarenko et al., 2023) used Revit in their study to model a historical heritage site with a high level of detail. BIM 360 is another BIM based solution enabling stakeholders to access and analyze project data, coordinate design changes and visualize construction progress in real-time, thereby enhancing project transparency and efficiency throughout the entire lifecycle of a building project (BIM 360, 2024).

In the group of 3D modeling, there are several versatile tools which provide features for visualizing the built environment. Industry leaders include but are not limited to SketchUp, Lumion, Blender, Unity, Unreal Engine, Adobe Dimension. All of these tools provide architects and urban planners with a highly usable platform for creation and manipulation of 3D models. Their usage enables efficient research of spatial relationships, design concepts and architectural elements within various urban contexts. As a tool with capabilities comparable to AutoCAD and serving as its competitor, research by (De Yong et al., 2020) revealed that SketchUp is primarily utilized for 3D modeling purposes. In the manner of 3D mapping, one of the commonly used software solutions is Cesium, specialized tool for creating 3D globes and maps from geospatial data, Cesium is instrumental in projects that require real-time visualization of large-scale environments. It's particularly useful for integrating various datasets into a cohesive 3D visualization platform (Cesium, 2024).

As an open-source GIS tool, QGIS supports spatial data analysis and visualization, crucial for environmental impact assessments and infrastructure planning. It is valued for its adaptability to various plugins and extensive data handling capacities (QGIS, 2024). It allows urban planners, geographers, and researchers to incorporate diverse datasets such as land use, transportation networks, and environmental factors to create comprehensive visualizations that inform decision-making processes and facilitate sustainable urban development strategies. On the other hand, as an enterprise software, ArcGIS provides robust GIS capabilities for comprehensive geographic data analysis that assists in site selection and urban planning. Additionally, ArcGIS offers seamless integration with other Esri products, making it a comprehensive solution for organizations requiring advanced geospatial analysis and mapping capabilities (Babayeva, 2013).

Navisworks is a powerful software solution commonly utilized in the construction industry for facilitating coordination, collaboration, simulation and visualization of complex building projects through its advanced 3D

model review and analysis capabilities (Navisworks, 2024). Dialux is a vital tool in architecture and construction, enabling architects and engineers to design and assess lighting solutions for buildings and outdoor spaces, ensuring well-lit and visually pleasing environments while meeting industry standards (Dialux, 2024).

**Table 2:** Existing tools for Digital Visualization of built environments

Tool	Type	Key Features	Primary Use Cases
AutoCAD	CAD	Precision 2D and 3D drawing, customizable, extensive tools	Detailed engineering plans, architectural drafting
Revit	BIM	Integrated BIM capabilities, multi-disciplinary support	Pre-construction modeling, cost estimation
SketchUp	3D Modeling	User-friendly interface, extensive plugin ecosystem	Preliminary 3D modeling, visualization
Navisworks	Simulation	Clash detection, 3D coordination, project review	Project integration management
QGIS	GIS	Open-source, data analysis, customizable	Environmental impact assessments, urban planning
Cesium	3D Mapping	Real-time 3D visualization, geospatial data integration	Large-scale project visualization, simulations
ArcGIS	GIS	Comprehensive spatial analysis, data management	Site selection, comprehensive urban planning
BIM 360	Collaborative BIM	Cloud-based, real-time data sharing, project tracking	Document management, stakeholder collaboration
Dialux	Analysis	Lighting design simulation, standards compliance	Lighting design for interiors and exteriors
TurboCAD	CAD	Affordable, versatile 2D and 3D CAD software	Small-scale architectural and mechanical design
SolidWorks	CAD/CAE	3D design, simulation, and analysis capabilities	Product design, mechanical engineering
Fusion 360	CAD/CAM/CAE	Integrated design, manufacturing, and engineering	End-to-end product development, prototyping

Table 2 presents a structured overview of described existing tools for digital visualization of built environments. Other than the name of the tools, it provides information about the tool type, key features and primary use cases of the presented tools.

### 3. CONCLUSION

While the current advancement of digital visualization tools is promising, several areas require further research. Future studies should focus on enhancing the interoperability of these tools to ensure seamless data exchange and integration across different platforms and software systems. The accessibility and usability of advanced tools like VR and AR should also be addressed. Additionally, investigating long-term impacts of digital visualization tools on project lifecycle management, maintenance and operation could provide insights into their limitations.

Developing more intuitive and user-friendly interfaces is of vast importance for wide use of these tools. Along with the focus on usability and intuitiveness, improved training programs could also support democratization of the use of such tools. These improvements could make them more accessible to a broader range of stakeholders. Lastly, investigating the sustainability aspects of these tools and their role in promoting

environmentally friendly design practices would align with global sustainability goals and enhance the societal value of the AEC industry.

Digital visualization tools continue to evolve and they become more integrated into the AEC industries. The possibilities for transformation of how projects are designed, managed and executed are emerging with the features and potential those tools are bringing. Embracing these technologies while addressing the existing challenges and exploring new research tracks will undoubtedly pave the way for more innovative, efficient and sustainable architecture, engineering and construction practices.

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# POSSIBLE DIRECTIONS FOR INTEGRATION OF LARGE LANGUAGE MODELS INTO EDUCATIONAL PLATFORMS

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**Abstract:** Recently, Large language models (LLM) received more attention due to the release of ChatGPT for public use at the end of 2022. It opened possibilities for use (and misuse) in many fields, including education. Focus from banning this technology, as one of the first responses by academic institutions to its emergence, should shift to proper integration into the teaching and learning context since LLMs are here to stay. The main aim of this paper is to discuss the integration of LLMs into educational platforms from a technical and learning perspective. Technical solutions that can ease the integration of LLM chatbots into educational platforms continue to evolve, but more investigation from a pedagogical point of view about this integration is needed. Since chatbots may hinder students' learning process and their critical thinking, appropriate approaches for integrating them must be modeled with caution.

**Keywords:** *Large language model, E-learning, Chatbot, ChatGPT, Learning Management System*

## 1. INTRODUCTION

Since ChatGPT became publicly available at the end of 2022, large language models (LLM) gained much attention. Due to the big potential for misuse, one of the first responses to the emergence of this technology from an educational context was banning it (Qi et al., 2023; Savelka et al., 2023). However, as time progresses, we can conclude that LLMs are here to stay (Kasneci et al., 2023), and the focus from prohibiting them should shift to proper integration into the context of teaching and learning.

On the other hand, the utilization of Learning Management Systems increased and attracted significantly more attention due to the COVID-19 pandemic (Ekuase-Anwansedo, 2022). It gave the educational technology sector a unique chance to expand (de Andrade et al., 2023). Various online learning platforms saw a rise in popularity (Perry, 2024). Over the years, these systems have positively impacted education by enhancing students' performance (Liu et al., 2020).

With the improved accessibility of interaction with LLMs, the potential for incorporation into learning platforms increased. Therefore, the main research question that this paper aims to investigate is the possibility and future research directions for integrating LLMs into educational platforms. This research question will be discussed from a learning and technical perspective. Analysis of scientific and professional literature is going to be conducted. Firstly, LLMs and their possible applications in education will be mentioned. As for the learning perspective, the usage of chatbots in this process before the massive impact of LLMs will be mentioned. Then, the possibilities that LLMs provide and the implications of their integration into education will be discussed. Finally, a general overview of integration solutions from a technical perspective will be provided.

## 2. INTEGRATION OF LARGE LANGUAGE MODELS

Progression of language modeling over the years and significant performance improvement due to model scaling led to the ability of these models to solve complicated tasks (Zhao et al., 2023). LLMs can handle complex tasks such as knowledge base answering, text classification, copywriting, text, and code generation (AWS, n.d.). These open up opportunities for incorporating them in many industries, including the educational system. Educators can use LLMs, such as ChatGPT, as a supporting tool for designing lesson

plans and assessments (Rana, 2023). However, they need to critically evaluate AI-generated materials for completeness and accuracy (Qi et al., 2023). They, and all stakeholders in education, need to gain literacy over these tools, including a fundamental comprehension of the methodology and sources utilized to generate results (Anders, 2023).

Regarding students, LLMs unfolded many possibilities for misuse in the educational environment for achieving academic goals faster and more efficiently. Critical thinking may be affected if ChatGPT is not used correctly since students can exploit it to complete assignments. But the question that arises is, can it be reversed? Can LLMs be used as assistants to improve critical thinking? Educators and learning designers must conduct further research on integrating AI applications into the student learning process to take full advantage of enormous opportunities for designing intelligent learning and teaching systems (Zawacki-Richter et al., 2019).

## **2.1. Learning perspective**

A chatbot functions as a virtual assistant that can respond appropriately to various queries from users (Clarizia et al., 2018). Education applications can be in multiple aspects, such as administration, assessment, advisory, research, and development (Okonkwo & Ade-Ibijola, 2021). However, it is primarily used in the teaching and learning area (Okonkwo & Ade-Ibijola, 2021). Integration of chatbots in education can provide a more personalized learning experience (Cunningham-Nelson et al., 2019). They can provide faster feedback and positively impact the student learning process (Yildirim-Erbasli & Bulut, 2023). On the other hand, developing a chatbot that will fit the needs of almost every student query is challenging. The difficulty of designing chatbots for open-ended conversations is present due to the struggle to accommodate the diverse range of ways users might want to interact (Brandtzaeg & Følstad, 2018). Predicting and mapping every user request isn't feasible (Clarizia et al., 2018). However, the emergence of "the finest AI chatbot ever" (Haleem et al., 2022) can potentially improve chatbots' usage in education.

Due to fear of making mistakes, anxiety, and lack of confidence, students are reluctant to ask questions when attending lectures (Salim, 2022). On the other hand, client applications of LLMs that represent chatbots allow them to ask anything and get the answer instantly. Luan et al. (2023) concluded that gaining vital knowledge through conversation with a chatbot boosts the motivation for eliminating anxiety provoked by uncertainty in learning. Solving problems through conversation with ChatGPT can improve independence and autonomy in the learning process (Luan et al., 2023). Students can be instructed to use ChatGPT to deepen their knowledge and understanding of specific topics. If the provided content for learning contains one example, they can use LLM to generate similar examples. They can ask for different variants of explanations of the same concept.

Personalized learning as a tailored approach to education that considers individual student needs, interests, and abilities (Persico & Steffens, 2017) can potentially be enhanced with a 24/7 available chatbot. Students may have knowledge gaps from previous courses, affecting their performance in learning new concepts. While learning from provided resources, students may chat with ChatGPT, asking questions and requesting examples if they come across concepts not well explained in provided resources due to possible consideration as prerequisite knowledge. By giving students quick, effective, and tailored support, ChatGPT can serve as a virtual mentor to enhance their learning in a personalized manner.

More investigation should be conducted about integrating LLMs into learning not for novice programmers but for students who have obtained basic programming knowledge and are learning specific technologies (e.g., different frameworks for developing web applications). Suppose they get essential hands-on experience and knowledge about concepts of new frameworks through classes. In that case, ChatGPT may be helpful for building complete projects as course assignments that should contain more advanced features than demonstrated in classes. It can suggest good practices for implementing different features and even provide code for implementation. Based on stability and community of technologies, due to resources it was trained on, ChatGPT performance will differ. Paying attention to prompting strategies may positively affect the quality of answers. OpenAI released prompting recommendations with examples for GPT models like GPT-4, such as writing clear instructions, providing reference lists, splitting complex tasks into simpler subtasks, etc. (OpenAI, 2024a). While ChatGPT may not always provide accurate solutions, it can suggest a direction for thinking during the early stages of learning new technologies, which may lead to solutions, especially when they lack experience, thus expediting the learning process (Stanojević et al., 2023).

A learning management system (LMS) represents online learning software with class management, content delivery, and student assessment features (Mahnegar, 2012). A learning content management system (LCMS) may be focused primarily on course content creation, which can be self-hosted or hosted on LMS (Mahnegar, 2012). As a broader term, LMS includes the logistics of managing learners, while LCMS is

focused on managing the content (Watson & Watson, 2007). Based on this difference, an LLM chatbot could become an LMS virtual assistant for any student's doubts about learning materials or be intentionally placed within learning content with usage guidelines to encourage the learning process by deepening reasoning about the subject through conversation.

Even though provided assessments of ChatGPT's answers' accuracy and dialogue quality are considered adequate (Tili et al., 2023), more evaluation in this area is needed. Usage in education may be affected by the different quality of answers based on the content of various courses. Therefore, evaluations should focus on different subject matter. For the theory aspect of courses, which is considered foundational or core theory, including stable, fundamental principles that serve as the basis for understanding a subject and are less susceptible to change over time, ChatGPT may give better answers in contrast to practical questions about new programming language or framework that emerged recently.

Since AI algorithms are susceptible to occasional errors (Tili et al., 2023), students must be aware that they must assess answers critically. If a learning environment with LLM integration is provided, teachers may monitor students' anonymous conversations with LLMs. They need to intervene if they notice incorrect answers or if students misuse the chatbot. Students must be educated on the ethical use of LLMs and the importance of academic integrity (UNESCO, 2023). On the other hand, monitoring conversations gives them insights into knowledge gaps and the most frequent questions. This information allows teachers to enhance their resources and pay more attention to certain class topics.

Some educational platforms already provide solutions for using OpenAI GPT through their platforms. For Moodle, one of the most popular LMSs, a plugin called OpenAI Chat Block is available for integration. Firat (2023) demonstrated integration of this plugin in Moodle. Educational platform Exercism, which offers paths for learning programming, has integrated ChatGPT support that is only available to users who donate to their platform. Accessing ChatGPT support on the Exercism platform results in an alert that says, "ChatGPT is a powerful tool, but it can also make it too easy to get unstuck and remove a lot of the learning opportunity that comes from wrestling with a problem. We recommend only using it when you're too stuck to continue without help." Taking shortcuts in the initial phase of learning programming may hinder critical thinking. This highlights the importance of investigating where, how, and when to use LLMs for educational purposes. In higher educational institutions, if students take exams onsite, they will surely become aware if excessive reliance on LLMs hinders their learning process.

Based on the literature survey discussed in previous paragraphs, potential directions for integration to boost personalized learning could focus on the following aspects:

- Personalized tutoring for deepening knowledge, covering knowledge gaps, and providing more examples,
- Support for building advanced programming projects,
- Advisory and guidance for the overall course or its specific parts.

## 2.2. Technical perspective

The fine-tuned GPT-3.5 LLM model in the form of a web application known as ChatGPT is the reason why LLMs have gained significant public attention since the end of November 2022, when they were released for public use. Since April 2024, ChatGPT has been available for free use without an account. However, creating one offers additional features, such as saved conversation history and access to a Plus subscription (20\$ per month), which provides a GPT-4 model (OpenAI, 2023). GPT-4 has over 1.7 trillion parameters in contrast to GPT-3, which has 175 billion (Ding et al., 2023) and represents the leading LLM. Meta and Google followed OpenAI and released their LLM chatbots, Llama and Gemini (previously known as Bard), respectively, in the following year. Gemini 1.0 Pro is accessible with a Google account, whereas the Gemini Ultra model requires a subscription priced at 19.99\$ per month. Llama represents an open-source model free for research and commercial use. Parameters for Llama range from 7 to 65 billion parameters (Ding et al., 2023). Also, Microsoft integrated a chatbot powered by GPT models into their Bing search engine, which is available for free use. However, as a leading innovator in this field, OpenAI's API solution will be discussed in the subsequent paragraphs.

Apart from the graphical interface, OpenAI offers API for the usage of GPT models such as GPT-3.5 turbo, GPT-4, GPT-4 turbo, etc. (OpenAI, 2024b) This API can be used to integrate communication with OpenAI GPT LLM models into educational platforms. The payment models are based on the resources used. These models are represented in price per million tokens used for input and output, with variations depending on the selected model (OpenAI, 2024b). Also, currently in the beta phase, the Assistants API by OpenAI has emerged, which can be used to develop AI Assistants (OpenAI, 2024a). In the case of educational platforms, instruction that an assistant should act as a teacher could be given. This API offers to generate a Thread

when the user starts a conversation (OpenAI, 2024a). Prompts sent by users in one conversation will be added to the Thread (OpenAI, 2024a). This allows the assistant to have the context of previous prompts. The payment model is per session (OpenAI, 2024b).

OpenAI defined API request and response protocol (OpenAI, 2024a) to which many open-source solutions conformed. To obtain a response to the prompt, the request body required fields are the name of the model being used and the messages array, which contains the role and prompt content (OpenAI, 2024a). In contrast to OpenAI Assistant API, which has threads for handling the history of messages, the array should also contain previous chat history alongside new prompts for the model to be aware of previous prompt messages. This implies that prompt user sessions must be handled by OpenAI API client applications. Summarizing previous questions and answers is one possible approach for lowering the number of tokens used for input per request.

OpenAI API clients have the option to receive a response either as a chat completion object or as a chat completion chunk object when the streaming option for obtaining partial results is enabled (OpenAI, 2024a). Chat completion objects and chunk objects contain the same fields, such as a unique ID for chat completion, a selected model for generating a response, creation timestamp, usage statistics about the number of used tokens, a list of chat completion choices with the actual response to the prompt, etc. (OpenAI, 2024a) The advantage of the streaming option lies in the ability to display a response to the user as it is being generated, thereby enhancing the user experience.

OpenAI API offers techniques for optimizing responses, such as fine-tuning the model and embeddings. GPT-3.5 turbo, babbage-002, and davinci-002 models can be fine-tuned (OpenAI, 2024b). This process can be used to improve the quality of responses and reduce cost and latency (OpenAI, 2024a) by training the model with new data (Zhang et al., 2024). Embeddings, on the other hand, are a method for transforming unstructured data, such as text data, into a structure that is simple for software to handle (Stropek, 2024). They are utilized for search, clustering, recommendation, etc. (OpenAI, 2024a) Embeddings play a crucial role in Retrieval Augmented Generation (RAG) solutions for obtaining relevant information from extensive datasets (Stropek, 2024). Text generation models like OpenAI's GPT-3.5 use this information to produce responses that are contextually relevant (Stropek, 2024). Also, batching should be considered to improve the performance of working with LLMs. The logic behind batching is that modal parameters may be loaded once and utilized to handle several requests rather than loading new parameters for every request (TitanML, 2024). Recently, OpenAI offered Batch API to handle queries that do not require immediate answers (OpenAI, 2024a).

On the other hand, desktop platforms for running self-hosted local open-source LLMs, such as Ollama, Jan, LM Studio, GPT4All, etc., are starting to emerge. The main reason for running models locally is to address privacy concerns (Reifschneider, 2023). The aforementioned applications provide the user interface for interacting with selected models. Among the supported models are Llama, Gemma, Mistral, etc. A leaderboard for ranking open source models by testing them on tasks such as grade-school science questions, math word problems, commonsense inference and reasoning, etc., is available (HuggingFace, 2024). These platforms also provide local servers that enable communication with downloaded models via an HTTP API that follows OpenAI API standards for the request-response cycle and streaming. Users should check if they fulfill hardware requirements before downloading and selecting the LLM model. Since these APIs are OpenAI compatible, they can be used in the development phase, and by modifying a few lines of code, the local LLM server can be replaced with OpenAI API.

Deployment of LLMs could be done on main cloud computing platforms such as Amazon Web Services (AWS), Azure, and Google Cloud Provider (GCP). They offer solutions for LLM deployments such as AWS Sage Maker, Azure Machine Learning, Azure Kubernetes Service, Azure Functions, Vertex AI, Cloud Run, and Cloud Functions (Padhy, 2024). Also, specialized niche platforms like Runpod, Replicate, and Paperspace could be considered since they are tailored specifically for ML workflows, offering pre-configured environments and simplified deployment (Padhy, 2024). Frameworks such as vLLMs and TGI emerged to ease the deployment of LLMs and enhance performance and concurrency (Gadwal, 2023).

New solutions for easier integration and deployment of LLMs emerged in the past two years, and this trend is expected to persist. On the other hand, more research should investigate appropriate ways of using LLMs in educational environments from a pedagogical perspective and the perspective of knowledge-acquiring methods.



### 3. CONCLUSION

OpenAI API is constantly being upgraded with new functionalities to ease the technical integration of GPT models into educational platforms. Fine-tuning, embeddings, and Assistants API could be considered for improving performances. In addition to the OpenAI API for GPT models, numerous other solutions that facilitate and accelerate the training process and deployment of LLMs are emerging. Technical solutions that support the integration of LLM chatbots into educational platforms are already available and will continue to evolve. For one of the most common LMSs, Moodle, the OpenAI Chat Block plugin emerged. Teachers can leverage this plugin to provide interactive support within the learning environment. However, despite the technical possibility of integration, further investigations from a pedagogical perspective are necessary. Potential integration directions needing further research include administrative and advisory support, personalized learning, virtual mentoring, and support for building complex programming projects. Given that chatbots may hinder students' learning process and their critical thinking, appropriate approaches for their integration must be modeled with caution.

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# ORGANIZATIONAL INTEROPERABILITY IN BLOCKCHAIN: A CASE STUDY IN PERSONAL HEALTHCARE

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**Abstract:** *Blockchain technology is gaining attention for its potential to transform sectors by improving data interoperability and security. This paper examines blockchain's crucial aspects and its application in healthcare with semantic ontologies. It addresses the current challenges in blockchain interoperability, the need for modular connectivity, and the role of common ontologies in ensuring unambiguous data exchange across systems. Particularly in healthcare, blockchain integration with Personal Health Records (PHR) ecosystems can greatly enhance data accuracy, patient trust, and system efficiency. The paper reviews health ontologies that could be integrated into blockchain to improve data handling and decision-making. It posits that applying ontologies to blockchain could create stronger, more interoperable, and transparent healthcare systems, thereby benefiting patient outcomes and operational efficiency.*

**Keywords:** *Blockchain interoperability, Ontologies, Personal Health Records, Organizational interoperability*

## 1. INTRODUCTION

The development of blockchain technology is characterized by diverse approaches, methods, and interpretations. To achieve broader acceptance of blockchain as a technological standard, especially in established industries, it is crucial to establish a common understanding of its fundamental principles and potential impacts. In this context, policymakers, internet users, and business leaders all must understand the implications of blockchain on regulatory frameworks, transparency, risks, advantages, and its potential to transform business models and operations. Business processes today often involve inter-organizational and intra-organizational interactions that take place online and require collaboration among multiple enterprises. This typically entails the coordination of a large number of participants - suppliers, clients, regulatory agencies, and partners. Integrating business systems can be complex if they are based on separate technological platforms or standards. Another important aspect relates to the development of Industry 4.0, particularly with the advancement of the Industrial Internet of Things, smart manufacturing, and cyber-physical systems, which enable interconnected technologies such as wireless sensor networks, embedded systems, cloud systems, and autonomous robots (Burns et al., 2019). Additionally, there are ongoing debates regarding the monopolies present in the online market, mainly due to companies such as Google, Amazon, eBay, Facebook, etc. (Haucap & Heimeshoff, 2014). In a market strictly controlled by a particular company or platform, there is always concern regarding the maintenance of reliability and objectivity in business transactions. Blockchain technology is characterized by decentralization, transparency, security, the immutability of data, and the potential for automation through smart contracts, and it could potentially address the aforementioned challenges. Additionally, the current information system in the healthcare sector faces challenges regarding interoperability, security, and transparency. Therefore, in this paper, we explore how organizational interoperability could be achieved for a personal healthcare application, leveraging the benefits of blockchain technology to create a coherent, secure, and patient-centered ecosystem.

## 2. THE CURRENT STATE OF INTEROPERABILITY IN BLOCKCHAIN

Interoperability refers to the ability of two or more components to work together, despite differences in language, interface and execution environment (Wagner, 1996). A factor adding to the confusion around interoperability is the unclear separation between interoperability and integration, as these terms are often used interchangeably. Integration could be defined as "the merger or combining of two or more lower-level elements into a functioning and unified higher-level element with the functional and physical interfaces satisfied" (IEEE, 1995). The goal of integration is to enable data exchange between different systems, often

through middleware or APIs and requires adjustments to existing systems to facilitate communication. On the other hand, interoperability refers to the ability of components to communicate effectively without the need for additional adjustments or special mechanisms. Interoperability implies the existence of standards, protocols, and formats that allow different systems to exchange data regardless of differences in their technical implementations. The main differences are:

**Table 1:** Differences between interoperability and integration

Interoperability	Integration
Coexistence	Unification
Autonomy	Assimilation
Loosely coupled	Tightly coupled

Source: Soares & Amaral, 2014

Interoperability is especially important in integrating business systems and applications within the company or between partners in the business chain. Also, the need for redundant systems and processes is reduced, which can reduce operating costs. A dynamic business environment often requires rapid integration and optimization, as well as rapid response to changes in market conditions and scaling of operations when IT systems can work together. In loosely coupled systems, components are minimally interdependent, which means that one component can be changed without significantly impacting other components. As such, they are easier to maintain and upgrade, and they allow for greater flexibility and scalability. By integrating and analyzing data from different sources, companies can gain better insights. In blockchain technology, the main problems are different protocols with different consensus mechanisms, data formats, and smart contract rules, which create challenges for establishing interoperability. There are solutions such as Hashed Timelock Contracts (HTLC), atomic swaps, sidechains, and relay chains, and solutions like Inter-Blockchain Communication Protocol (IBC) and Cross Chain Message Passing (XCMP) which connect similar blockchains. There is also a trend towards modularity in blockchain, where each component is specialized for a specific task. For connecting with external data, oracles serve as a crucial link. They facilitate the inclusion of off-chain data into the blockchain, enhancing its applicability to real-world interactions. However, there is a lack of standardization in APIs, common data models, processes and reference software architecture (Belchior et al., 2022). This is especially noticeable when it comes to vertical industries. However, existing research efforts still need to be improved regarding the investigation of privacy in cross-chain exchanges, which is crucial for maintaining data security and confidentiality when interacting between different blockchains.

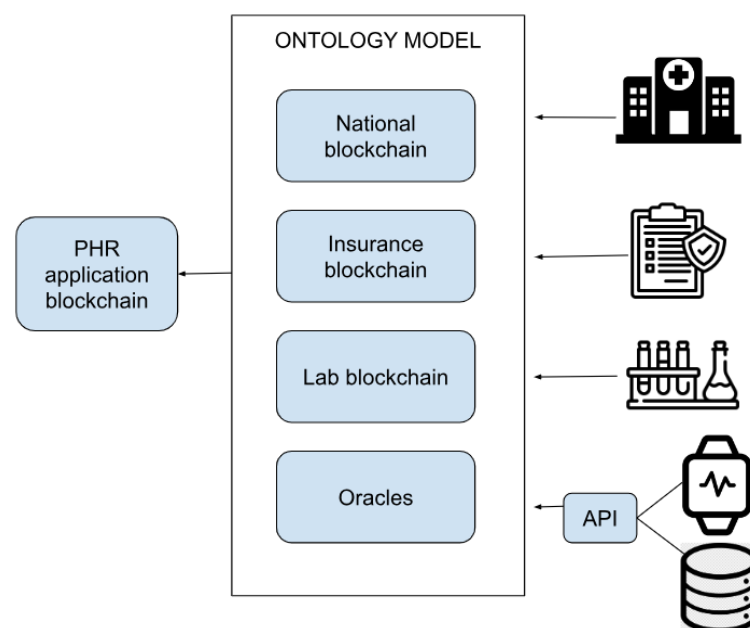
### 3. LEVERAGING ONTOLOGIES FOR ENHANCED BLOCKCHAIN INTEROPERABILITY IN ENTERPRISE ECOSYSTEMS

“Enterprise” is seen as “one or more organizations sharing a definite mission, goals and objectives to offer an output such as a product or a service”. (ISO 15704, 2000). One way to achieve enterprise interoperability is through a federated approach. This approach does not require the involved parties to have the same models, languages, and working methods, but they must share an ontology. It is suitable for peer-to-peer and virtual enterprises, but it is also considered one of the most complex approaches, and there is little activity in this direction (Chen, 2006). The first step in implementing a federative approach is to define a common ontology that will be accepted by all participants in the network. This ontology includes standardized terminology, concepts, and relationships (Rahman & Hussain, 2020). The goal is to ensure that all participants “speak the same language” when exchanging information. Data from different sources must be mapped to the common ontology before their integration or exchange. This alignment ensures that data are interpreted consistently and accurately across the network, reducing ambiguity and increasing the reliability of information. In blockchain technology, there is an observed overlap of standards and a lack of industry-specific standards for vertical industries (GSMI, 2020).

#### 3.1. Application in Healthcare

Several studies bring out crucial points in getting this mass data about patients' health, such as standardization of data, storage capacity, location, safety and how to filter analyze and quickly obtain such data (O'Driscoll et al., 2013). One problem relates to trust in the accuracy and completeness of health records. Ensuring that patients' health data are accurate and complete is crucial. Errors or outdated information can lead to misdiagnoses, inadequate treatment, or missed opportunities for disease prevention, undermining patients' trust in the healthcare system and jeopardizing their safety. Another issue concerns privacy and security.

Health data are sensitive and require high protection levels against unauthorized access, theft, or misuse. Breaches can severely damage patients' trust and reduce their willingness to share necessary information for effective treatment. Coordination and continuity of care are also essential for building trust. Patients often interact with multiple healthcare providers and institutions. Lack of coordination can lead to conflicting advice, duplicated tests, or missed treatments, diminishing trust and complicating the monitoring of patients' health. The quality of decision-making depends on the availability and accuracy of health data. Patients and healthcare professionals must rely on reliable information to make informed treatment and care decisions. A lack of reliable data can lead to inadequate decisions, undermining patients' trust in their care and the healthcare system as a whole. In all that, especially privacy and security blockchain is increasingly used as a solution. (Tertulino et al., 2024). A challenging problem is the provisioning of semantic interoperability in healthcare data, as information is stored in isolated technological silos and managed using different semantic models designed for specific applications. Interoperability in healthcare can be explored in various categories, such as the interoperability of information exchanged between healthcare applications, coding of terms, healthcare business processes, clinical guidelines, and so on (Iroju et al., 2013). Also, one of the key barriers to the adoption of PHR is the interoperability between PHR and Electronic Health Records (EHR) (Tsai et al., 2020). For this case, the focus will be on the interoperability of EHR, PHR, Life insurance and wearable IoT devices.



**Figure 1: PHR ecosystem**

EHR is a digital system for storing and sharing a patient's health information, including allergies, vital signs, appointments, lab results, medical imaging, and diagnoses (Roehrs et al., 2017a). EHR is now considered a crucial component of the healthcare sector, although challenges related to interoperability and privacy persist. PHR contains patient data, and the patient owns that data. In PHR, data collected from wearable devices can also be integrated. Although PHR is patient-oriented, it can be integrated with EHR (Roehrs, et al., 2017b) and shared with third parties. EHR collects various details about patients, including medical diagnoses, conditions, and health monitoring metrics, along with prescribed treatments and medications, diagnostic analyses, and individual identifiers such as full name, date of birth, gender, residence details, as well as related financial records encompassing insurance specifics and billing accounts (Matulevičius et al., 2022). A significant obstacle in developing a patient-oriented system lies in the lack of interoperability among EHRs used in various healthcare facilities (George & Chacko, 2021). Tang and colleagues (2006) emphasize that the interoperability of PHR with multiple healthcare systems requires the implementation of standards for communication, messaging, and content-encoding.

At the technical level, various mechanisms for interoperability can be employed to facilitate communication between different blockchains, drawing upon concepts from Service-Oriented Architecture (SOA). These mechanisms include sidechains, relays and other interoperability solutions such as IBC. The IBC protocol enables seamless interoperability and token transfers between compatible blockchains, aligning with the principles of modularity and standardized communication. Generic message protocols such as Layer Zero act as an underlying infrastructure providing cross-chain communication services, further enhancing

interoperability across diverse blockchain networks. Sidechains are separate blockchains that are attached to a parent blockchain, enabling tokens and other data to be securely transferred between the main chain and the sidechain. Relay chains are integral to some blockchain architectures like Polkadot. These solutions provide the foundational infrastructure necessary for complex, multi-chain interactions, reflecting the principle of modular and interoperable service design. Each of these solutions, however, comes with trade-offs. When integrating PHR with other healthcare institutions, the specific requirements for security and accuracy of medical data make multi-chain solutions more suitable compared to other interoperability options like atomic swaps, HTLC, and notary schemes. It is more advantageous to adopt blockchain interoperability solutions designed for secure and efficient data transfer, particularly those that support a multichain design and have built-in capabilities for complex message-sending and verification processes. Such protocols ensure that data remains secure and intact during transit, which is vital for the management of medical records and the interaction between PHR systems and other healthcare entities such as EHR systems, insurance companies, and laboratories in addition to described, blockchain-to-blockchain communication mechanisms, decentralized oracles play a crucial role by bridging the gap between blockchains and the external world. They provide a secure and tamper-proof method for integrating off-chain data into on-chain environments. Additionally, understanding the semantics of external data is crucial for ensuring deterministic execution of smart contracts that are based on the principle of consensus (Al-Breiki et al., 2020).

**Figure 2: PHR interoperability**

would involve mapping the term "Medication" to "Therapy." This mapping ensures that all stakeholders have a consistent understanding of the terms, thus facilitating smoother data integration and processing across platforms that include PHR applications, EHR systems, insurance companies, and laboratories.

Some existing ontologies, such as The Nuadu ontology collection developed by Sachinopoulou et al. (2007), use OWL and Protégé to create a comprehensive model for PHR. This model covers data such as personal traits, nutrition, and health activities. These ontologies integrate various data sources, thereby enhancing organizational interoperability and efficient health information management. A higher-level Formal Ontology connects all domain ontologies for seamless integration. In this study, the authors conducted a literature review on semantic ontologies to map research across ten defined areas, including disease vocabulary, medical vocabulary, medical procedures, drugs, medical data, human role, emergencies, technology, buildings, and services (Hosseini et al., 2023). Ontologies can be tailored to specific domains to enhance the management and analysis of domain-specific data. For instance, authors (Bjelica et al., 2020), introduced an ontology specifically designed to meet the unique requirements of pregnancy care, demonstrating the adaptability of ontologies to specialized healthcare processes. Among the examples of such specialized ontologies is SNOMED CT (Systematized Nomenclature of Medicine—Clinical Terms), a comprehensive, multilingual medical terminology system that encompasses a wide range of medical concepts including diseases, procedures, devices, medications, and symptoms. Additionally, the Human Phenotype Ontology (HPO) (Gargano et al., 2024) offers a standardized vocabulary for describing symptoms, findings, and phenotypes related to human diseases, which is particularly useful for the detailed characterization of health conditions in the context of personalized health records. Standards such as HL7, openEHR, and CDISC ODM Record System Functional Model (PHR-S FM) can be used as a foundation for PHR ontology.

### 3. DISCUSSION

Organizations often use different information systems that have been developed following various standards. A common ontology enables efficient data exchange between these systems and helps maintain the accuracy, consistency, and integrity of data. Moreover, a common ontology enhances collaboration among different organizations and allows adaptation to changes without the need for significant system reconfiguration. Addressing interoperability within a particular industry could set a precedent for creating standards across various sectors, as the fundamental need is for domain-specific knowledge (Lima, 2018). Therefore, ontologies provide a solid foundation and one of the solutions for achieving organizational interoperability. Regarding PHR, in future work, it is necessary to develop, analyze, and, if necessary, adapt specific PHR ontologies for implementation in blockchain systems. Another important research direction is data privacy and interoperability among different blockchain networks, focusing on the importance of privacy during data exchange and how this can be achieved. It is crucial to protect the general privacy of data and align it with regulatory requirements, especially since health data are sensitive. This involves implementing robust privacy protection measures and ensuring compliance with health data protection regulations to safeguard sensitive information during its exchange across platforms.

### 4. CONCLUSION

Blockchain technology offers significant potential for transforming healthcare systems by improving data interoperability and security. By utilizing ontologies, healthcare institutions can ensure consistent and accurate data exchange across different systems, thereby improving the quality of healthcare services and patient outcomes. Additionally, inherent properties of blockchain such as decentralization and transparency contribute to a robust framework for data privacy, addressing key issues in healthcare data exchange. Future work should focus on developing specialized PHR ontologies tailored for blockchain implementation, enhancing interoperability between different chains, and ensuring compliance with stringent healthcare regulations to protect sensitive patient information. This approach could pave the way for a more integrated, efficient, and secure healthcare ecosystem.

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# DEVELOPMENT OF A CONTENT-BASED FILTERING MOVIE RECOMMENDATION SYSTEM BASED ON THE AHP METHOD

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**Abstract:** *This paper explores the possibilities of developing movie recommendation applications through the integration of various technologies, including MongoDB, Spring, and Angular, along with the application of a custom AHP algorithm and Content-Based filtering technique. The result of the research provides a better understanding of the challenges of improving the user experience in the field of movie recommendation systems.*

**Keywords:** *movie recommendations system, content-based filtering, AHP method, Spring, user preferences*

## 1. INTRODUCTION

With the expansion of the Internet and significant changes in today's digital age, the approach to gathering information has changed, and the importance of data analysis has increased. With more and more content on the Internet, users rely on recommendations to find products that match their interests. In this context, research and development of recommendation systems become crucial to meet the modern user's needs and improve the user experience on the Internet.

Content-based filtering systems make their recommendations based on user behavior, displaying products like those the user has previously viewed. Collaborative filtering systems for recommendation take into consideration the behavior of other users with similar preferences. Hybrid recommendation systems adopt elements of both previously mentioned approaches, thereby incorporating the advantages of both.

Although there is a diversity of approaches and technologies in the development of recommender systems, the analysis of the existing literature has identified room for expanding the available solutions. The analyzed solutions do not use the synthesis of content-based filtering and the AHP method, which creates space for research and analysis of the potential advantages of integrating these approaches. This work aims to explore the possibilities, analyze the benefits, and design a movie recommendation system that uses the Content-based filtering approach and the adapted AHP method. For the practical realization of the goal of the work, a specific combination of Angular, Spring, and MongoDB technologies was chosen to enable the effective implementation of the research.

The rest of the paper is structured as follows. In Chapter 2, three techniques used for the movie recommendation systems were presented, as well as papers that served as a starting point for further research. In Chapter 3, the basic concepts of the used approach are described, while the solution design is presented in Chapter 4. In the end, the conclusion is presented together with future research directions.

## 2. RELATED WORK

According to the authors (Ko et al., 2022), recommendation systems are information filtration mechanisms designed to deliver customized item suggestions to individual users within diverse service environments that can store or gather numerous data. The quantity of objects that do not match the user's preferences is minimized by examining every user's complete data and the data of a set of users related to the user (Ko et al., 2022).

Developers aim to create systems with superior performance and efficiency, adept at aligning users' preferences to improve movie viewership. The techniques used for the movie recommendation system can be classified as (1) Collaborative filtering, (2) Content-based filtering, and (3) Hybrid filtering (Jayalakshmi et al., 2022).

## 2.1. Content-Based Filtering

The Content-Based Filtering (CBF) technique recommends relating objects ground on particulars of objects previously selected by the user (Ko et al., 2022). A user's profile can be formed according to his item rating history, which is analyzed by systems implementing a content-based recommendation technique (Lops et al., 2011). Essentially, this technique discerns particular characteristics in items previously rated and recommends items with corresponding features (Shani & Gunawardana, 2011).

CBF is based on the premise that users who have positively rated items with similar characteristics once will enjoy items with those characteristics again (Çano & Morisio, 2017). But, as always, there are certain limitations to the system's functioning, such as low recommendation quality because of the inability to offer insight into new and diverse recommendations (Ko et al., 2022).

## 2.2. Collaborative Filtering

The collaborative filtering (CF) technique matches users with similar preferences and provides them with the same recommendations (Troussas et al., 2018). Those recommendations can be items that the user was not previously aware of but that he might end up liking (Elahi et al., 2007). Furthermore, this technique uses rankings and reviews to discern similarities between groups of users and then produces recommendations according to the same characteristics among users (Çano & Morisio, 2017). It is human nature to exchange opinions, and that is the foundation of the CF technique (Schafer et al., 2007).

As stated in (Çano & Morisio, 2017), insufficient data in the model can lead to issues such as the cold start problem (a scenario where minimal information is known about user's preferences (Schein et al., 2002)), grey sheep problem (users with unique or divergent preferences and have very low correlations with numerous users (Gras et al., 2016)). Recently, a notable trend has been towards adopting a Hybrid System filtering model to address these limitations (Ko et al., 2022).

Various movie recommendation systems, like PocketLens and CinemaScreen, have emerged. They often use collaborative filtering (CF) techniques due to their ability to include user ratings of items (Lu et al., 2015). Collaborative filtering has found applications across various platforms like YouTube, Netflix, and Spotify, showcasing its widespread adoption. It is a fundamental component within hybrid systems, illustrating its versatility and effectiveness in recommendation algorithms (Pradeep et al., 2020).

## 2.3 Hybrid

A hybrid technique combines collaborative filtering with content-based filtering or combines different methods. It usually involves individually making predictions using content-based and collaborative techniques and then merging them. This integration aims to increase the accuracy and effectiveness of recommender systems (Pradeep et al., 2020).

The primary objective of many researches focusing on the Hybrid recommendation technique is to address the scarcity of rating data by merging the particulars from CBF and CF models (Ko et al., 2022). An integrative recommender system combining CBF and CF techniques provides accurate movie recommendations with increased precision (Lu et al., 2015).

According to (Kumar et al., 2015), on Netflix, as many as two-thirds of watched movies were previously recommended by the application. The authors (Kumar et al., 2015) have created a movie recommendation application called MovieRec based on the K-means algorithm. It is implemented in PHP with a simple console. MovieRec recommends those movies based on the information left by the user himself, as well as on the history of viewed movies, which is very similar to the system described in this paper (Kumar et al., 2015).

In the work of the authors (Aljunid & Manjiah, 2019), a movie recommender system based on CF with an alternating least squares algorithm using Apache Spark was proposed. In contrast, the application made (Kaushik et al., 2018) used Deep learning and Transfer learning as a basis, and it is implemented for the most part using Python.

Through the analysis of the works above, an opportunity emerged for developing a movie recommendation system that will implement a different combination of technologies, algorithms, and approaches, which will be further elaborated in this paper.

### 3. CONCEPTS OF THE APPROACH

This chapter presents the basic concepts on which the research of this paper is based.

#### 3.1. Search technique and algorithm

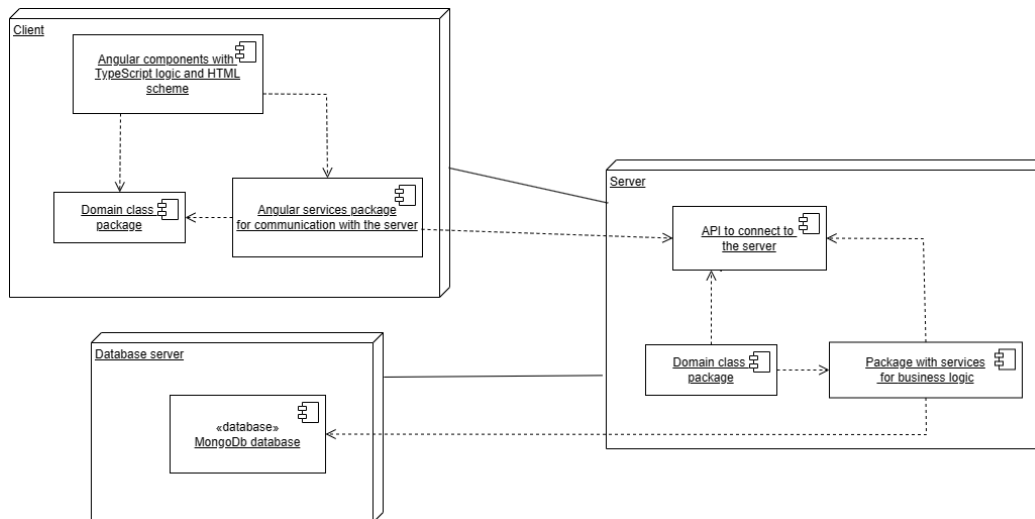
Technologies for movie recommendation systems were presented in the previous chapter. The approach of this paper consists of the Content-Based Filtering (CBF) technique because it does not consider other user profiles while making recommendations. This approach is preferred as it ensures customized recommendations directly align with the user's preferences and interests.

After selecting the technique and narrowing down the data processed when recommending movies, the next step is choosing the algorithm for ranking and recommending movies. The application's logic was created based on the fundamental principles of the Analytic Hierarchy Process (AHP). AHP is a mathematical model used for decision-making in situations where it is necessary to compare and rank several options according to several criteria (Ramanathan, R., 2024). The AHP method has proven to be useful for movie recommendation systems because it helps to understand and evaluate user preferences, which enables more precise recommendations to be made that better match user preferences.

#### 3.2. Solution Architecture

This application uses a three-tier architecture. The three-tier architecture addresses recurring design and development challenges, facilitating more efficient application development efforts. This architecture comprises three distinct tiers: the user interface tier, the application logic tier, and the database tier (Chen et al., 2003).

The user interface layer provides users with a easy to use and accessible means to interact with the application. Unlike the works that served as the basis of the research, this application offers a unique user interface design made in Angular, which is adapted to the ease of use of the application for users (Chen et al., 2003).



**Figure 1:** Deployment architecture

The application logic layer handles control functions and manages the underlying logic for information flow. It is positioned in the middle and serves as a vital link connecting the user interface with the database, effectively concealing technical complexities from users. In contrast to the application in the paper (Kaushik et al., 2018), which was implemented in Python, the application in the paper (Kumar et al., 2015) in PHP, and the movie recommendation system in the paper (Aljunid & Manjiah, 2019), which used Apache Spark, the application logic layer of this application is implemented in Spring. Due to its great popularity and widespread use, the Spring framework makes it easy to find resources and solve problems that may arise during the system (Johnson et al., 2004).

In the database tier, MongoDB is used for data manipulation. MongoDB, an open-source document database stands as the leading choice among NoSQL databases. (DB Engines, 2024), was a suitable choice for the system described in this paper due to its high performance in reporting. In MongoDB, a record is represented as a document, which is a structured collection of field and value pairs, alike to JSON objects. (Wang et al., 2015). JSON objects were beneficial when establishing communication between applications and users, more precisely, the database and front end. Figure 1 shows a deployment diagram that graphically displays the described architecture.

#### 4. SOLUTION DESIGN

Through the synergy of all the previously mentioned concepts, a solution was created, which is described in the following.

##### 4.1. Conducted analysis

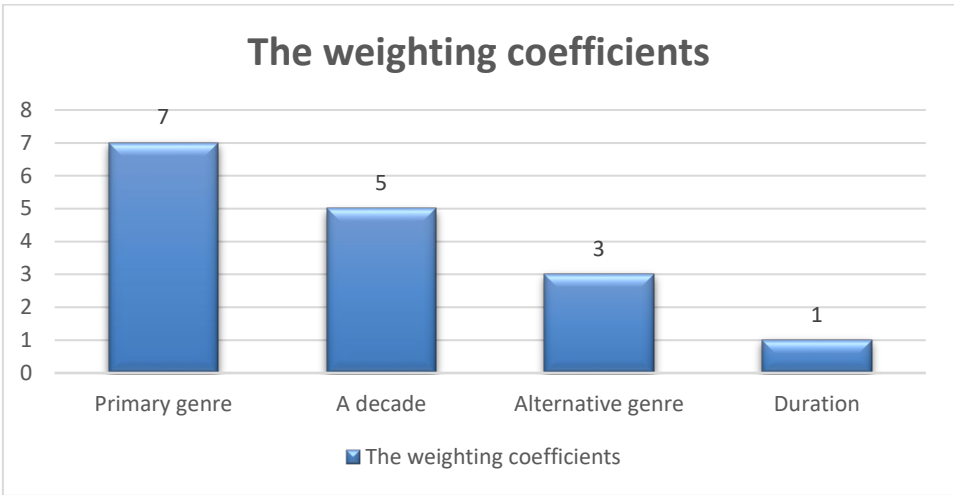
The movie recommendation system of this paper relies on user preferences entered during the registration and their interactions within the application. It ranks all movies in the database based on a scoring system. Each movie receives points for meeting criteria specified by the user's preferences.

Upon opening the application's home page, users are presented with 14 movies having the highest points or the best rank. Based on the research, four criteria were observed by which movies can be compared. The criteria selected among others are (1) The primary genre of the movie, (2) Alternative movie genre, (3) The decade of the movie's release, and (4) Duration of the movie.

By surveying a sample of 20 respondents, it was successfully observed what is most important to (those) users when choosing a movie. The criteria are listed from most important to least necessary based on survey responses:

1. The most important thing is that the primary genre of the movie matches the one that belongs to the user's favorite genre.
2. The second most important observation was that the movie was made in the user's preferred decade.
3. The user wants the alternative movie genre to match his favorite genres.
4. It is important that among the recommendations are those movies whose duration matches the one that the user likes.

Weighting coefficients were assigned for the mentioned criteria when comparing movies from the database with user preferences. The weighting coefficients in the first version of the application are shown in Figure 2.



**Figure 2:** The weighting coefficients

Further improvement of the algorithm focused on introducing continuous monitoring of the user's behavior and preferences within the application itself. Within the "Users" collection in the database, each user has a property called "history" that stores information about the ID of each movie they viewed details of through the application (for instance, by clicking on the movie's image to open a new page containing its details).

This information is utilized to track movie genres from the user's viewing history, in addition to their stated preferences. This tracking is needed because if a user indicates that their favorite genres are A and B, but

they show interest in movies of genre C through their interactions with the application, then genre C is also considered an interest option for the user.

What does the scoring calculation look like now? It's based on the current weighting coefficients, shown in Figure 2, and introduces coefficients related to the primary genres of movies from the user's history. When ranking movies, those whose primary or alternative genre matches one of the primary genres in the user's history receive additional points. If the primary genre of the currently viewed movie matches a primary genre from the user's history, the movie gets 3 points. If the alternative genre of the presently viewed movie matches a primary genre from the user's history, the movie gets 1 point.

Here is an example for easier understanding. The user enters the following data during registration, shown in Table 1:

**Table 1:** Example of the user's preferences

Information	Response
Favorite genres/preferences	romance, comedy, action
Favorite decades of movies	2000s, 1990s
Do you like movies shorter than 2 hours?	Yes

Based on this information, each movie in the database is reviewed and ranked. Table 2 lists examples of movies from the database and how the scoring would look according to the user preferences listed above:

**Table 2:** Example of ranking movies

Criterion		Movie characteristic	Points		Movie characteristic	Points
Primary genre	Movie 1	Action	7	Movie 2	Romance	7
A decade		2000s	5		1980s	0
Alternative genre		Thriller	0		Comedy	3
Duration		2h 30m	0		1h 37 m	1
		Total	12		Total	11

## 4.2. Implementation

In this part of the paper, the implementation of the movie recommendation system will be presented.

### 4.2.1. Database design

In this paper, the designed database supports a movie recommendation system, providing a comprehensive set of information about movies, actors, genres, directors, users, and reviews. The "users" collection stores information about system users. Each document in this collection contains information about the user, e-mail, username, and password that is hashed and stored in the database. Additionally, the system stores the list of genres that belong to their preferences, the desired decade of movies, and a Boolean value indicating whether they prefer movies longer than 2 hours. It also contains the movie history, which the user viewed through the application, which will also participate in the recommendation algorithm. Information is stored about movies that the user has added to the Watchlist, as well as for those for which he has left a review (reviewed\_movies).

### 4.2.2. Communication

Communication between the frontend and backend is done through requests in JSON format. In the header of each request, there is a JWT (JSONWebToken) token. Therefore, the backend always knows which user sent the request.

### 4.2.3. Method for generating recommendations

The recommendMovies method implements the logic on which the recommendation system is based. The method receives as input a list of user preferences, favorite decades, a Boolean value indicating whether the user likes a movie longer than 2 hours, and a history of viewed movies. Finally, the method returns recommended movies based on the scoring system. Initially, the method initializes several variables, such as the weighting coefficients for the criteria mentioned in the previous chapters, a list of all movies, and a map for

storing the results of the method's execution. By iterating through the user's browsing history, the primary movie genres of that list are extracted and stored in a separate list. After that, there is a scoring procedure for each of the films based on the criteria previously defined. The method ranks movies based on scores and returns information about the 14 best-ranked movies.

### 4.3. User experience

On the front page, the user is greeted by a screen with options to log in, register, and view all movies. The registration process allows the user to enter basic information, including first and last name, birthdate e-mail, username, password, duration of preferred movies, favorite genres, and decades. Based on this data, the application suggests movies that best match the user's interests.

Users not logged in can view all movies in the database, with the option of searching by movie name or genre. After successful login, users are shown 14 movies, recommended based on preferences collected during registration. Users can view movies in detail, thus updating the user's viewing history. The modal window shown in Figure 3 details the selected movie and allows users to add it to the Watchlist easily. This feature enables users to track movies they want to watch later. Additionally, the application uses the user's viewing history to update recommendations and ensure they are as relevant and tailored to their interests.

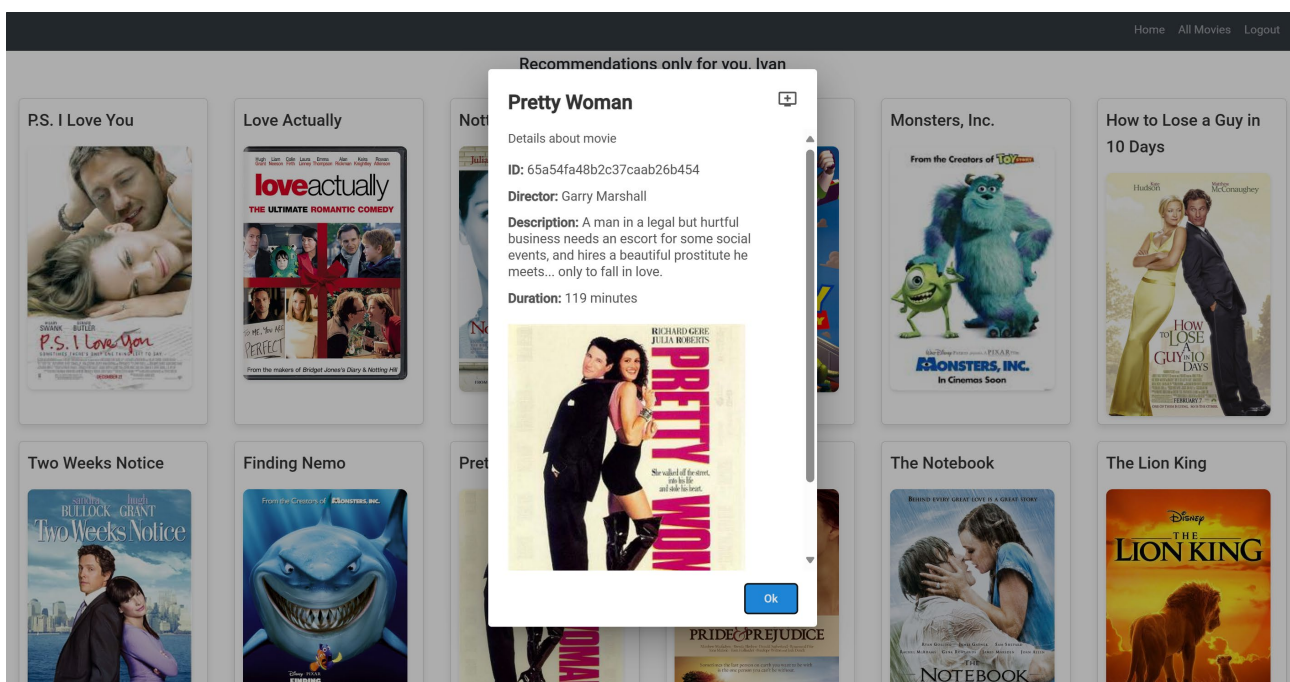


Figure 3: Modal window

## 5. CONCLUSION

This research paper explored the possibilities of developing a movie recommendation application through the integration of various technologies, including Angular, Spring, and MongoDB, along with the application of a custom AHP algorithm. The result of this integration is creating an application that effectively recommends movies based on the user's individual preferences using the Content-Based Filtering technique.

The direction of further research will be improving the recommendation system, primarily by enhancing the algorithm and expanding the number of respondents for determining the weighting coefficients. Until now, users have only chosen from the list of offered genres. Another direction of the system upgrade is to enable the entry of customized preferences and introduce another dimension when ranking movies.

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# A METHODOLOGICAL APPROACH OF DEVELOPMENT OF AN NFT PROJECT

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**Abstract:** *This paper explores the development of the NFT (Non-Fungible Token) project, with a focus on methodology for NFT project and development of an NFT collection. Firstly, the paper provides the definition of NFT and its relationship with blockchain technologies. The paper also offers a short analysis of existing NFT projects and domains of their applications. Proposed methodology describes in detail the steps in the development of the NFT project, mostly focusing on practical development of the collection. The technical aspects of the project are being explored, including 3D model making, collection generation, wallet creation, smart contracts and minting using current technologies and tools. Marketing strategy is also briefly analyzed, highlighting the role of creators on platforms for NFT trading. The most important contribution of the paper is the development of a methodological approach for creation of an NFT project.*

**Keywords:** *NFT, blockchain, metaverse*

## 1. INTRODUCTION

The development of technology and the digital transformation of modern society are unstoppably shaping new areas of economic activity, and one of the most interesting phenomena that has arisen from this rapid development is the emergence of non-fungible tokens (NFT). This type of digital asset, based on blockchain technology, has been a central topic of research and development in the last couple of years. NFT projects, spanning diverse domains such as art, games, music and collectibles, have become key elements of the global digital ecosystem. Providing an approach to the development of an NFT project, regardless of the domain or individuals background is the main purpose of the research.

Blockchain technology represents a secure and transparent basis for the mapping and (peer-to-peer) transfer of value over the Internet (Steinmetz, 2020). Specifically, blockchain can be used to store metadata that represents ownership or other rights to a resource. Additionally, the technology provides the appropriate infrastructure for the implementation of smart contracts, which enable the automation of business logics (Ante, 2021; S. Wang et al., 2019). Being largely autonomous, they execute predefined actions when agreed upon conditions are met. All smart contract prerequisites are transparently recorded on the blockchain, providing the ability for all network participants to verify basic information. This resolves issues of trust between the parties. The key mechanism is the idea of tokenization, where the "digital container" is formed through a smart contract that maps values to the blockchain in decentralized and transparent way. This process further makes those values programmable, transferable and tradable (Ante, 2021, 2022; Cong & He, 2019).

The structure of this paper first gives insight into the concept of NFTs and their underlying technology, it provides examples of implementation of NFTs in real-life scenarios. The following section presents specific methodology for creating NFT projects with all the steps and tools needed for development. Then, the development of an NFT project is described in more detail. Lastly, the paper provides conclusion about the most important steps in development of an NFT project and future direction of research.

## 2. NFT TECHNOLOGY

NFTs can be found in the form of digital assets or physical assets (Lau, 2020). In their digital form, they can be used as an art form, event tickets, virtual properties, game items etc. In their physical form, they can represent ownership contracts, licenses, houses, cars or any other non-interchangeable asset (Simić et al., 2024).

In its digital form, NFT is a unique digital asset recorded on the blockchain, used as proof of ownership or authenticity for a digital asset or physical object. In contrast to fungible assets, NFTs are unique and non-fungible (World Economic Forum, 2023). As the name suggests, non-fungible means something that is not



replaceable, for example, a work of art has its own unique value, and one work is not identical to another. To better understand the concept of non-fungibility, we can look at it this way: although there are multiple copies of the Mona Lisa painting, there is only one true copy that is original and authentic, because of the specific attributes that make it unique (Dalai, 2022).

NFTs can also provide a digital counterpart to unique assets in the analog world. Their programmability allows customization of properties. For example, this may involve automatically receiving resale royalties from the creator (*Non-Fungible Tokens (NFT) | Ethereum.Org*, n.d.). This way, a creator can receive funds every time their work is part of a successfully completed trade on any NFT market or peer-to-peer exchange.

Non-fungible tokens have much wider possibilities of application and are not only intended for art. The very principles behind NFTs can vastly improve the concepts of ownership of all types of assets in the physical or digital world. So, for example, digital art, digital real estate or digital clothing can carry proof of ownership right in their original code (Gurock et al., 2022).

Examples of applications of NFTs include fashion industry. The creation of NFTs in the fashion industry provides companies a way satisfy the needs of their customers. NFT collections are a marketing tool for acquire new customer segments and establishing a presence in the metaverse space. Since NFTs do not degrade or wear out, their authenticity can be easily verified, thus ensuring greater investment value in rare luxury fashion brands and their fashion NFTs, which have a unique value for their owners. The market for non-fungible tokens that yield wearable fashion clothing in the metaverse is still small but has attracted the attention of luxury fashion brands (Simić et al., 2024).

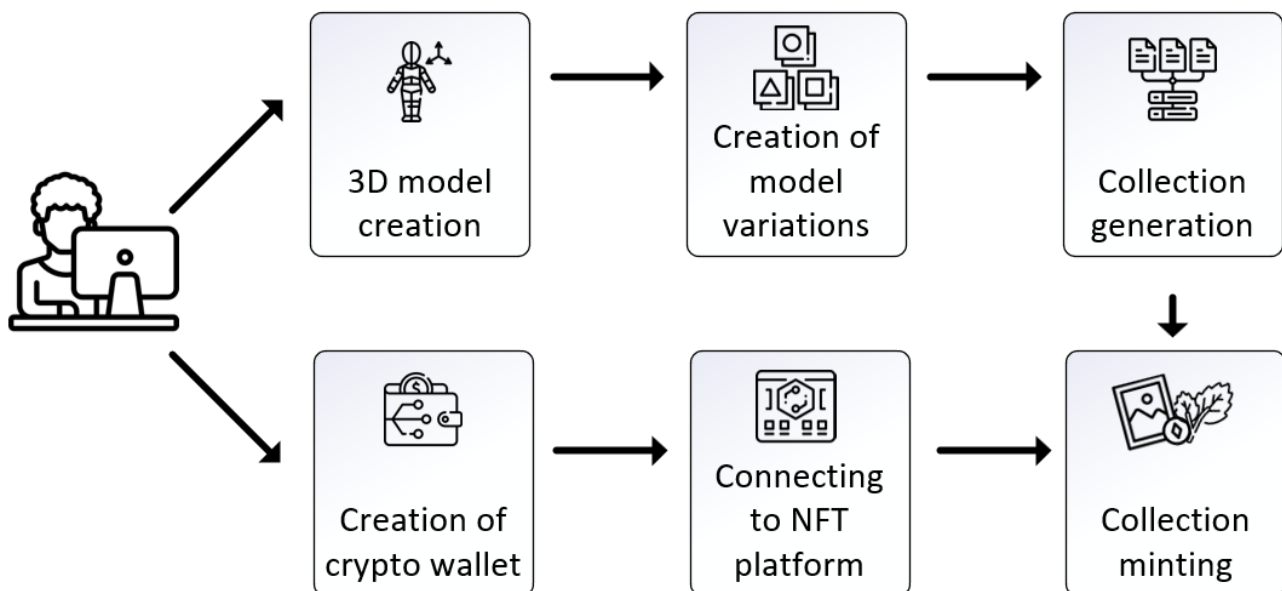
Applications of NFTs in the gaming industry also show great potential. NFTs can provide ownership records of in-game items and promote economic marking place in the ecosystem, benefiting both developers and players. This approach allows game developers to also have a role as NFT publishers of the features including weapons and skins. This way, they can earn royalties each time their items are resold. The players can obtain personal exclusivity game items, have a public record of all available assets, and are able to trade them on an open market (Q. Wang et al., 2021).

### 3. METHODOLOGY FOR CREATING NFT PROJECTS

Many different approaches can be considered regarding the development of NFTs. This mostly depends on the domain of their application. This paper focuses on NFT collection as a digital asset and offers a holistic methodology for their development as a main contribution. The methodology for development of an NFT project proposed in this paper includes multiple key steps:

1. **Creating a base 3D model:** This step is the starting point of the whole process. Creating the original 3D model is crucial as it will define the basic design and aesthetic of your NFT collection. A quality 3D model attracts the attention of potential buyers and adds value to created NFT.
2. **Expanding a model by adding variations:** Adding variations or variants to the base model allows creation of multiple unique NFTs within the same collection. This includes additional items or features to the base model. This increases the appeal of the collection as customers have more choice and the ability to find the NFT that best suits their preferences.
3. **Creating a collection as pictures:** Organizing models into a coherent collection adds to the aesthetics and story of an NFT collection. This can include setting themes, styles or a story that connects all the models within the collection. A collection can have more emotional or artistic value if it is well thought out.
4. **Creating a crypto wallet:** A crypto wallet is required to store your NFTs and allows you to control and manage them. Choosing the right blockchain platform for your wallet is important because it will affect security, transaction costs, and access to markets where you can sell your NFTs.
5. **Connecting to the NFT platform:** Choosing the right NFT platform is crucial as it will serve as the marketplace for your NFTs. Different platforms have different functionalities, fees and audiences, so it's important to choose the one that best suits your needs and goals.
6. **Setup on NFT platform:** When putting your collection on an NFT platform, detailing and presenting your NFTs can make a big difference in their appeal. This step allows potential buyers to better understand and trust your collection.
7. **Minting:** Minting is the process of creating the NFTs themselves on the blockchain. This makes your digital artifacts unique and irreplaceable. Minting allows your NFTs to be recognized and verified on the blockchain, making them authentic and enabling their sale and transfer of ownership.

Each of these steps presented in figure 1, plays a key role in the process of creating an NFT collection, contributing to its quality, authenticity, and market value.



**Figure 1:** Methodology for creating an NFT project  
 "Icons made by Freepik and Umeicon from www.flaticon.com"

Development of an NFT project or collection requires a combination of several software and tools. One of the combinations includes the software listed below, available to everyone and free to use.

- **BLENDER:** Blender is a powerful, free, and open-source software for three-dimensional modeling, animation, rendering and creation of visual effects. The important aspect of Blender is its ability for complex 3D modeling. Users can create detailed objects, characters and scenery using a variety of tools and techniques. Blender includes a powerful rendering system that enables the creation of high-quality images and animations. Users can adjust lighting, textures, materials, and cameras to achieve the desired visual effect (Gumster, 2020). This flexibility is essential for the creation of diverse NFT collections. Community of enthusiasts constantly contributes to its development through plugins and scripts, which provides additional functionality and tools that allow users to customize the software to their specific needs i.e. development of NFT collection. Accessible across multiple operating systems, Blender accommodates users ranging from novices to professionals.
- **FZ-RANDOMIZER:** FZ Randomizer is a free plugin for Blender. It allows users to randomly vary different elements within Blender, such as items of features. FZ Randomizer provides the ability to introduce unpredictability and variation into 3D models and scenes, allowing the creation of diverse NFT collection. It can calculate the number of possible variations, ensure their uniqueness, if necessary, generate the number of requested variations and finally save in any desired form and at any location in the computer. It is important to note that there is also the possibility of setting percentages of the probability that a certain object will appear on one of the generated images (Richard van der Oost, n.d.).
- **METAMASK wallet:** MetaMask is a digital wallet that has become a key tool in the world of cryptocurrencies and decentralized applications (DApps). This wallet is specifically tailored to work with the Ethereum blockchain with web browser integration, providing users with a simple and secure way to manage their digital assets. It allows users to easily access their funds and digital assets and interact with the Ethereum network. MetaMask functions as a bridge between users and the Ethereum blockchain, allowing them to securely store, send and receive Ethereum and ERC-20 tokens. In addition, MetaMask provides support for smart contracts, which allows users to interact with various decentralized applications that are built on the Ethereum network. One of the key benefits of MetaMask wallet is that it follows the evolution of blockchain technology, constantly updating its functionalities to reflect the latest trends and standards in the Web3 space and metaverse (Ghobadi, 2022).
- **GOERLI network:** The Goerli network is an Ethereum testnet that plays a key role in the development and testing of smart contracts, decentralized applications (DApps) and NFTs on the Ethereum blockchain. This testnet uses a "proof-of-authority" (PoA) consensus mechanism, where certain entities, known as authorities, have the authority to confirm transactions. PoA enables fast block times and high efficiency, which makes Goerli suitable for rapid iterations and testing in the development process. The Goerli network uses a specific token, known as "GöETH", which has no real value and is used solely for testing purposes (*What Is Goerli Testnet?* - *GeeksforGeeks*, 2023). By utilizing the Goerli testnet, developers can experiment with the creation and interaction of NFTs without incurring real financial risks. This allows for thorough testing of NFT smart contracts and ensures their functionality and security before deployment on the Ethereum mainnet.

- **MANIFOLD STUDIO:** Manifold Studio enables the creation of a personal Web3 platform for creativity and the sale of any digital goods, including NFTs. These tools provide the highest level of authentication and full control by allowing users the ability to decide how to distribute their work and where to sell. It supports testing of the NFT collection, and displaying it on sites such as OpenSea, LooksRare and Rarible (*Welcome to Manifold Studio | Manifold Docs*, n.d.).

### 3.1. Marketing strategy for NFT projects

Marketing strategy is of utmost importance for a successful NFT collection. The phase of developing a strong marketing strategy for an NFT collection should follow its development (Lanza, 2024). This strategy needs to combine creativity, emotional connection, and practical benefits to create not only a collection, but an experience that will have a deeper meaning for customers. This process includes:

- Creation of advertising materials: Video content, GIFs and PR texts would be created with the aim of first showing the charm of graphics, and then emphasizing their meanings and encouraging an emotional connection with each individual digital amulet.
- Engagement of influential personalities: The key partners in the promotion of the collection would be influential personalities with a large audience who believe in some of the values by which the NFT were inspired and see their deeper meaning and true purpose. Through their social networks and public appearances, they would promote the collection, its meaning and all the benefits provided by owning one of the tokens of the collection.
- Providing additional benefits for customers: It is important to provide additional benefits for NFT owners such as gaining access to exclusive content or perks tied to their ownership of specific NFTs. Also, NFTs could serve as tokens of membership or loyalty within decentralized communities.
- Personalization and combination: Collectors, i.e. regular customers, would have the option of submitting a request for personalization of their tokens after a certain number of purchased tokens. During personalization, NFTs can be combined with each other and thus give a deeper and more personal value to the customer.
- Development of the community through interaction: Forum discussions and debates would be an integral part of all social networks in order to gain insight into what is expected of creators by the community and what are its problems and doubts of individuals in it through a less direct way.
- Creation of virtual events: Online conferences could be organized/attended once a month, at which Web3 experts would also be guests, who would explain to customers the importance of tokens from that side and their future direction as a new technology. This could further educate the community, and the organizers and creators would receive confidence in them. Virtual format of event could further contribute to adoption of NFTs, as one of the newer technology advancements.

The comprehensive marketing strategy should not only be focused on product promotion, but also on creating a deeper and long-lasting relationship with customers (Kuhle et al., 2023).

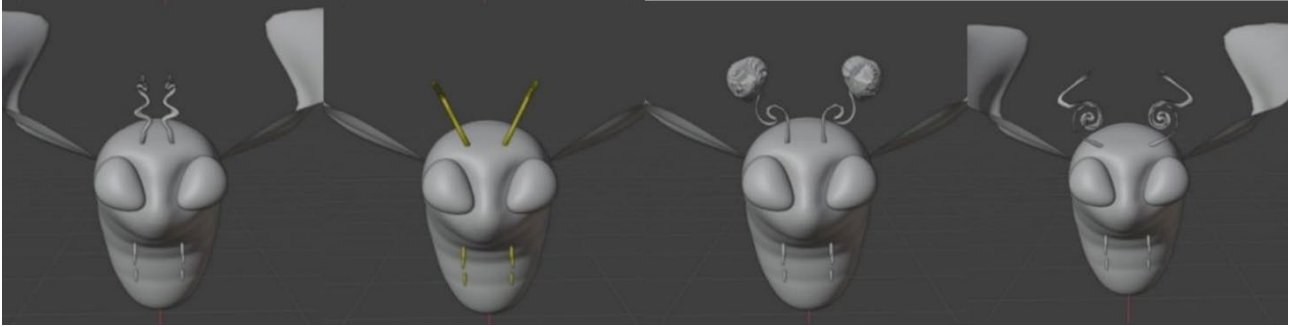
## 4. DEVELOPMENT OF NFT PROJECTS

This section details the process of creating an NFT collection following the proposed methodology. It includes steps such as a creating multiple variants of a 3D model, setting up a digital wallet, connecting a smart contract, and minting. The process of creating a 3D model using Blender 3D modelling software is presented in figure 2.



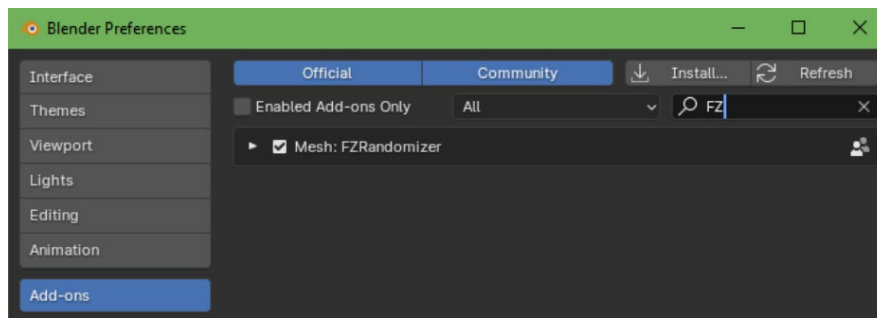
**Figure 2:** Development of 3D model

Creating variations to the base model is presented in figure 3 and includes additional features such as various antennae and wings shapes. This adds to the individual character of each NFT within the collection.



**Figure 3:** Creating variations in 3D model

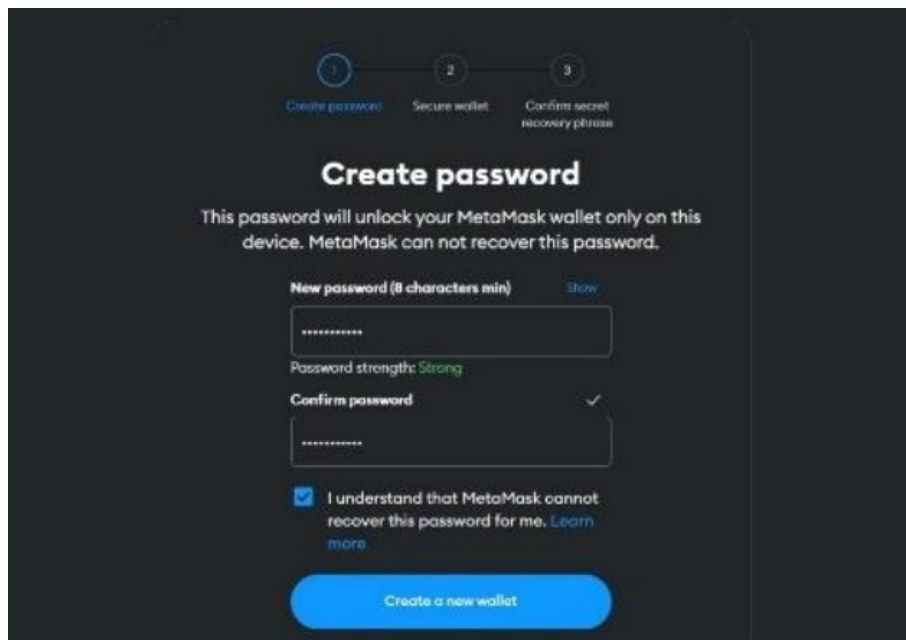
Adding FZRandomizer add-on, shown in figure 4, allows users to randomly vary different elements of 3D model within Blender. It ensures uniqueness, generates requested variations, renders them and exports them as pictures to be used later on during minting.



**Figure 4:** Adding FZRandomizer add-on

Plugin FZRandomizer provides the option of setting the probability of an object appearing in the collection and implementing new rules if there is a need. If the probability of some parts is less than others, this can be used to make the token more sought-after and, in most situations, more collectible.

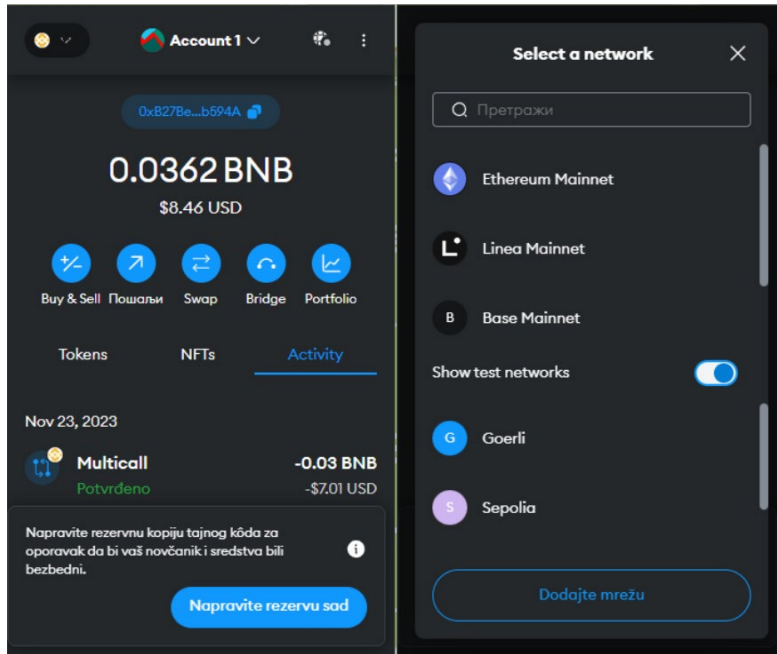
The MetaMask wallet is added as a plugin to any browser and is very easy to configure and use. Its use is convenient because it is not necessary to have a separate application or even exit the current browser window to make a transaction. Figure 6 shows creation of MetaMask wallet through desktop browser.



**Figure 5:** Creation of MetaMask wallet

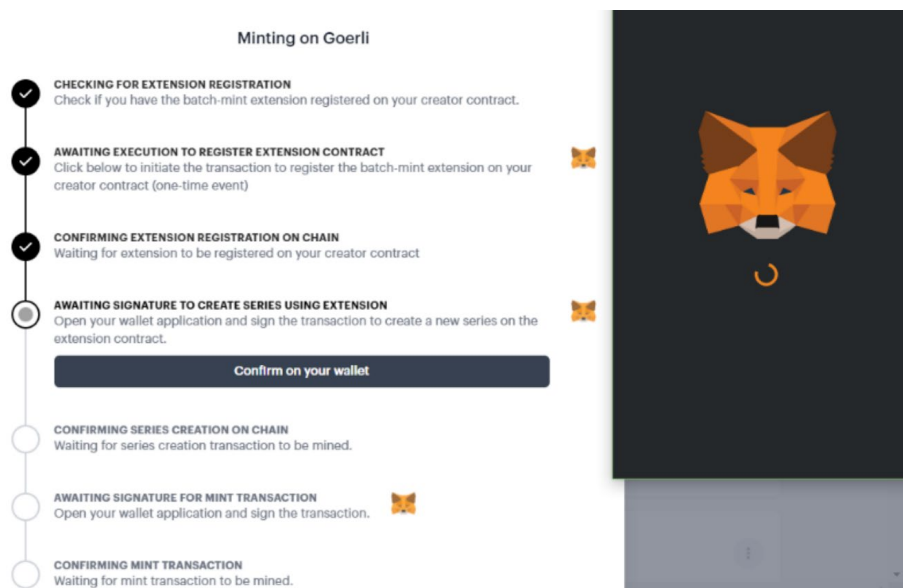
The Goerli testnet is an Ethereum network that is used to test smart contracts and NFTs. It uses Proof-of-Authority (PoA) consensus algorithm suitable for fast iterations and testing during the development process

without any financial risks. This requires changing network in MetaMask as shown in figure 6 allowing for thorough testing of NFT smart contracts in an environment that simulates the Ethereum mainnet.



**Figure 6:** Changing the network to Goerli testnet

For the purpose of this example, the contracts were created on the Manifold Studio platform. Firstly, it is necessary to connect to the MetaMask wallet. After the request is sent by the platform, a browser add-on is automatically opened in the browser, requiring authorization of the transaction. The process of minting with all necessary steps can be seen in figure 7.



**Figure 7:** Minting NFT collection on Manifold Studio platform

After placing the created collection on the platform and filling in the mandatory data, the smart contract is automatically generated. The deployment of the smart contract on the blockchain network and the execution of a transaction, must be confirmed through the MetaMask wallet.

## 5. CONCLUSION

In this paper, the dynamics and complexity of NFT projects are explored considering the rapid development of technology and the increased interest of users. Understanding the fundamentals of blockchain technology, the history of NFTs, and analysing existing NFT projects provided a deeper insight into the different approaches to the digital token market. Through a methodology that included a description of the process, the use of tools and technologies, the steps in the development of an NFT collection were presented in detail.

Looking at the technical aspect, from creating 3D models to creating smart contracts and minting the collection, the paper highlights the importance of combining different elements to create a unique and attractive NFT collection. It also gives insight into the role of marketing strategies in promoting the NFT project. This research contributes to a better understanding of the development process of NFT projects and also provides examples of specific technologies that can be used.

Through the implementation of the proposed methodology for development of an NFT project, individuals can equip themselves with the required knowledge to autonomously create and mint their own NFT collections, irrespective of one's creative domain. This approach provides clear guidance on all the necessary steps including 3D modelling, minting and marketing of an NFT collection, while also proposing open-source software that can be used in the process.

Future work regarding this topic could include expanding methodology towards additional aspects of NFT projects including setting terms of sale and prices, analysing sales and creating and interacting with community.

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# CHALLENGES OF GREEN AND DIGITAL TRANSFORMATION



# ASSESSING SERBIAN IRON AND STEEL EXPORTS TO THE EU UNDER CBAM

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**Abstract:** *Iron and steel products in Serbia is mostly oriented towards export to the EU market. The aim of the paper is to assess Serbian exports to the EU of various products from the iron and steel sector that will be covered by Carbon Border Adjustment Mechanism (CBAM) and conduct a comparative analysis of greenhouse gas (GHG) emissions of these products to the EU. The findings of this paper suggest that 60% of total value of Serbian iron and steel exports will be effected by the CBAM. Additionally, it is observed that five specific iron and steel products dominate Serbian exports to the EU and are significantly exposed to CBAM regulations. Furthermore, the analysis reveals that the direct emissions associated with these products are, on average, 25% higher than the emissions within the EU, while indirect emissions are, on average, more than three times higher than those in the EU.*

**Keywords:** *Carbon Border Adjustment Mechanism, European Union Emissions Trading System, iron and steel, Serbia, Green Deal*

## 1. INTRODUCTION

In order to address the challenges posed by climate change and mitigate GHG emissions, numerous states and regional governments have implemented ambitious strategies (Hainsch et al., 2022). Many countries have adapted carbon pricing mechanisms to incentivize companies to lower their CO<sub>2</sub> and other GHG emissions. In April 2022, a total of 73 emissions trading systems (ETS) and carbon taxes were implemented, collectively covering more than 23% of GHG emissions. One of the first and largest carbon pricing mechanism is European wide system called European Union Emissions Trading System (EU ETS). EU ETS is a mechanism that started in 2005 and has since significantly contributed to GHG emissions reduction. In 2022, the EU ETS covers 11,000 enterprises within the 27 EU states and three non-EU states (Norway, Iceland and Lichtenstein), which accounts for 45% of the total GHG emissions in these countries (Vićentijević et al., 2023).

From the beginning of implementation of EU ETS, EU policy makers were conscious of potential issues of carbon leakage. Carbon leakage occurs when EU companies relocate their carbon-intensive production to countries with lower or without carbon pricing policies. In order to deal with these problem EU introduced new mechanism called Carbon Border Adjustment Mechanism (CBAM). CBAM is an import tariff on products from carbon-intensive sectors such as iron and steel to reduce carbon leakage and aims to provide incentive to companies outside EU ETS to reduce their GHG emissions. Six sectors are included in first phase of implementing CBAM. Together with products under the sectors of hydrogen, cement, fertilizers, electricity and aluminum, one of the sectors covered by CBAM is iron and steel (European Parliament, 2023b), which is a sector with one of the highest emissions globally. In 2019, iron and steel companies produced around 2.6 Gt CO<sub>2</sub>e or 7% of total emission world wide. (International Energy Agency, 2020).

The EU is the biggest trading partner of Serbia. In 2022, Serbia's exports to the EU were €17.7 billion (64.1% of total Serbian exports), while imports from the EU amounted to €21.4 billion (54% of total Serbian imports). Furthermore, the iron and steel sector is traditionally one of the most important export sectors of the Serbian economy. Between 2019 and 2023, on average, iron and steel accounted for 7.2% of the total value of Serbian exports to the EU (European Statistical Office, 2024). Moreover, as a candidate country for EU membership, Serbia is obliged to harmonize its legislative framework with EU regulations, including those related to energy and industrial policy. Due to the fact that Serbia is neither part of the EU ETS nor does it have its own carbon pricing system, Serbian iron and steel exports will be under CBAM scope.

The primary objectives of the paper are: 1) to determine the amount of the Serbian exports of iron and steel to EU and to which extent it will be covered by CBAM. 2) to analysis structure of Serbian export of iron and steel



products and to identify the main export products from these industries 3) to assess both indirect and direct emissions intensity of main export products from iron and steel sector in Serbia and to compare to the EU average.

## 2. METHODS

Academic interest in the CBAM has increased, resulting in a growing body of literature. Academic research on CBAM has primarily concentrated on three key areas. Firstly, scholars have examined its legal implications and compatibility with World Trade Organization (WTO) regulations, as explored by Gehring (2023) and Lim et al. (2021). Secondly, there is a focus on evaluating CBAM's potential effectiveness in combating carbon leakage, with papers by Khouardjia and Finus (2020) and Sun et al. (2023) contributing to this aspect. Lastly, researchers have investigated CBAM's ramifications on the European Union's external trade relations with other nations, as studied by Øverland and Sabyrbekov (2022) and Smith et al. (2023).

Moreover, an expanding number of papers are examining topics that assess the effects of CBAM on specific sectors or individual states, taking into account the emissions of companies operating within CBAM-covered sectors. For instance, Tastan (2022) explored the effects of CBAM on the Turkish economy, Takeda and Arimura (2024) focused on its effects on Japan, while Magacho et al. (2024) examined its impact on developing countries. Additionally, Li et al. (2023) and Zhao et al. (2024) analyzed the implications of CBAM on the Chinese iron and steel industries, with a focus on potential policy adjustments by the Chinese government.

The primary methodological approach employed in this paper involves conducting a comparative analysis between emission levels in Serbia and the average emission intensities observed within the EU. This analysis encompasses both direct emissions, which are directly released into the atmosphere from production of iron and steel, and indirect emissions, which result from upstream activities associated with production processes, mostly electricity generation.

For the purpose of the research, data for Serbian export of iron and steel was used from both European Statistical Office and UN Comtrade databases under Combined Nomenclature (CN) commodity code for the period between 2019 and 2023. Data on emission intensity for the individual iron and steel products for both Serbia and EU was obtained from the publication of Vidovic et al. (2023), produced for the European Commission's Joint Research Center.

## 3. CARBON BORDER ADJUSTMENT MECHANISM

The EU has been a pioneer in carbon pricing, establishing the first ETS in 2005. When creating the ETS, the EU recognized the need for specific regulations for sectors such as iron and steel production, which are at risk of carbon leakage i.e., the risk that production capacities might relocate to countries with no carbon pricing or lower rates of carbon taxes. To address this, the EU provides free emission permits, known as free allocations, to these vulnerable sectors to protect EU domestic production capacities. The free allocation in the EU ETS is calculated based on historical emissions data and benchmarks, which represent the average emissions intensity of the most efficient installations within each sector and serve as a reference point for allocating emission allowances. While this measure has protected industries at risk of carbon leakage (Koch & Basse Mama, 2019), it has not sufficiently incentivized the reduction of GHG emissions in these sectors (Jakob, 2021). In addition to free allocations, the EU ETS employs a mechanism called indirect cost compensation which allows individual member states to provide subsidies to sectors at risk of carbon leakage due to significant indirect costs from the carbon pricing of electricity sector emissions. Similar to free allocations, indirect cost compensation is determined using efficiency benchmarks for electricity consumption (European Parliament, 2023a).

In 2020, the EU adopted the European Green Deal, ambitious plan in which EU committed to a 55% reduction in GHG emissions by 2030 compared to 1990 levels (Hafner & Raimondi, 2020). A key instrument of this initiative is the CBAM, a tariff on imports of products from high-emission sectors like iron and steel, designed to reduce carbon leakage. The CBAM aims to level the playing field by ensuring that the carbon price for products produced inside and outside the EU is the same, while also creating incentives for companies to invest in cleaner technologies. If importers can prove that a carbon price has already been paid during the production of the imported goods, the corresponding amount can be deducted. (European Parliament, 2023b). According to the plan, by 2034, the free allocation permits and indirect cost compensation will be completely phased out, with the affected sectors then subject to the CBAM tariff (European Parliament, 2023b).

Starting from October 2023, the transition period for the CBAM began, during which importers are only required to report both direct and indirect emissions from imported products. From 2026, the CBAM will be fully implemented, requiring imported products to pay a carbon price equivalent to what EU companies would pay

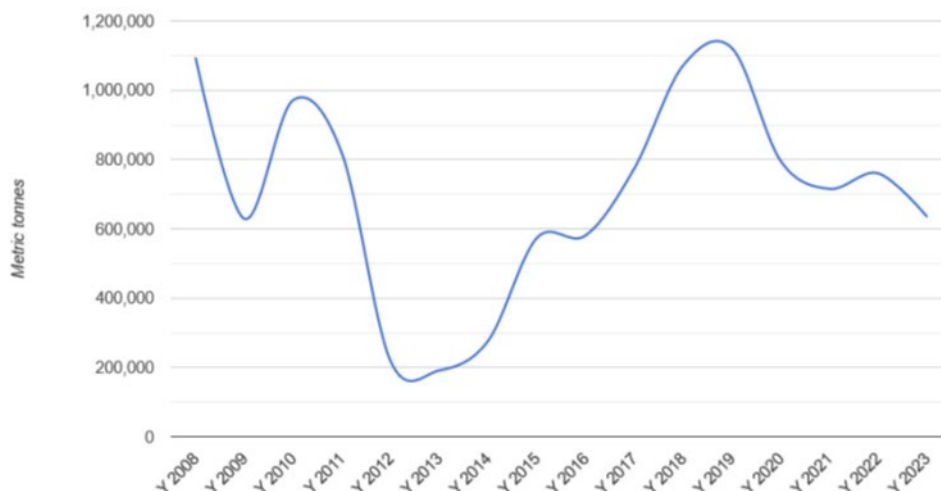
under the EU ETS. Initially, only direct emissions will be included in the CBAM system for most iron and steel products.

Under CBAM regulations, the iron and steel sector is defined as products under CN commodity codes 72 – Iron and Steel, and 73 – Articles of Iron and Steel, with few exceptions (European Parliament, 2023b). The regulation also includes products under CN code 2601 12 00 – Agglomerated Iron Ores and Concentrates, other than roasted iron pyrites. However, since the annual Serbian export of these products to the EU amounts to less than a thousand euros, they were not included in the analysis.

Although introduction of carbon pricing has been under consideration by the Serbian government, Serbia has not yet implemented its own system (Vićentijević et al., 2023). Therefore, the majority of the Serbian iron and steel sector will be subject to CBAM tariffs. Furthermore, as a candidate country, Serbia is obliged to harmonize its legislation with the EU as a condition for becoming a full member.

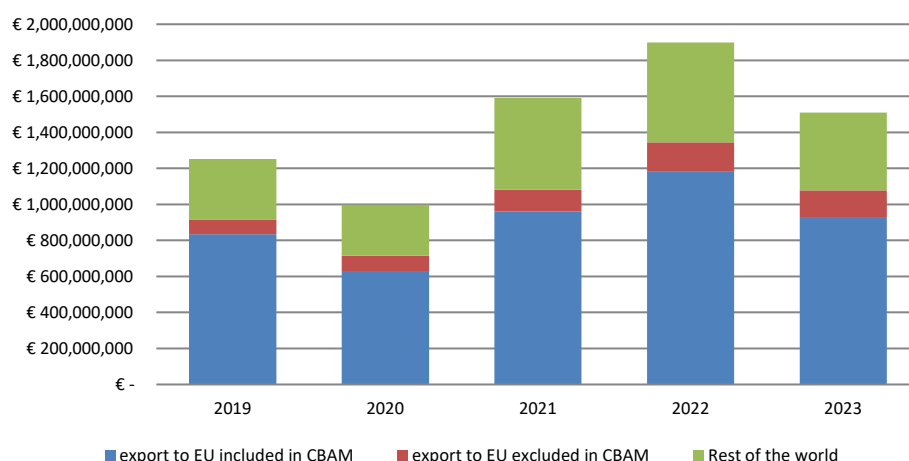
#### 4. SERBIAN EXPORT OF IRON AND STEEL

In 2022, Serbia was the 47th largest producer of iron and steel, with a production of 1.7 million metric tons. (World Steel Association, 2023). The largest production facility in Serbia for iron and steel is the Smederevo Steel Plant, which has been operating since 1913 under the name SARTID. Following the Second World War, the company was nationalized and operated by the government. However, due to sanctions in the 1990s and the loss of markets and suppliers, the company faced bankruptcy. In 2003, Serbia's steel producer was sold to U.S. Steel. Nevertheless, after the financial crisis in 2012, U.S. Steel sold the company back to the Republic of Serbia, leading to a significant reduction in production, as shown in Figure 1. In 2016, the Republic of Serbia privatized the Smederevo Steel Plant to the Chinese company Hesteel. (Stojanović-Višić et al., 2023) This privatization enhanced the company's international competitiveness and increased steel production, making it one of the top Serbian export companies, as can be seen in Figure 1.



**Figure 1:** Export of steel in EU from Serbia  
Source: European Steel Association, 2024

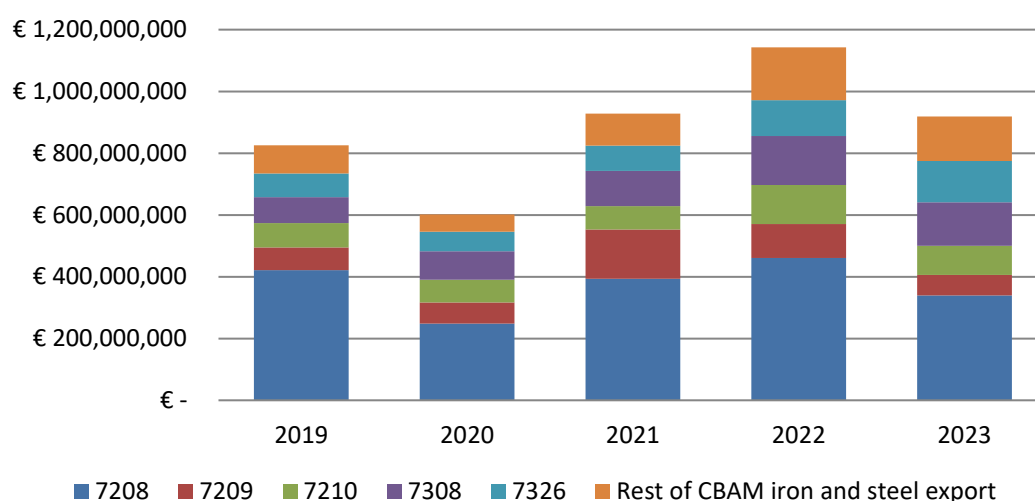
As depicted in Figure 2., the primary export market for the Serbian iron and steel industry is the EU. From 2019 to 2023, on average, 70% of value of Serbian iron and steel exports were directed towards the EU, with the annual amount of exports from this sector averaging around one billion euros. Furthermore, a majority of Serbian products from the iron and steel sector exported to the EU are subject to CBAM regulations. On average, from 2019 to 2023, approximately 90% of value of Serbian iron and steel exports to the EU fell under the scope of CBAM regulations. Based on the data presented, it can be inferred that around 60% of the total value of Serbian iron and steel exports will be affected by CBAM. The value of total iron and steel exports of CBAM-regulated products to the EU in 2023 was 925 million euros. Furthermore, CBAM regulated iron and steel products comprised on average 6.3% of Serbia's total exports to the EU during this period, representing a significant segment Serbian export (European Steel Association, 2024).



**Figure 2.** Serbian export of iron and steel (CN code 72 and 73)

Source: calculated by authors based on data from UN Comtrade and European Statistical Office, 2024.

Furthermore, the study discovered that five products from the iron and steel sector, categorized according to the four-digit CN trade code, dominates Serbian exports to the EU, as depicted in Figure 3 and Table 1. The individual annual export value of these products exceeded 50 million euros during the observed period. The analysis excluded iron and steel products falling outside the scope of CBAM regulations.



**Figure 3.** Serbian export of iron and steel included in CBAM

Source: calculated by authors based on data from European Statistical Office, 2024.

Products falling under codes 7208, 7209, and 7210 are characterized by their composition solely of iron and steel, devoid of any added metal elements. Such products undergo further processing in order to adopt to the requirements of various other industries. In contrast, products classified under code 7308 include a diverse range of structures and parts of structures from iron and steel for the construction sector. Additionally, code 7326 comprises all iron and steel articles not classified under more specific codes.

**Table 1.** Top five iron and steel export products from Serbia to EU by value

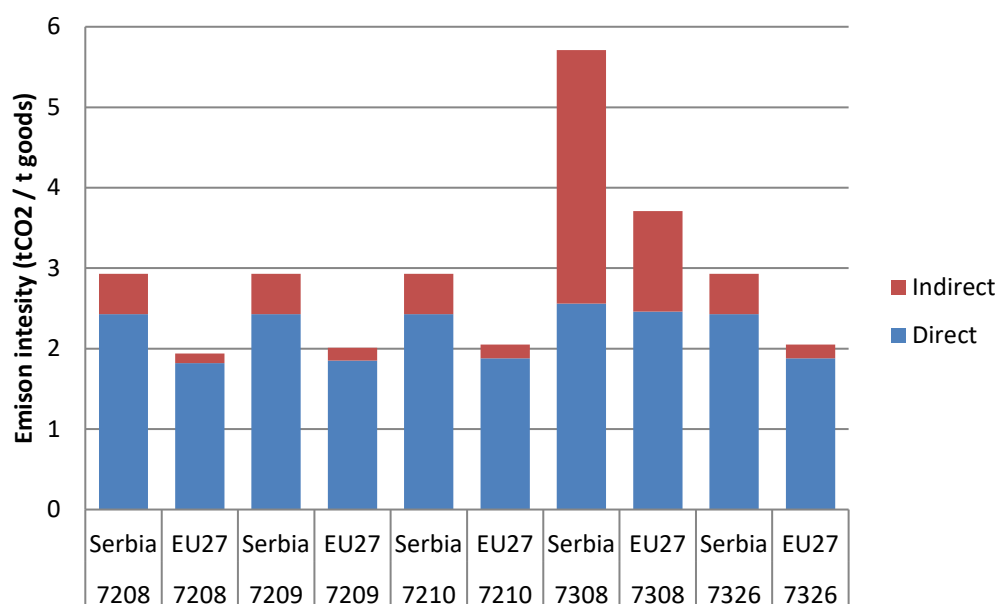
CN Code	Discription
7208	Iron or non-alloy steel; flat-rolled products of a width of 600mm or more, hot-rolled, not clad, plated or coated
7209	Iron or non-alloy steel; flat-rolled products, width 600mm or more, cold-rolled (cold- reduced), not clad, plated or coated
7210	Iron or non-alloy steel; flat-rolled products, width 600mm or more, clad, plated or coated

7308	Structures (excluding prefabricated buildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock-gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel
7326	Other articles of iron or steel

Source: UN Comtrade, 2024.

## 5. EMISSION INTENSITY OF SERBIAN IRON AND STEEL EXPORT

Emission data for the iron and steel industry is used in the calculations in the publication by Vidovic et al. (2023). In this publication, GHG emissions are divided between direct and indirect emissions. The direct GHG emission intensities are calculated according to the CN product codes covered by the CBAM regulation for 2019 based on total production of these products in Serbia and EU, expressed in tones of CO<sub>2</sub>e per tone of goods. Indirect emissions were calculated based on country-specific carbon emission factors for electricity, relying on data from the International Energy Agency and calculated as a five-year average for the period 2015-2019. Since emission data for CN code 7326 is given for subproducts, emission levels for the product under code 7326 90 98 - Other articles of iron or steel were used, which account for two-thirds of the total Serbian exports to the EU under the code 7326.



**Figure 4.** Emission intensity for Serbia and EU for top 5 Serbian iron and steel export to EU  
Source: Vidovic et al. (2023).

In Figure 4., both direct and indirect emission intensity levels for Serbia and the EU27 are depicted for the top 5 Serbian iron and steel exports to the EU. On average, direct emissions in Serbia are approximately 25% higher than in the EU27. However, this disparity varies across products. Specifically, products under CN code 7308, which includes structures and parts of structure made of iron and steel, exhibit a similar level of GHG emission intensity as in the EU. Emission intensity in the EU is 2.46 tCO<sub>2</sub>e per ton of product, while in Serbia it is 2.56 tCO<sub>2</sub>e per ton of product, only 4% higher. However, other sectors in Serbia demonstrate higher emissions, ranging between 30% and 35% compared to the EU average.

In contrast, indirect emissions in Serbia surpass the EU27 average by a significant margin, approximately three times higher, primarily because the predominant component of indirect emissions is electricity generation. Although, according to EU regulation (European Parliament, 2023b) indirect emissions for iron and steel products will not fall under the scope of the CBAM in first period, the EU has retained the option to incorporate them in the future. If CBAM eventually starts to include indirect emissions, it could drastically lower the competitiveness of Serbian iron and steel products in the EU market.

The total emission intensity of GHG (direct and indirect emissions of GHG) for products under CN codes 7208, 7209, 7210, and 7326 shows that the EU emission intensity for these products is an average of 2 tCO<sub>2</sub> per ton of goods, while in Serbia it is 2.93 tCO<sub>2</sub> per ton of goods, 46.5% higher than in the EU. Moreover, the total

emission intensity for products under 7308 in the EU is 3.71 tCO<sub>2</sub> per ton of goods, while in Serbia, it is 5.71 tCO<sub>2</sub> per ton of goods, 54% higher than in the EU.

## 6. CONCLUSION

The EU's Carbon Border Adjustment Mechanism (CBAM) is poised to significantly impact Serbia's iron and steel industry, given the substantial portion of exports subject to CBAM regulations. Around 60% of Serbian iron and steel exports to the EU could be affected, potentially reshaping trade dynamics and competitiveness in these sectors. This underscores the importance for Serbian stakeholders to adapt to the evolving carbon pricing landscape, ensuring continued resilience and competitiveness in the EU market.

The research has examined the export structure of iron and steel from Serbia to the EU, with a specific focus on products exhibiting a significant export value exceeding 50 million euros between 2019 and 2023. The analysis revealed that five distinct products, categorized by the CN trade code, dominate Serbia's exports to the EU and are included within the scope of the CBAM.

The comparison of direct and indirect emissions between Serbia and the EU27 highlights significant disparities in the iron and steel sector. Firstly, direct emissions in Serbia are generally higher, especially in products of solely of iron and steel. Secondly, indirect emissions are considerably greater, primarily resulting from the utilization of fossil fuels in electricity generation. Although current EU regulations do not include majority of iron and steel sub-sectors indirect emissions in CBAM, the potential for future inclusion underscores the importance of Serbia's efforts to reduce indirect emissions. Serbia should consider exploring policy options for adaptation to CBAM. One potential measure is the introduction of carbon pricing aligned with EU ETS to avoid paying CBAM tariffs while also generating additional revenue for financing the green transition. The other policy measure is enhancing electricity generated from renewable energy sources, which would lower indirect emission.

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# ARE RENEWABLE ENERGY SOURCES REALLY GREEN - THE EXAMPLE OF HYDROPOWER?

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**Abstract:** *Due to the consequences of the fossil era, humanity is faced with developmental and environmental issues of how to meet resource needs. For several years, green energy from RES has been the solution to all major environmental problems. At the same time, the question of the impact of production on the environment arises. The hydropower segment, with its negative effects on the environment and space, calls into question the fundamental idea of green energy as an environment-, nature- and people-friendly alternative. In the article, I want to present the negative consequences of the construction of a hydroelectric power plant on the middle Sava, which, if placed in the last untouched part of our longest river, would cause irreversible environmental and social consequences.*

**Keywords:** *fossil era, renewable energetic resources, environment, green energy, hydroelectric power, river Sava*

## 1. INTRODUCTION

The development the so-called industrial society, caused many environmental and social consequences. Throughout the ages of development, the growing population has faced various challenges. Throughout the ages of development, the growing population has faced various challenges.

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Throughout the ages of development, the growing population has faced various challenges. Environmental, social, energy, which have shaped society and the relationship to nature and the environment.

Due to the neglect of environmental content and the unbridled exploitation of natural resources and a society that relied only on two elements, energy and economy, conditions have arisen in the environment and society, which are manifested in the rise of global temperature, degradation of the environment and, in some places, due to the lack of resources, which in some places already affect the existence of individuals.

The improvement of living conditions resulted in population growth and thus an increase in the demand for various goods, which the consumer-oriented society only intensified. Excessive use of resources and raw materials, especially in the developed countries of the North, have become the cause of many environmental and social inequalities and injustices.

Environmental injustices, however, have resulted in negative impacts on the environment and, consequently, on society, which are already significantly affecting the existence of living beings on the planet.

Despite the fact that negative consequences of past non-ecological practices have occurred in the environment, which are the cause of human migration and numerous and growing social and environmental ecological conflicts, the global trend is still directed towards the growth of energy use and their unbridled consumption. As a result of the use of fossil fuels and inadequate technological systems in industry, in the production of electricity and individual use, the trend of increasing energy consumption will intensify until 2040.

## **2. ENERGY, CONSUMPTION AND POLITICAL DEPENDENCE**

Most of the developed countries, due to the consumer-oriented society and its needs, face a shortage of energy products and dependence on external providers. The Covid-19 crisis and the conflict in Ukraine showed that countries underinvested in their own energy potentials and were significantly dependent on sources from abroad. This economic dependence, as we have already seen in cases related to Ukraine, leads to a marked political dependence, which also affects the supply and price of energy products. The crisis with energy products from Russia has caused more and more countries to turn again to the reuse of coal and thus to the continuation of loads. The state of dependence on foreign resources also in the European Community has caused more and more countries to focus on finding their own energy potentials and therefore on greater self-sufficiency.

### **2.1. Energy poverty**

The problem of energy poverty refers to countries, environments and individuals who, due to financial incapacity, cannot ensure their own investments in energy renovation systems. If we want to solve global environmental and ecological problems, it is therefore necessary to switch to RES, but with some essential points, so that in practice no additional burdens are caused in the environment and space.

Long-term energy policies must be based on the dispersion of resources, which, even in unpredictable political conditions, enable a sufficient supply of energy to consumers.

Despite the fact that the EU already adopted measures in the post-covid crisis, which should enable countries to cope with crisis situations more easily and which should follow greater energy self-sufficiency, when some measures are introduced into the environment, concerns arise about their environmental and ecological orientation.

The very definition of RES comes from the renewable domain, meaning that resources can be renewed regardless of their use. However, this definition is rather loose, as it does not contain limitations through the concept of sustainability, which is based on the balance of economic, energy, and above all, environmental contents that have been neglected in the past. OVE also does not define exactly what renewable resources are and what they are, or rather it does not deal with the question of how we got this so-called green energy. Considering the many negative consequences of green technologies, according to environmentalists and ecologists, green projects are only a cover for the continued exploitation of resources and nature, or the enforcement of capitalism with a green face, which is nothing more than the continuation of the neoliberal, consumerist and profit-oriented growth paradigm (Plut, 2014, Kirn, 2012, 2022). If we take e-mobility as an example, this is certainly true in the initial phase of metal production and battery construction for electric cars (Senegačnik, Žnidarič, Vuk, 2020).

Other technologies and procedures, especially interventions in the environment, if we are talking about the production of energy from hydroelectric power plants, are also environmentally harmful, and at the same time represent a distinctly negative impact on the environment and the existing fauna and flora.

## **3. HYDROPOWER PLANTS AND THE ENVIRONMENT**

Although HPPs are supposed to represent one of the pillars of renewable energy production, in reality this is not the case. We ecologists are of the opinion that energy from renewable sources represents a truly green execution, just like e-mobility, but in both cases, due to the consequences at the beginning of the tap, viewed as a whole, the production is extremely harmful to the environment, nature and people.

In order to obtain hydro energy at all, it requires interventions in the environment, which are far from a sustainable policy, which is supposed to represent a balance with environmental contents. Damping the river itself and placing the dam in the natural course of the river represents an intervention that has significant negative consequences for the environment, the river itself and all living things that live in the pristine river. What is even more important is that many underground sources of drinking water are fed from the rivers, which can significantly change their water quality when they are dammed.

The silt that forms under or in front of the dam contains substances that significantly change the quality of the water for the worse, because toxic non-degradable substances accumulate in it due to the river's limited self-purification abilities.



### 3.1 Hpp construction and (un) sustainability

Despite the fact that the natural potential is financially immeasurable, at least in terms of intrinsic values, and at the same time we are witnessing the growing consequences of human negative environmental practices, which are manifested in the degradation of nature and the environment.

Under the guise of using renewable resources and green energy, in terms of sustainability, there are also today in Slovenia tendencies to build the last free-flowing areas of the Sava River with hydroelectric power plants.

According to FIP (2024), dams are artificially established obstacles, the work of human hands, which have restricted free-flowing rivers with dams, barriers and locks, to ensure water supply, obtain energy, enable easier navigation or increase flood control (the example of the Netherlands). In the case of Nozozemska and its specific conditions, due to the depression and the higher ocean level, protection against floods withstands the thesis of increased anti-flood safety, but elsewhere, according to Toman (2022), this does not withstand serious consideration, since according to him, floods are solved in the contributing area of the river, in the upstream part of the streams, not in the lower ones and even less by building dams or by building HPPs. The example of floods years ago in Slovenia, when deliberate releases of water in Austria on the Drava river flooded a large part of the Drava field, is a practical example that dams and HPPs are not built for these cases. I personally think that artificial, unnatural interventions in rivers actually only helped to produce problems and not to reduce them.

### 3.2 Types of obstacles

There are many different types of obstacles on rivers. Dams are one of the common and well-known types. The rest are dams, locks, culverts, crossings and ramps.

dam: a structure that blocks or restricts the flow of water and raises the water level to form a reservoir

small weir: a structure that regulates flow and water level, but often allows water to flow freely over the top

sluice: a movable structure whose purpose is to control the flow and level of water

culvert: a structure that allows water to flow under an obstacle

ford: A structure that creates a shallow place with good footing where a river or stream can be crossed by wading on foot or by vehicle

ramp: A ramp or bed sill designed to stabilize the channel bed and reduce erosion; recognizable by its stepped shape.

Source: AMBER (2020).

Such unnatural barriers reduce the ecological connectivity of the watercourse, hinder the flow of water, nutrients and sediments, reduce the self-cleaning of rivers, and for living beings, they represent an obstacle to their movement. Large dams completely change the character of water bodies, turning rivers and transitional waters into reservoirs with prevailing lake conditions.

### 3.3 Pressure drivers

There are several sources of point pressures that are generated from different drivers. They can be divided into energy, agricultural, industrial, environmental and human social segments and urban development.

According to the EEA (2018), barriers represent the most common pressure on surface water. If European countries are removing them due to economic inefficiency in terms of reconstruction and restoration, and their demolition is supposed to reconnect 25,000 km of river sections, in Slovenia, despite the high density of barriers on rivers, there are tendencies to increase (Pengal et al., 2022). Among the most threatened areas where energy companies want to build new HPPs is the Balkans. According to RiverWatch (2022), the construction of as many as 3,281 facilities is planned in the Balkans, 108 of them are under construction, and 1,726 of them are in the operational phase. Many of these facilities are to be built in protected and environmentally sensitive Natura 2000 areas, or in other environmentally protected areas.

Planned facilities and facilities under construction in the Balkan countries;

- Slovenia: 370 buildings planned and 1 under construction
- Croatia: 149 facilities planned and 1 under construction
- Bosnia and Herzegovina: 374 facilities planned and 35 under construction
- Serbia: 803 facilities planned and 20 under construction
- Kosovo: 89 facilities planned and 10 under construction
- Montenegro: 93 buildings planned and two under construction

- North Macedonia: 180 facilities planned and 12 under construction

Source: RiverWatch (2022)

Pengal et al. (2022) identified 61,781 barrier records in the Danube and Adriatic basins. 51,859 in the Danube basin (Dp) and 9,922 in the Adriatic basin. Considering the length of Slovenia's river network (44,580.80 km), we have 1.39 barriers per river kilometer in Slovenia. The barrier density for Dp is 1.37 and for Jp is 1.47. In both cases, the numbers are high compared to other areas in the EU.

Table 1. Density and assessment of barriers for selected European countries

Country	Density of barriers (no./km)	Estimated number of barriers
Austria	0,51	8.607
Switzerland	8,11	171.693
France	0,35	63.932
Slovenia	0,13	1.321
Italy	0,49	65.756
Serbia	0,59	14.901

Source: Pengal et al., 2022.

Because, according to WWF(2020), the destruction of aquatic environments is three times faster than the destruction of terrestrial ecosystems and since 1980, interference with freshwater ecosystems has caused an 84% decline in the populations of freshwater vertebrates (mammals, birds, amphibians and fish), we are environmentalists and an environmentally oriented profession against the construction of power plants, which would significantly restrict the last parts of free-flowing rivers. Especially the central part of the Sava River, which offers shelter to many indigenous animal species. The unnatural intervention that the construction of HPPs on the middle Sava would represent would at the same time significantly change the living habitats along the river, reduce the water quality and affect the drinking water reservoirs along the river, which supply the inhabitants of the towns located along the river. According to the EEA (2018), unnatural barriers are also the cause of pressures on surface waters, affecting 40% of water bodies.

The buildings themselves, and especially the dams, would visually and spatially significantly change the environmental picture of the landscape, which is now still surrounded by nature. Last but not least, the negative consequences of interventions on the river are most noticeable at already existing facilities, especially in the lower part of the Sava River (HE, Sevnica, HE Brežice and others).

The fundamental problems of dams on rivers and their consequences in the environment

According to Toman (2022), the fundamental problems of barriers on rivers are;

- the damming of rivers firstly affects the longitudinal connectivity of the system, interrupts the connections of the lower and upper streams, as a result it greatly changes the living communities in flowing waters, which significantly affect the quality of water sources for drinking water supply
- the consequences of changes in the course of the river affect the reduction of the river's self-cleansing capacity. In fast-flowing, turbulent rivers, the self-purification of the river can reach up to 30%, which means that the river can "digest" up to 30% more load (mainly organic) than it naturally enters the river. On the example of the Sava River, the self-cleaning capacity was evaluated 30 years ago and actually reached somewhere around 20% (Toman, 2020).
- due to a change in the flow, there is a secondary load, which is the result of the deposition of dangerous substances in front of the barrier, the passage of toxicants into the food chain (via algae, aquatic invertebrates all the way to fish). Due to changes in the main food pathways in the dammed part, eutrophication occurs, which is latent (hidden) in flowing waters. In the case of the Sava, this is already evident in the reservoirs of the lower Sava, not to mention the reservoirs on the Drava, since we still do not have tertiary treatment included. The removal of nutrients (N and P) is also negligible.
- barriers change productivity, i.e. one of the most important processes in flowing waters from the point of view of living communities and habitats. As a result, the riverbeds in the lower part deepen (an example can be the Mura due to accumulations on the Austrian side), which further changes the communities and, consequently, the self-cleaning ability.
- it is also important to point out falsehoods regarding flood safety. HPPs are not built for flood protection, but at the beginning of the tap.

- last but not least, any accumulation represents a change in metabolic processes. In a silty accumulation, a large part of the sediments are organic substances, because the conditions are often anoxic, as methanogenesis occurs, the product of which is the greenhouse gas methane, which is 10 times more environmentally influential than carbon dioxide from the point of view of greenhouse gas production. (Toman, 2022).

Toman (2022) is critical of human impacts on water resources and ecosystems as he says;

Various experts have been dealing with the many negative impacts of barriers for a long time (Liermann et al., 2012), but they entered the wider public discourse only in the last decade. The consequences of placing barriers on different watercourses are similar and can be generalized to some extent, but river ecosystems are unique and complex, so the consequences of interfering with them are also complex and specific. In other words, each individual barrier has its own consequences. Rosenberg et al (2000) summarized the cumulative impacts of barriers as follows:

- establishment of new reservoirs within the water cycle of the basin (Petts, 1984);
- changes in natural water and sediment flows and seasonal patterns of river flows (Vorosmarty and Sahagian, 2000);
- changes in ecosystem processes: nutrient cycling and primary production (Pringle, 1997; Rosenberg et al., 1997),
- biogeochemistry of downstream and coastal areas (Ittekkot et al., 2000);
- fragmentation of riverine habitats (Dynesius and Nilsson, 1994) and associated/dependent organisms (Dudgeon, 2000, Pringle et al., 2000);
- Deterioration and loss of flood plains and riparian areas downstream of barriers (Nilsson and Berggren, 2000);
- deterioration and loss of river deltas and estuaries (Rosenberg et al., 1997) and lowering of sea level (Chao, 1995);
- deterioration of the state of irrigated terrestrial ecosystems and related surface waters (McCully, 1996);
- problems with drainage, eutrophication, pollution and contamination (Zalewski, 2000, 2002);
- cyanotoxic contamination of reservoirs, river water and trophic levels (Zalewski, 2000);
- genetic isolation as a result of habitat fragmentation (Pringle, 1997; Neraas and Spruell, 2001);
- impacts on biodiversity (Master et al., 1998);
- destruction of fish habitats and populations, and consequent decline in fishing (Petts, 1984);

Considering the negative impacts of HPP construction on the environment and living and non-living nature, the construction of HPP and the consequences of building interventions on the environment and space are unsustainable policies that have nothing to do with sustainable concepts. Deception by capital about the so-called green hydropower is the fruit of a materialistic and economically profitable view, which, considering all the listed negative consequences of intervention in space, has only one sign, i.e. the continuation of burdening and exploitation of nature and the environment. From an environmental point of view, the sustainable growth of energy consumption and thus energy production is unsustainable and does not lead to a reduction of the burden on the environment, but on the contrary, to its greater degradation (Kirn, 2020, Žnidarič, 2023).

### 3.4 Solutions related to barriers on rivers and streams

The construction of HPPs on free-flowing rivers is definitely not a solution for the energy policies of individual countries. Smaller interventions in the environment are represented by other alternative sources, such as solar power plants, heating systems, geothermal energy, wood and wood biomass. Of course, at the same time, it must be emphasized that all the best technical standards, or BAT, must be taken into account when implementing RES systems. Another measure is reduced consumption. The Western, so-called developed world is extremely wasteful when it comes to the underdeveloped. For example, the United States has consumed more fossil fuels and minerals in the past 50 years than all other countries combined. Instead of people talking about reduced individual consumption, the consumption trend continues.

The third and last but not least, very important measure is that when deciding on the measures, the profession and the interested public face each other and include them in the decision-making process of whether such prospects even fit into the environment or not.

## 4. CONCLUSION

In accordance with the Biotic Strategy, Slovenia committed itself to the restoration of free-flowing rivers. Restoring the original situation is almost impossible due to past interventions. The situation will be able to change for the better only in decades, when nature will recover. Therefore, in terms of the negative consequences, any new approach is not only questionable, but harmful. The task of us and future generations is to draw attention to the problems and to look for ways and measures that will reduce the burden on the environment. By building hydroelectric power plants, we will only increase the load. If we want to survive on a limited planet, we will have to change our attitude towards nature and the environment, and definitely reduce our consumption habits, otherwise we will fall into even greater conflicts between people and nature.

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# THE POWER OF DIGITAL SOCIAL NORM NUDGES IN ENHANCING SUSTAINABLE FASHION CONSUMPTION

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**Abstract:** The development of e-commerce has complicated the decision-making process. Emphasizing conscious decision-making has yielded inconsistent results for sustainable consumption, often overlooking the unconscious influences. This study used digital nudges to enhance sustainable fashion consumption (SFC) among Gen Z consumers in southeastern Europe, whose environmental awareness does not always translate into buying habits. Recognizing Gen Z's emphasis on togetherness and sustainability, the study focused on social influence and the environmental performance of fashion products. One hundred participants (41 males, 58 females, and 1 non-disclosed) were divided into two groups and completed six online questionnaires on purchase intention, willingness-to-pay, green trust, green perceived value, and word-of-mouth for six fashion product categories. The six MANOVAs confirmed that participants exposed to social norm nudges (experimental group) in fictitious e-commerce settings scored higher on all dependent variables. The results suggest that social nudges are a cost-efficient, promising tool for fashion retailers, providing a holistic understanding of products' environmental and social values for Gen Z.

**Keywords:** Neuromarketing, Sustainable Fashion Consumption, Generation Z, Digital nudges, Social Influence.

## 1. INTRODUCTION

Consumers, especially Generation Z, are increasingly focusing on brands' sustainable actions (Jung and Jin, 2016). Cognitive psychology and behavioral economics suggest that most decisions are made unconsciously, influenced by social and emotional cues (Weinmann et al., 2016). Nudges, which modify decision-making environments (choice architecture), aim to promote optimal choices. This study aims to establish a cause-and-effect relationship between digital social norm nudges and sustainable fashion consumption (SFC).

**Table 1:** Study's research objectives, questions, hypotheses and variables

Category	Research objectives, questions, hypotheses and variables	
Independent Variable	Strong digital social norm nudges presented along with sustainable fashion products.	
Dependent Variables	1.	GPV; Green Perceived Value of sustainable fashion products
	2.	PI; Purchase intention toward sustainable fashion products
	3.	GT; Green trust toward sustainable fashion products
	4.	WOM; Word-of-mouth intention for sustainable fashion products
	5.	WTP; Willingness to pay for sustainable fashion products

Research Hypotheses	<p><i>RH1:</i> Sustainable fashion products with digital social norm nudges will have higher scores in the GPV questionnaire than sustainable fashion products without digital social norm nudges.</p> <p><i>RH2:</i> Sustainable fashion products with digital social norm nudges will have higher scores in the PI questionnaire than sustainable fashion products without digital social norm nudges.</p> <p><i>RH3:</i> Sustainable fashion products with digital social norm nudges will have higher scores in the WTP questionnaire than sustainable fashion products without digital social norm nudges.</p> <p><i>RH4:</i> Sustainable fashion products with digital social norm nudges will have higher scores in the WOM questionnaire than sustainable fashion products without digital social norm nudges.</p> <p><i>RH5:</i> Sustainable fashion products with digital social norm nudges will have higher scores in the GT questionnaire than sustainable fashion products without digital social norm nudges.</p>
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## 2. LITERATURE REVIEW

Social norms have been applied as digital nudges in e-commerce to promote sustainable consumption. Cialdini and Jacobson (2021) define social norms as the behaviors, attitudes, beliefs, and codes of conduct within a group that unconsciously influence individual actions. Cialdini's (1993) social proof principle explains the effectiveness of social norm nudges, as individuals trust the opinions of others in decision-making environments. Social norms, as "affective" nudges, elicit emotional responses and produce more significant behavioral changes than cognitive nudges (Charry and Tessitore, 2021). Lee et al. (2020) linked nudges to activation in the anterior cingulate cortex, which is involved in emotional regulation and socially responsible actions. Based on social identity theory (SIT), people share emotional connections and social interactions, comparing their behaviors and opinions with social norms to shape their self-perception and social identity (Rela, 2022). This leads individuals to adopt the characteristics of their social groups for approval (Rela, 2022). Given Generation Z's limited attention span (8 seconds) and tendency to avoid complicated choices, researchers have tested digital nudges to promote sustainable fashion consumption (SFC) (Salleh et al., 2017). Studies found that verbal nudges were more effective than visual nudges in promoting SFC (Roozen et al., 2021), informational labels as nudges increased SFC (Lee et al., 2020), and social norm nudges were more effective than default nudges or a combination of nudges (Mirbabaie et al., 2023). Nudges can enhance customers' perception of products' environmental and economic value, leading to more sustainable choices (Gupta and Joshi, 2016). Kim and Seock (2019) highlighted norm-based behavioral intervention's impact on perceived product value through a social approach, suggesting individuals engage with sustainable products if others do so, fostering moral obligation, social acceptance, and avoidance of social rejection (Ahn et al., 2020). This study will examine sustainable consumption holistically, focusing on product-related factors (perceived product value and trust), economic factors (WTP), and contextual factors (Testa et al., 2021). GPV is a determinant of GT, PI, WOM, and perceived product value for Generation Z's SFC (Chen & Chang, 2012). Further research is needed to support the effectiveness of digital social norm nudges in online fashion retail.

## 3. METHODOLOGY

The study applied an experimental between-subject design. The specific design and participants' random allocation to control and experimental groups increase internal validity (McKay-Nesbitt & Bhatnagar, 2017) and reduces learning biases (Lee & Watkins, 2016). The data was analyzed with SPSS ver.27. The study targeted the part of Generation Z cohort born between 1994 and 2003. Participants were recruited with the non-probability convenience-purposive sampling method. In convenience sampling, the participants are selected due to their instant availability, making this method one of the most time and cost-efficient (Andrade, 2021). The purposive sampling enhances study's internal validity and the richness and representativeness of the data due to the inclusion criteria (Andrade, 2021).

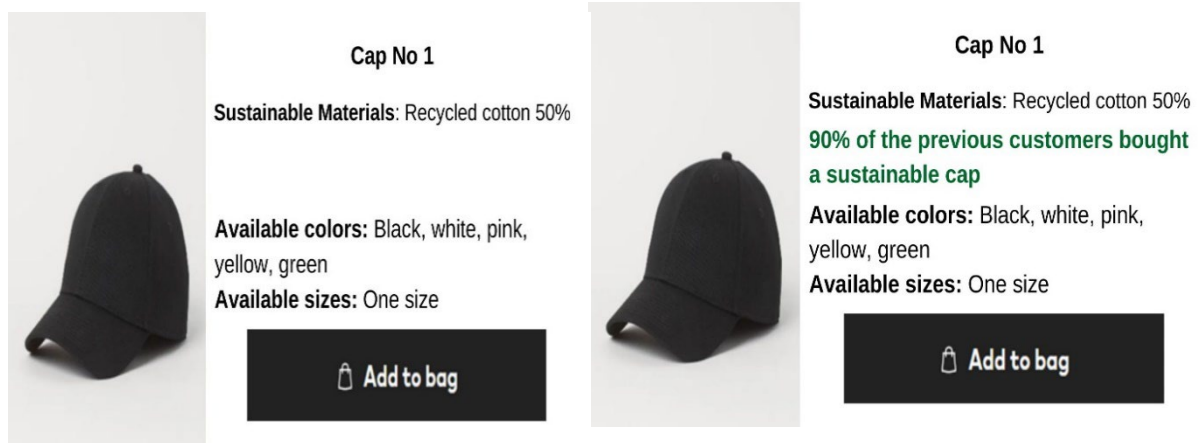
Table 2 represents questionnaires' items and reliability score per variable.

**Table 2:** The questionnaires for each dependent variable

Variable	Measurement items	Scale reliability
Purchase intention (PI)	1. "The probability that I would consider buying this piece of clothing is" 2. "My willingness to buy this piece of clothing is" Grewal, Monroe, and Krishnan, (1998)	$\alpha=0.803$
Green perceived value (GPV)	1. "This product's environmental functions provide very good value for you" 2. "This product's environmental performance meets your expectations" 3. "You prefer this product because it has more environmental concern than other products" 4. "You prefer this product because it is environmental friendly" 5. "You prefer this product because it has more environmental benefit than other products" (Chen, & Chang, 2012)	$\alpha=0.882$
Green trust (GT)	1. "You believe that this product's environmental image is generally reliable" 2. "You think that this product's environmental functionality is generally dependable" 3. "Overall, you believe that this product's environmental claims are trustworthy" 4. "This product's environmental concern meets your expectations" 5. "This product keeps promises for environmental improvement" (Chen, 2010)	$\alpha=0.902$
Word-of-mouth (WOM)	1. "If asked, I would say positive things about [product name] services to other people" 2. "If asked, I would recommend [product name] to other people" (Yi, & Gong, 2013)	$\alpha=0.940$
Willingness-to-pay (WTP)	1. I would pay more for a green product that is making efforts to be environmentally sustainable. 2. I would be willing to pay this extra percentage on the green products to support the organization's/product efforts to be environmentally sustainable (Kang et al., 2012)	$\alpha=0.760$

Study's fashion products were presented in a H&M's e-commerce environment due to its global recognition (Bonilla et al., 2019). A call-to-action button and product's available sizes, colors and eco-friendly materials were added to increase e-commerce environment realism (Figure 1). Both groups were exposed to identical information and product categories (i.e., t-shirt, jacket, hat, scarf, cap, and pair of jeans) to avoid biased answers.





**Figure 1:** An example of control (left) and experimental (right) condition

Study's descriptive norms promoted the desired behavior as it minimizes backfire effects (Richter et al., 2018). The study applied simplified social nudges as they produce less psychological resistance, negative responses and they require less information processing (Lee et al., 2020).

**Table 3:** Social norm nudging techniques applied in the study

Nudge form
<i>90% of the previous customers bought a sustainable cap</i>
<i>82% of the previous customers bought a sustainable hoodie</i>
<i>85% of the previous customers bought a sustainable jacket</i>
<i>On average, previous customers purchased at least 4 sustainable products</i>
<i>3 out of 4 customers selected the sustainable scarf</i>
<i>The majority of previous customers selected the sustainable t-shirt</i>

The study conducted online with the “allocate.monster” program (Fergusson, 2022) which randomly allocated participants to one of the two google forms and to two experiment's conditions. Participants' answers provided once to avoid duplicated answers.

In total, 100 participants were recruited. 4 represents control group's demographics.

**Table 4:** Participants' demographics in the control group

Demographic	Category	N	%
Gender	Male	21	42
	Female	29	58
	Prefer not to say	0	0
Age	18-28	50	100
	29-39	0	0
	40-50	0	0
	50+	0	0
		0	0
Educational level	I finished high school	4	8
	I graduated from an IEK (Institute of Vocational Training)	6	12
	I graduated from a TEI (Technological Educational Institute)	2	4
	I graduated from an AEI/University/College	24	48
	I have a Master's degree	13	26
	I have a PhD	1	2
	Other	0	0

**Table 5:** Participants' demographics in the experimental group

Demographic	Category	N	%
Gender	Male	21	42
	Female	28	56

	Prefer not to say	1	2
Age	18-28	50	100
	29-39	0	0
	40-50	0	0
	50+	0	0
Educational level	I finished high school	4	8
	I graduated from an IEK (Institute of Vocational Training)	0	0
	I graduated from a TEI (Technological Educational Institute)	8	16
	I graduated from an AEI/University/College	28	56
	I have a Master's degree	8	16
	I have a PhD	1	2
	Other	1	2

Internal reliability was evaluated using Cronbach's alpha coefficient. The Cronbach's alpha for GPV, PI, WTP, WOM and GT questionnaires' items signified excellent reliability levels (Table 6).

**Table 6:** Cronbach's Alpha values of study's questionnaires

Questionnaire	Cronbach's Alpha	N of Items
GPV	,986	30
PI	,972	12
WTP	,971	12
WOM	,970	12
GT	,988	30

## 4. RESULTS

Six separate one-way MANOVAs were conducted to examine the effects of various nudges on the dependent variables. The nudge "90% of the previous customers bought a sustainable cap" led the experimental group to exhibit higher levels on each dependent variable, especially GT levels ( $F(1, 45.698)=60.995$ ,  $p<.001$ ,  $\eta^2=.384$ ). The social norm nudge "85% of the previous customers bought a sustainable jacket" significantly influenced the experimental group's scores, with a stronger effect on WTP levels ( $F(1, 98)=47.317$ ,  $p<.001$ ,  $\eta^2=.326$ ). The nudge "On average, previous customers purchased at least 4 sustainable products" resulted in higher scores across all variables for the experimental group, with the strongest effect on WTP ( $F(1, 98)=47.131$ ,  $p<.001$ ,  $\eta^2=.325$ ).

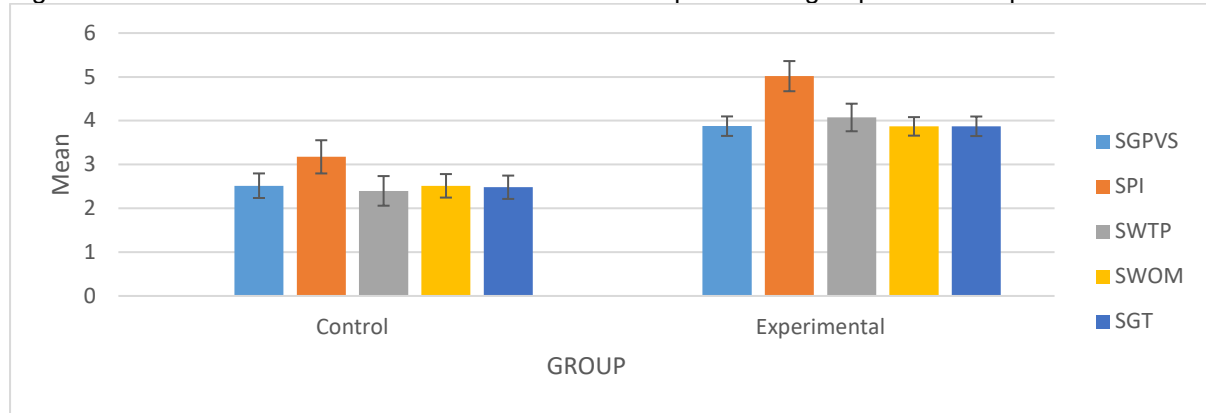
The nudge "3 out of 4 customers selected the sustainable scarf" caused higher scores on every dependent variable in the experimental groups, with GT levels having the highest effect ( $F(1, 98)=55.986$ ,  $p<.001$ ,  $\eta^2=.364$ ). The nudge "The majority of previous customers selected the sustainable t-shirt" produced significant results for the experimental group across all dependent variables, especially on GT value ( $F(1, 98)=56.380$ ,  $p<.001$ ,  $\eta^2=.365$ ). The final nudge, "82% of the previous customers bought a sustainable hoodie," significantly affected all dependent variables in the experimental group, with the highest effect on WOM levels ( $F(1, 98)=81.229$ ,  $p<.001$ ,  $\eta^2=.453$ ).

The multivariate tests indicated that all nudges had a statistically significant effect on the dependent variables (Table 7). Wilks' Lambda ( $\Lambda=0.578$ ) showed a significant difference between groups' means, and the partial eta squared ( $\eta^2=0.422$ ) demonstrated the independent variable's strong effect on the dependent variables' scores. The high observed power ( $=1.000$ ) led to the rejection of the study's null hypotheses, indicating that strong social norm nudges can indeed guide Gen Z customers to select more sustainable products, regardless of their category or nudge strength. These results align with Demarque et al. (2015), who found that strong digital social norm nudges produce statistically significant results in sustainable consumption. Additionally, the findings support Lee et al. (2020) and Roozen et al. (2021), suggesting that nudges can be applied in fashion retailers to increase SFC, particularly WTP and PI. Unlike Mirbabaie et al. (2023), where the experimental group had higher but not significantly different SFC than the control group, this study found statistically significant higher scores in every parameter of SFC for the experimental group.

**Table 7:** Multivariate test results for Intercept and GROUP effects on dependent variables

Effect		Value	F	Hypothesis is df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power <sup>c</sup>
Group	Pillai's Trace	,422	13,734 <sub>b</sub>	5,000	94,000	,000	,422	68,668	1,000
	Wilks' Lambda	,578	13,734 <sub>b</sub>	5,000	94,000	,000	,422	68,668	1,000
	Hotelling's Trace	,731	13,734 <sub>b</sub>	5,000	94,000	,000	,422	68,668	1,000
	Roy's Largest Root	,731	13,734 <sub>b</sub>	5,000	94,000	,000	,422	68,668	1,000

Figure 2 visualizes the mean scores of the control and experimental group on each dependent variable.

**Figure 2:** Representation of mean score of control and experimental control per dependent variable

The specific section of data analysis concludes the impact of nudges on each variable separately. These statistics provide data about the effectiveness of nudges per variable. The nudge “82% of the previous customers bought a sustainable hoodie” produced the highest effect on GPV values with  $\eta^2=.424$ , followed by PI  $\eta^2=0.383$ , WOM  $\eta^2=0.453$  and GT values  $\eta^2=0.414$ . Only the nudge “90% of the previous customers bought a sustainable cap” signified stronger effect on customers’ WTP levels with  $\eta^2=0.368$ .

Gender had an insignificant effect on nudging intervention and Gen Z customers’ SFC, with values ranging from  $p=0.163$  to  $p=0.634$ . The literature shows that socioeconomic status and age are stronger predictor of nudge influence on individuals’ behavior than gender, the results of this specific study corroborate Roozen et al. (2021) findings that gender has insignificant effect on SFC.

## 5. RESULTS AND DISCUSSION

Study’s primary objective was to examine the efficacy of strong digital social norm nudges on increasing Gen Z customers’ SFC in terms of GPV, PI, WOM, WTP and GT. Digital social norm nudges were used as mental shortcuts by Gen Z customers that trigger customers’ emotions and lead to sustainable choices (Joshi & Rahman, 2016).

The primary objective of the study was to examine the efficacy of strong digital social norm nudges on increasing Gen Z customers’ sustainable fashion consumption (SFC) in terms of general perceived value (GPV), purchase intention (PI), word-of-mouth (WOM), willingness to pay (WTP), and green trust (GT). Digital social norm nudges, which serve as mental shortcuts for Gen Z customers, trigger emotions and lead to sustainable choices (Joshi & Rahman, 2016).

The first research hypothesis (RH1) was confirmed, showing that digital social norm nudges can influence Generation Z's GPV of sustainable fashion products. This aligns with Woo and Kim (2019), who found that projecting a green product's social value increases customers' perceived value, leading to higher consumption. Gen Z emphasizes social aspects in decision-making to strengthen social relationships and gain acceptance (Chaturvedi et al., 2020).

The second and third hypotheses were also accepted. Nudges in e-commerce settings can increase PI and WTP for sustainable fashion products, which is crucial as sustainable clothes are often more expensive (Roozen, 2021). Similarly, Demarque et al. (2015) found that strong social norm nudges significantly increased both PI and the amount of money customers are willing to spend on sustainable products. This can be explained by Cialdini's (1993) social proof principle, where awareness of norms leads to trust and behavior imitation, especially with moral choices (Trudel, 2019).

The fourth hypothesis confirmed that social norm nudges increase Gen Z's WOM intentions for sustainable products. According to Cialdini's (1993) social proof principle, individuals seek cues from significant others before initiating a behavior. Saleem and Ellahi (2017) found that observing others' online behavior towards sustainable products reassures consumers, leading to trust and higher WOM intentions.

The final hypothesis was also supported, showing that digital social norm nudges can increase GT values. Gen Z's environmental awareness and online connection lead them to trust customers' feedback more than brands' communication strategies (Thomas & Monica, 2018). Adamkiewicz et al. (2022) proposed that eco-labels highlighting environmental and social value increase product trust. Khare and Pandey (2017) suggested that consumers' trust increases due to their need to express environmental values.

Regarding nudge effectiveness, "82% of the previous customers bought a sustainable hoodie" had the strongest influence on GPV, PI, WOM, and GT values, while "90% of the previous customers bought a sustainable cap" had the highest WTP. This aligns with Demarque et al. (2015), where social nudges with 70% and 90% had a strong effect on sustainable consumption. However, very strong social nudges can lead to psychological reactance, reducing effectiveness due to perceived threats to freedom and mistrust (Richter et al., 2018).

## 6. CONCLUSION

While this study aimed to examine an under-researched topic, several limitations need to be acknowledged. Nudging techniques should be tested in real-life settings, as purchase environments are more complex due to the presence of more stimuli that may alter consumers' decision-making processes (Melendrez-Ruiz et al., 2021). Another limitation is the focus mainly on the environmental impact of the fast-fashion industry. Roozen et al. (2021) noted that the fast-fashion industry violates many human and work rights, and it is important to test social nudges' effectiveness in reducing these practices. Hence, communication practices need to be tested to increase information transparency and promote ethical fashion product consumption (Williams & Hodges, 2020).

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# DIGITAL TRANSFORMATION OF THE GOVERNMENT: SIMPLIFICATION OF PROCEDURES IN GUATEMALA

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**Abstract:** *In this context of innovation, implementing a digital transformation strategy represents a great opportunity for organizations to increase productivity and thereby enhance their competitiveness; however, due to the complexity of its nature, the development of a digitalization program in public administration goes beyond technological aspects and involves the formulation of a comprehensive strategy that addresses multifaceted challenges. In search of improving the services provided to its citizens, a methodology has been developed in Guatemala to simplify procedures that has been applied in several public institutions, displaying positive outcomes. This approach can be extended to other digital transformation programs that aim to modernize government frameworks and meet the evolving needs of citizens.*

**Keywords:** *digital transformation, digital government, e-government, simplification of procedures, modernization of public administration*

## 1. INTRODUCTION

Transformation is a fundamentally human process and, as such, encompasses all areas of life in society. Civilization is evolving at an increasing pace thanks to the adoption of new technologies that have changed the way how we act and even how we think. We are facing one of the most dynamic transformation processes in history and, therefore, participating in the digital revolution is not only an opportunity but also a necessity for organizations to remain competitive. The shift of paradigms that the digitalization of society entails has also impacted public administration, forcing governments to adapt swiftly to meet the needs of their citizens, who demand faster and simpler processes, for which digital transformation is a crucial strategy. However, the complexity of governmental structure, as well as its regulatory framework, implies not only acquiring and installing technological tools but also developing a comprehensive strategy to implement an effective digital transformation program, ensuring above all that citizens are at the centre of the innovation process (Cubo, 2022).

Technological adoption has changed paradigms in the way society communicates, conducts commercial transactions, and accesses services, leading citizens to demand interaction with their governments through digital platforms. When properly adopted, Information and Communication Technologies (ICTs) have proven to be greatly beneficial in government institutions to become more efficient by streamlining and consolidating processes, eliminating obsolete and unnecessary activities, and defining single points of access to public administration. It has also helped to improve inter-institutional communication and coordination to address multidimensional problems and achieve government goals. Government modernization contributes to improving transparency by making processes visible and reducing arbitrariness in decisions; and allows obtaining information to understand appropriately how citizens approach and interact with institutions to provide them with a valuable service following their needs and expectations, being the completion of procedures the main reason to visit government offices.

Previous implementations of public administration modernization programs in the Latin American region have shown that governments that have best leveraged the opportunities offered by technological tools are those that have developed a comprehensive digital strategy (Organisation for Economic Cooperation and Development, 2016). However, developing an effective digital program also requires political will to ensure the commitment of all the stakeholders, as well as inter-institutional collaboration and coordination, which represents a great challenge in facing bureaucratic structures and outdated procedures present in many countries. Therefore, to implement an effective procedure simplification program in Guatemala that encourages transformation and innovation, a methodology has been developed that seeks standardized and collaborative participation from all the institutions involved, whose development and results will be presented subsequently. First, the background that inspired the simplification of procedures will be mentioned, to then

describe the developed methodology and the stages it comprises, and finally present and discuss the results obtained after its implementation, and the conclusions drawn.

## **2. PRELIMINARIES**

Procedures are the set of regulated processes through which users approach a public entity to obtain a result, which may be a right, a permit, or an obligation. Although procedures are services provided by the institutions to the population, they have traditionally been understood oppositely, with the population being obliged to comply with the established requirements and adhere to the bureaucratic processes of the entities. According to a study conducted in 2017, Guatemala was the Latin American country with the highest number of procedures managed by the central government, of which approximately half corresponded to registration and certification procedures (Inter-American Development Bank, 2018). The fact that there are so many procedures is due to multiple factors, such as duplication of functions, outdated and repetitive norms, unnecessary differentiation of activities, excess of requirements, and little effort to undertake modernization. The same study also mentions Guatemala as the third country in the region with the highest proportion of procedures requiring more interactions in state offices for their resolution and the sixth country with the lowest use of digital channels for the management of procedures.

The first measures taken in Guatemala for the digitization of public services began in the early millennium. In 2005, a single registry office was created to organize and centralize citizens' personal information, and three years later laws were enacted for the recognition of electronic signatures and access to public information. In 2011, Guatemala adhered to the International Declaration on Open Government and the following year a presidential commission was created to promote open and electronic government initiatives. In that same year, the National Development Plan K'atun 2032 was elaborated, which established in one of its axes the application of electronic tools to guarantee transparency, efficiency in services, and outreach to citizens (2014, p. 99). At the end of the decade, the initiative Guatemala Moving Forward was created through public-private alliances, in which one of its four strategic bets is to transform Guatemala into a 100% digital state by 2030 (2023, p. 37).

The pandemic impacted several critical areas for economic and social development, but it also accelerated digital transformation initiatives and made evident to the population the importance of technological applications to improve quality of life, among which the provision of public services is included. In 2021, the Digital Government Plan 2021-2026 was developed, which aims to improve the quality and efficiency in the provision of public services (2020, p.17); nevertheless, the major milestone was the enactment of the Law for Simplification of Administrative Requirements and Procedures, whose objective is to modernize government management by simplifying, accelerating, and digitalizing procedures, using ICTs to facilitate the interaction between individuals or legal entities and government agencies (2021, Art. 1), which establishes the formulation of a program to simplify all procedures of the Executive Branch and designates the Presidential Commission for Open and Electronic Government as the entity responsible for its fulfillment.

## **3. METHODOLOGY**

To carry out the program for simplifying government procedures, a methodology has been developed based on the content of the Law for Simplification of Administrative Requirements and Procedures and using as a reference the application of similar administrative simplification proposals made in other Latin American countries. This methodology is based on principles of process and project management and incorporates elements of digital transformation, information technologies, human talent, and continuous improvement. The methodology was designed to standardize the simplification processes of the Executive Branch institutions and to facilitate the advice and monitoring provided by the Presidential Commission for Open and Electronic Government as the coordinating and integrating entity of the program. This methodology consists of six stages that follow a logical sequence and can be adapted to the administrative management of each entity, which are: planning, diagnosis, redesign, implementation, evaluation, and continuous improvement.

### **3.1. Planning**

This stage aims to define the activities to be carried out, delimit the scope of the program, and guide the execution of subsequent stages. Its first step is to establish a simplification committee, which is the entity responsible in each institution for leading the efforts to plan, execute, and evaluate the simplification program. Additionally, a multidisciplinary technical team may be integrated to support the committee by executing the activities. The first action of the committee will be to prepare an inventory of procedures to establish the scope of work, identify all the procedures that the institution is responsible for, and determine the personnel involved, their legal basis, requirements, and information on the importance of the procedure. This information will serve as a basis for qualifying the level of importance of each procedure and selecting



priority procedures to simplify, which will receive greater resources and effort. Finally, a plan must be elaborated to execute the program in the institution, which defines its objectives, and addresses the stages of the process, with the work schedule, executors, expected results, and compliance indicators, allocating the necessary resources to develop the activities. This plan should be as detailed as possible, aiming to anticipate all possible problems and challenges that may arise during the program.

### **3.2. Diagnosis**

After identifying and prioritizing the institution's procedures, all necessary information will be collected to conduct a general diagnosis that helps to understand the initial situation of the procedures and identify the current issues. This involves exhaustive research that includes process mapping with execution times and personnel involved, legal assessment, evaluation of IT equipment and physical spaces, and the participation of other institutions in the process. During the diagnosis, the initial values of the indicators that will be used to measure operational management should be set up to evaluate the program's effectiveness. These indicators will be common for all institutions and will serve to evaluate the program for both the institutions and the Presidential Commission. Upon completion, an operational diagnosis is performed for each procedure, documenting each process, and diagramming its flow of activities, classifying activities according to their nature: operational, support, strategic, or measurement. Finally, a value analysis is conducted to identify activities that add value to the process from the user's perspective. For this, the criteria used to prioritize procedures may be used, as well as others related to process management.

### **3.3. Redesign**

The previous process analysis is the main input to redesign procedures, aiming to reduce the number of steps, time, and resources to those essentials, as established in their legal basis, and keep only the requirements outlined in current regulations and that provide valuable information that is not provided by other requirements or that the institution does not already possess. The redesigned procedure should use the most of ICTs to reduce transfer and control activities and avoid the physical presence of the citizen. Subsequently, the standards and procedures manuals must be updated, and the expected values in the indicators to assess the effectiveness of simplification must be defined. The redesign also includes a proposal for the acquisition and installation of new technological tools, as well as the adaptation of physical spaces; for this, it is important to evaluate the information and documentation management, especially in cases where large volumes of data need to be digitized. Likewise, it is important to evaluate cybersecurity to guarantee the integrity of systems and secure handling of information. The above considerations should be reflected in a training plan that focuses at strengthening the capabilities of staff, developing their technological skills, and, primarily, addressing change management. The redesigned processes will be integrated into a single final proposal that will be published through citizen participation mechanisms and presented to the main authority of the institution, who will analyse and approve it. Concurrently, the regulatory frameworks for the procedures must be updated to align with the new proposals and manage changes with the corresponding legal bodies.

### **3.4. Implementation**

After the redesign proposals are approved, the implementation begins with training of employees in areas directly or indirectly involved in handling procedures, following the designed plan. In addition, widespread dissemination of the new procedures throughout the institution should be carried out to promote organizational identity and a citizen-oriented work culture. Simultaneously, technological tools will be progressively installed, starting with the most important and resource-intensive activities, such as digitization of files, creation of databases, and implementation of document management, cybersecurity systems, and electronic payment platforms. After strengthening the technology infrastructure, electronic forms and service desks will be implemented and, afterwards, inter-institutional linkage instruments to ensure the interconnectivity of governmental systems. Finally, a public awareness campaign should be carried out, prioritizing dissemination to direct users, such as business associations, universities, public and private institutions, companies, associations, and union chambers, among others. This may be carried out through the institution's official communication channels, as well as other mass media channels, if possible.

### **3.5. Evaluation**

This stage aims to assess the results obtained, as well as the fulfilment of objectives in all stages. Therefore, it's crucial to establish adequate management indicators initially so that measurements can accurately determine the effectiveness of the simplification program for both the institutions and the Presidential Commission as the coordinating entity. This stage is divided into two activities: monitoring and evaluation. Monitoring takes place throughout the entire program and seeks to measure the progress of the program and weigh the results obtained in each of the activities, as established in the simplification plan. It evaluates both

program management and process deliverables, evaluated periodically to identify possible deviations and take corresponding corrective actions promptly. The evaluation is conducted upon completing each milestone in the simplification process, verifying the obtained results based on compliance with the established objectives. The management indicators used by the Presidential Commission to evaluate the efficiencies and improvements obtained are quantity of requirements, process activities, execution time, unit cost, executors, participating areas, and linked institutions. Additionally, the institutions may define other indicators for their internal evaluation and, also, must implement mechanisms for citizens to evaluate the management of the procedure and provide valuable feedback to improve the process.

### 3.6. Continuous improvement

Institutions are dynamic organizations that must adapt to the new circumstances of their environment, especially in the technological and organizational sphere, since new tools and management models are constantly emerging that can help provide more efficient services. Therefore, after completing the simplification of procedures, it is necessary to ensure the continuity of the program and its progress through a process of continuous improvement that ensures the sustainability of the innovation cycle. First, the simplification committee within the entity must be confirmed, which may keep the same organizational structure or be integrated into an institutional modernization team. During the execution of the program, self-assessment channels should be established to receive feedback from both citizens and collaborators, to identify opportunities for improvement. It is also essential to professionalize staff through training and education to foster an organizational culture open to change and innovation, involving managers and authorities, who will lead the processes of continuous improvement in their respective areas.

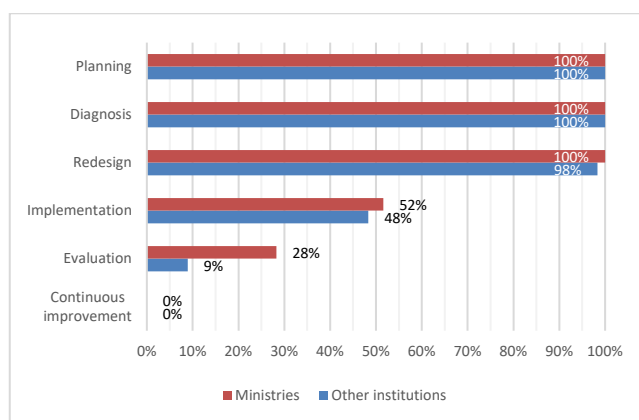
## 4. RESULTS

The execution of the simplification program began on 31 August 2021, in line with the Law for Simplification of Administrative Requirements and Procedures. This methodology has been implemented in 62 institutions of the Executive Branch, of which 14 are government ministries and 48 are other public institutions, such as secretariats, commissions, councils, and governorships. After all institutions completed the planning stage, 1760 procedures were identified in all entities, which were digitally published on a single platform containing the National Procedures Catalogue (NPC). Likewise, other inter-institutional portals were established to manage linked procedures between various entities and are available on independent web platforms.

**Table 1:** Procedures by type of institution.

Priority level	Ministries	Other institutions	Total
Prioritized procedures	924	112	1036
Non-prioritized procedures	538	186	724
<b>Total</b>	<b>1462</b>	<b>298</b>	<b>1760</b>

During the first two years of the program, the execution of the planning, diagnosis, and redesign stages was completed, as well as the implementation of electronic systems for prioritized procedures, which were supposed to be completed by 31 August 2023, according to the Law, granting an additional year to complete the program entirely. According to the monitoring conducted by the Presidential Commission in the 62 institutions working on the simplification program and the data provided by these, as of 31 March 2024, overall compliance with the implementation stage was 51%. Additionally, some institutions have conducted surveys of the citizens to evaluate the simplified procedures, which have shown approval of more than 90%.



**Figure 1:** General progress of the simplification program as of 31 March 2024.

To evaluate the results obtained in the simplification, a sample of 261 optimized procedures has been calculated, with a confidence level of 95% and a margin of error of 5%. By analysing the measurements provided by the simplification committees and verified by the Presidential Commission on the management indicators, when comparing their situation before simplification, established in the diagnosis stage, and after simplification, calculated after the redesign and validated in the implementation stage, the efficiencies achieved in the program have been rated. The general result of this implementation has been positive in all evaluated areas, with efficiency values ranging from 14% to 41%.

**Table 2:** Obtained efficiencies after simplification.

Management indicator	Average efficiency	Standard deviation
Requirements	14%	25%
Process activities	33%	36%
Execution time	41%	33%
Unit cost	26%	39%
Executors	27%	27%
Participating areas	17%	27%
Linked institutions	12%	32%

## 5. DISCUSSION OF RESULTS

After two and a half years since the launching of the program and having completed several stages of the simplification process, the results obtained during its execution have been positive. Although these results are partial because the deadline for the completion of the program has not yet arrived, significant results have been achieved with the simplified procedures and the actions carried out in organizational management. In total, 1760 procedures have been identified in the 62 institutions of the Executive Branch that provide direct services to citizens, of which 83% are carried out by the 14 government ministries. To focus the program's efforts on the most important services, the institutions have prioritized 58% of their procedures, which have been simplified first to maximize the impact of the process.

In compliance with the Simplification Law, in the first two years of program execution, the institutions developed their simplification plan and conducted the diagnoses and the redesigns of all their procedures, which were published digitally through the National Procedure Catalogue (NPC) and other inter-institutional portals related to various topics. With half a year remaining until the deadline for implementation, the institutions have reported a general progress of 51% in program compliance. Most of the necessary activities for the development of systems and adaptation of infrastructure, as well as for staff training, have been carried out; however, further progress is still needed in disseminating the simplified process and officially launching the new electronic systems and procedures, which is expected to be completed in the coming months. Nevertheless, the partial results have been positive, and this has already been perceived by the users, who have expressed their approval of the optimizations made in the simplified procedures.

Despite the positive results achieved, the implementation of the simplification process has not been easy in all institutions. Some of them, especially the ministries, have under their organizational structure some entities that in practice function autonomously and whose monitoring does not depend on the Presidential Commission, but on the central simplification committee of the entity. In these cases, joint support has been sought to guarantee the appropriate development of the different stages and compliance with the established objectives. In these cases, the worktables defined in the planning stage have been of great help to carry out the program in these sub-entities, which demonstrates the importance of observing appropriately each of the stages of this methodology, since the progress made in each stage facilitates the execution of the activities in the following ones.

When evaluating the measurement indicators, it is evident that efficiency has increased in all evaluated areas. With the simplification, a reduction of 14% in the requirements has been achieved, which represents on average the elimination of one document required from citizens per procedure. Likewise, the direct involvement of individuals in the management of procedures has been reduced by 27%, while the intervention of multiple organizational areas has been avoided by 17%, and the involvement of other institutions by 12%. Furthermore, savings of 26% have been achieved in procedure costs, which are crucial for the financial health of institutions, considering the annual increase in the volume of applications. However, the two areas where the greatest efficiencies have been achieved are the number of process activities and the time for their execution, with values of 33% and 41%, respectively, demonstrating the significant operational effectiveness achieved with the implementation.

## 6. CONCLUSION

In a global context of competitiveness and innovation, the implementation of Information and Communication Technologies (ICTs) in public administration constitutes an excellent strategy to increase productivity in organizational management, since it allows improving the quality of public services while contributing to enhancing efficiency and transparency in processes. However, developing a digital transformation program involves not only acquiring technology but also developing a comprehensive strategy to formulate an effective institutional modernization program. Within the framework of governmental digitalization promoted in recent decades and due to the enactment of the Law for Simplification of Administrative Requirements and Procedures, a methodology has been developed to standardize the simplification of procedures in the institutions of the Executive Branch, which consists of six stages: planning, diagnosis, redesign, implementation, evaluation, and continuous improvement.

After two and a half years of launching the simplification of procedures, positive results have been achieved in various areas despite the program not being completed yet. In the 62 institutions where the simplification process is being executed, the first three stages have been completed, and a general progress of 51% has been reported in the implementation stage. The 1760 procedures identified in all entities have been published electronically through the National Procedures Catalogue and other inter-institutional portals developed to facilitate citizen access. Furthermore, the evaluation of the process shows a general increase in efficiency in the management of procedures, as 14% of the requested requirements have been eliminated and direct intervention by individuals has been reduced by 27%, generating savings of 26% and significant improvement in operational management by eliminating 33% of the activities and reducing execution time by 41%, demonstrating the program's effectiveness.

Since the simplification process execution is still underway, management indicator values may likely change; however, the partial results currently presented by the program are encouraging and demonstrate the effectiveness of digital transformation initiatives in public administration. It is important to remember that this methodology has been developed as a dynamic process and includes a continuous improvement stage, so it does not end when reaching the deadline but rather remains over time in a cycle of constant innovation. Therefore, it is recommended to update the results of this study upon completing the first cycle of simplification and use them as a basis to compare future modernization processes. Likewise, comparing the results of this study with those obtained in other countries is recommended to adopt best practices and seek constant improvement of the developed methodology.

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# DIGITALIZATION AND E-HEALTH DISPARITIES IN DIFFERENT CULTURES

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**Abstract:** *The purpose of this research paper is to identify, highlight, and address the disparities or digital divide that exists within the health care cultures of different countries, contrasting the differences in the availability, accessibility and the coverage of advance automated medical health care equipment, facilities, and amenities. Comparison refers to Europe and Africa and their possibilities to achieve health care governance and sustainable goal 3 for good health and well-being of the human resource. Data from Serbia and Sierra Leone were used as case studies. The research includes an overview of the topic, literature review, SDGs 3 indicators, comparative analysis, conclusion and references.*

**Keywords:** *E-health, digitalization, digital divide, sustainable development, Serbia, Sierra Leone.*

## 1. INTRODUCTION

With immense reflection, it is true that technology has become the spinal cord of every aspect of life especially in the medical health care sector in these recent times. Ranging from ancient times when health care treatment was conducted manually on sick patients with magic and herbal remedies to the emergence of advanced digital and electronic health care treatment that is easier and less time consuming in the present information society.

Digitalization and E-health disparities in different cultures is concerned with the level of governance or coverage of automated health culture in both developed and developing or underdeveloped countries. The highlight of the digital divide that exists in the electronic medical health sector between Europe and Africa is as a result of the unavailability or inadequate and the availability or the accessibility to the human resource in Europe and Africa with the needed resources. "The causes of disparities include patients having difficulty navigating the health care system; doctor-patient communication difficulties due to language barriers or cultural beliefs; provider stereotyping of patients; patient mistrust of providers; family structure impacting patients' ability or desire to seek health care service; and beliefs about benefits of alternative or folk medicine that differ across racial and ethnic groups and impact upon health care utilization" (Saeed and Masters, 2001, Cooper, et al., 2002). In attempt to tackle these disparities brought about the formulation of the sustainable development goal 3 for the promotion of good health and well-being of the human resource that in order to breach the gap of access to digital and E-health care between developed and developing or underdeveloped countries it is needed to be implemented and achieved in full spectrum in developing and underdeveloped countries. The human resource is the most valuable asset in all sectors of life consisting of men and women, young and old, employed and self-employed who contributes to the economic, financial, development and entrepreneurial growth of a country. Therefore, humans need to be physically, emotionally, psychologically and medically fit or sustained to perform their functions in these sectors well to achieve all the sustainable development goals.

Prior to the concern and the well-being of the human resource, the medical sector is striving to achieve a global spectrum of universal health coverage through recent advanced technologies where electronic health care will be available and accessible to all countries whether in Europe or in Africa. But because of the economic financial breakdown and the lack of the needed resources makes it difficult to afford a wide range of universal health governance in Africa. With the digitization of the health and medical institutions will make it easier to diagnose, detect, track, trace, cure and prevent illnesses, diseases and stubborn health issues that are threat to the health and lives of the human resource. Custodio et al (2009) mentioned that "The role of information technology is to bring health services to remote areas in order to improve access to health care. IT is a vital tool in achieving the goals of health care reform to increase health care access, improve care delivery systems, engage in culturally competent outreach and education, and enhance workforce development and training."

## **2. LITERATURE REVIEW**

### **2.1. Digitization**

Dufva et al. (2019) explained that “Digitization is the action of transforming various physical or analogue actions into digital systems.” OECD (2019) “Digitization is the conversion of data and analogue processes into machine reading formats, i.e., 1 or 0, a format that can be read and processed by computers.” McAfee et al. (2017) mentioned that “digitization involves changes generated by the learning machines, platforms for creative thinking development (platform thinking) and crowd-based action.” Saldanha et al (2017) asserted that “Digitization appears to facilitate cooperation beyond organizational boundaries. Companies can no longer afford to rely on internal resources exclusively and, therefore, must open their organizational boundaries to engage with external expertise and skills.” Mammadli et al. (2020) explained that “Digitization may contribute to innovation or even be the main component in understanding how technology transforms the economy.”

### **2.2. E-health**

E-health has become an integral part of the health care system as it addresses a range of difficulties in medicine, including reducing errors and providing more efficient services with more accurate results. Such is the case with the use of electronic medical records, in which all information about a patient is stored, thus preventing inappropriate administration of medication during medical care and ensuring that the patient is treated quickly and comfortably. However, its implementation depends on adequate planning and strategies so that virtual medical care can be performed. “The success of e-health in a country is related to several factors, including user acceptance and the types of infrastructure, systems, and management used” (Collins 2021). According to Yang (2016) “E-Health serves as a basis for knowledge sharing, quality of service.” Da Fonseca et al (2021) “E-health can be defined as a set of technologies applied with the help of the internet, in which health care services are provided to improve quality of life and facilitate health care delivery.”

### **2.3. Digital Divide**

With an immense view on digital divide, clearly shows the gap or the void created between those countries in Europe that has access to all the needed resources used to achieve sustainable development and standard of living and those countries in Africa that does not have access to all the needed resources used to achieve sustainable development and standard of living. Nevertheless, “a digital divide is an economic and social inequality regarding access to, use of, or impact of information and communication technologies” (U.S. department of Commerce 1995). Hanna (2021) enacted that the digital divide is a term that refers to the gap between demographics and region that have access to modern information and communication technology (ICT), and those that don't or have restricted access. West (2011) analyzed that the digital divide is a simplistic phrase used to explain the gap between people who can easily use and access technology, and those who cannot. Mossberger et al (2003) conceptualized that “the digital divide consists of multidimensional aspects of technological inclusion: “an access divide, skills divide, an economic opportunity divide, and a democratic divide.”

### **2.4. Sustainable Development**

When we think about the phenomena “Sustainable Development” what comes to mind is identifying the constraints or roadblocks in the living conditions of the human resource by providing and maintaining the human needs and proffering solutions that will improve and sustain the standard of living of the human resource through the organized strategies and principles that aim at meeting the human development goals. According to De Neve et al (2020) the term sustainable development first entered mainstream policy cycles with the publishing of the Brundtland report in 1987, in which it was defined as development that meets the needs of the current generation without compromising the ability of future generations to meet their own need. The main aim for the introduction of the sustainable development goals is to end world poverty and hunger, address climate change and environmental protection, and ensure universal access to health care, education and equality. Dempsey et al (2011) mentioned that “sustainable development generally refers to achieving a balance among the environmental, economic, and social pillars of sustainability, the meaning and associated objectives of the social pillar remain vague.” Salas-Zapata et al (2011) elucidated that “The emergence of sustainable development as a political and social project of humanity has promoted the orientation of efforts in order to find ways for sustainable societies.” Handmer et al (1992) stated that “sustainable development is a way of international change and improvement that keeps or increases this attribute of the system meeting the needs of the population.” Pearce et al (1989) argued that “sustainable development requires policies that enable future generations to have at least as much wealth (or stock of assets) as the present generation received.”

## 2.5. The Human Resource

It is said that most successful business owner will go all out to safeguard their most prominent assets in their company which is the human resource. In this context, the human resource are men and women that are either employed and self-employed people working in an organization or any business establishment to earn a living, that has tendency to get sick, or develop any health issue during their term of work. Megginson (2024) defined Human resource as “the total knowledge, skills, creative abilities, talents, and aptitude of an organization’s workforce, as well as the value, attitudes, and beliefs of the individuals involved.”

## 3. CONTRASTING THE DISPARITIES OR DIGITAL DIVIDE BETWEEN EUROPE AND AFRICA

The medical health sector in Africa cannot be compared with the medical health sector in Europe as a whole. Africa lacks the most basic advanced medical health amenities considered as necessity in the medical health establishments in Europe to the extent that this is regarded as a digital divide between Africa and Europe causing a gulf towards achieving sustainable health development. Moreover, the health services in Sierra Leone is nothing to write home about as compared to Serbia. Sierra Leone lacks the necessary adequate quality electronic medical equipment such as Sphygmomanometer used for measuring blood pressure, the electrocardiogram monitors used for testing heart rhythms, ultrasound machines used for scanning internal organs of the human body to detect diseases or injuries especially for the purposes of conducting surgical operations, treatment, or other electronic health equipment and services in order to achieve a sustainable development goal and health care governance for good health and well-being of its citizens. At the other hand Serbia as part of Europe is well equipped with the most essential advanced medical electronic amenities needed to conduct surgical operations, treatment on medical patients, other health services and to achieve a sustainable development goal and health care governance for good health and well-being of their human resource. According to the results of the public opinion survey presented in Belgrade on the 2<sup>nd</sup> of June 2022 about two thirds of Serbian citizens believe that preserving a healthy environment is more important than the economic growth. (UNDP, 2022). The existence of the digital divide between Serbia and Sierra Leone reflects on the identified indicators that are yet to be eradicated if the sustainable development goal 3 is achievable.

The first indicator of the Sustainable development goal that reveals the disparities in health care culture between Sierra Leone and Serbia is Maternal mortality. Because of lack of advance automated medical equipment, amenities and facilities like electronic fetal monitoring, ultrasonography, blood pressure screening, maternal/fetal pulse oximetry, infusion pumps and many more in the hospitals and medical centers in Sierra Leone has caused high percentage deaths of pregnant women due to complications from pregnancy childbirth. Whiles Serbia medical hospitals are well equipped with the necessary advanced electronic amenities needed to prevent and control high maternal mortality rate in the health of pregnant women. Therefore, there is high death rate of pregnant women during labour in Sierra Leone than Serbia.

The second indicator is Neonatal and child mortality. Because of inadequate electronic medical facilities or amenities like oxygen incubators for babies, electricity and many more in the hospitals and health centers of Sierra Leone, many infant children or children less than 28 days old dies rapidly because they are not given the immense or the appropriate medical attention and treatment they need to get well. Whiles Serbia has all the appropriate automated medical amenities and facilities therefore, infant children that are sick are well cared for and given the appropriate treatment they need to get well.

The third indicator considered is Infectious diseases. These diseases include HIV/AIDS, hepatitis, waterborne diseases and many more. The existence of these diseases in Sierra Leone leads to the death of many men, women and children because some cannot afford the medical treatment and many family do not have medical insurance therefore makes it difficult to prevent and control these disease. Whiles in Serbia it is easy to prevent and control these diseases from spreading because patients have medical insurance and they are given the appropriate medical treatment for the well-being of the citizens.

The fourth indicator is Noncommunicable diseases. This involves illness like psychosis and neurosis or loss of memory (insanity or mental health issue), cardiac arrest and many more. Sierra Leone medical sector lacks the adequate digital medical health equipment like cardioverter defibrillator, biventricular pacemakers, cardiac loop recorders and many other that helps in detecting mental disorders in the brain and the level of mental disorder, and facilities to control and give the appropriate treatment to people or patients with mental health issues and other diseases, to help them regain their consciousness. Whiles Serbia’s medical sector has all the electronic health amenities or facilities and equipment to control and give the appropriate treatment their patients with cardiac arrest, mental health issues and many more.

As the fifth indicator analyzed is Substance abuse. This involves substances like narcotic drug abuse, harmful use of alcohol and many more. Sierra Leone has few or inadequate laboratories with advanced electronic or digital health devices to detect harmful drugs intake in the human body. While Serbia health sector has



adequate laboratories that are well equipped with advanced electronic or digital health devices that can detect harmful drugs intake in the human body.

The sixth indicator is Road traffic. Sierra Leone lacks every electronic equipment and proper traffic, road and transportation systems like adequate traffic lights to control road traffics and to prevent high numbers of deaths, accident injuries from road traffics. Whiles Serbia is very well equipped with all the electronic equipment and systems to control road traffics and to prevent high deaths and injuries as a result of road traffic. Therefore, their road or traffic systems are very organized.

The seventh indicator is Universal health coverage. Sierra Leone lacks Universal Health Coverage Services. The human resource in Sierra Leone has no access to full range of quality health care services like medical health insurance they need or electronic health insurance, when and where they need them. Reports shows that only 39% of the country has achieved universal health coverage within Sierra Leone. Whiles Serbia is well equipped with Universal Health Coverage Services. The human resource in Serbia has access to full range of quality health services they need like the electronic health insurance when and where they need them. Serbian citizens have free access to health care services. 98% of almost the entire Serbian population is covered by health insurance.

Finally, the eight indicator is Environmental Health. Sierra Leone faces unique environmental health challenges in various aspect which includes water pollution, diseases prevention, air pollution, and sanitation because of lack of good environmental health systems and electronic environmental cleaner equipment like street or road sweeper machines vehicles, street vacuum machines vehicles and many more. 16% population in Sierra Leone has access to basic sanitation services with 28% defecating in the open and 81% have no access to basic water services. Whiles in Serbia the Environmental health conditions 26% citizens worries the most about air pollution, 13% worries about the water quality and 12% worries about illegal dump sites. Therefore, Serbia has a good environmental health system compared to Sierra Leone.

#### 4. COMPARATIVE ANALYSIS

**Table 1:** Comparative analysis of SDGs 3 indicators between Sierra Leone and Serbia

Indicators	Siera Leone			Serbia		
	2015	2019	2021	2015	2019	2022
Maternal Mortality	6.51%	4.62%	11.65%	12%	6.2%	9.7%
Neonatal and Child Mortality	35.95%	34.1%	15.6%	6.7%	9%	5.8%
Infectious diseases	2.86%	5%	1.50%	12.2%	6.6%	2.64%
Noncommunicable diseases	70.2%	68.4%	18%	21.2%	21%	21.1%
Substance abuse	21.1%	3.91%	1.85%	52%	53.0%	53.5%
Road Traffic injuries	2.37%	1,918	27.3%	9%	8.2%	7.5%
Universal Health Coverage	93.3%	50%	39%	90%	91.8%	98%
Environmental health	10.5%	3.4%	1.25%	98%	25%	16%

According to the comparative analysis Serbia was able to have Maternal mortality control than Sierra Leone within 2015, 2019 and 2022/2021, Neonatal and child mortality in Serbia is lower than the Neonatal and child mortality rate in Sierra Leone within 2015, 2019, 2022/2021. Infectious disease is lower in Sierra Leone than in Serbia within 2015, 2019 and 2022/2021. Non-communicable disease is lower in Sierra Leone than in Serbia within 2015, 2019, 2022/2021. Substance abuse is lower in Sierra Leone than in Serbia 2015, 2019, 2022/2021. Road traffic injuries is higher in Sierra Leone than in Serbia within 2015, 2019, 2022/2021. Sexual and reproductive health care is better in Serbia than in Sierra Leone 2015, 2019, 2022/2021. Universal health coverage is well implemented in Serbia than in Sierra Leone within 2015, 2019, 2022/2021. Environmental Health care is much better in Serbia than in Sierra Leone 2015, 2019, 2022/2021.

#### 5. CONCLUSION

The possibility of attaining sustainable development of the human resource in Africa is very slow as compared to Europe. If strong strategies are not planned and implemented it will be difficult for Africa to achieve the 50 percent of the health and well-being indicators goals. Considering the aim of seeking balance in the achievement of health and well-being between Africa and Europe, the facilities, equipment, technologies, health inventions and sustainable resources need to be provided and made available in Africa. The research used available data to emphasize the created by the digital divide between Africa and Europe or Sierra Leone and Serbia in terms of advancement, technologies and sustainable resources.

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# ASSESSING ACCESSIBILITY OF ONLINE GOVERNMENT SERVICES IN SERBIA FOR VISUALLY IMPAIRED USERS

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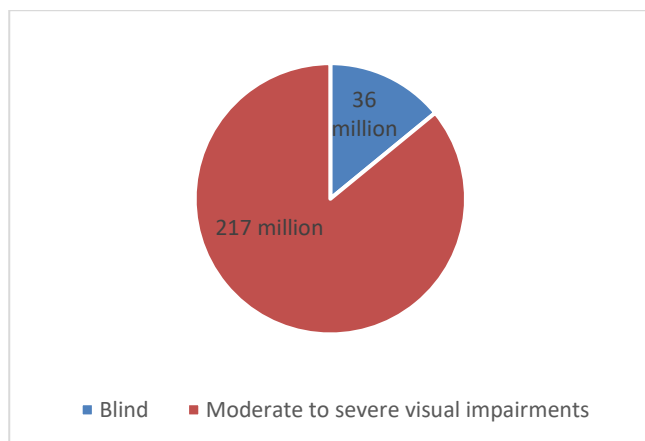
**Abstract:** *In the digital age, organizations must incorporate online platforms as a part of their operational activities. A website serves as a visual representation of an organization's expertise, utilizing eye-catching elements to captivate human attention and encourage interaction. However, this kind of user interface development strategy is not suitable for people with visual impairments, and therefore those websites might not be accessible to them. This paper analyzes and studies accessibility principles, standards, and existing regulations. The primary focus is on evaluating these practices in the design of a Serbian e-government website as a case study. The benefits and limitations of current practices were identified alongside the recommendations for user interface design improvements to enhance website accessibility, particularly for users with visual impairments.*

**Keywords:** *accessible websites, human-computer interaction, interface design, e-government, visual impairments*

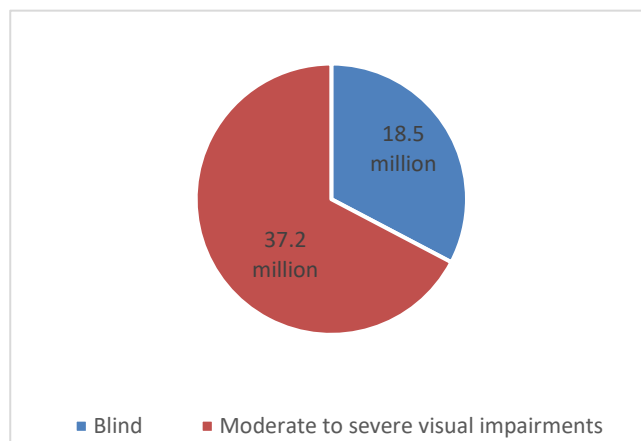
## 1. INTRODUCTION

With the increasing reliance on the Internet, particularly during and post the COVID-19 pandemic, the development and upkeep of web presence for any organization operating in the public domain have become essential. Websites typically rely on visual elements organized into a sophisticated structure to convey valuable information to users. However, not all users can access information in this manner, necessitating special attention during website development to ensure accessibility for those with visual impairments. According to Ackland et al. (2017), there were an estimated 253 million individuals with visual impairments in 2015 (Figure 1). Looking ahead, predictions suggest that by 2050, the total number of people with visual impairments will decrease to 55.7 million, but there will be a shift in the ratio between blind individuals and those with severe visual impairments (Figure 2), indicating a relative increase in the percentage of blind individuals (Fricke et al., 2018).

The data presented indicates the necessity for websites to cater to the current and forthcoming needs of users with visual impairments. The importance of addressing these challenges is recognized by the European Union, which has established a directive on website accessibility requirements that is still in the process of implementation (European Union, 2019).



**Figure 1 - Current ratio of people with visual impairments**



**Figure 2 - Predicted ratio of people with visual impairments by 2050**

This paper focuses on governmental services and websites, as access to such services is mandated by law in Serbia for all citizens, regardless of any disabilities they may have. According to Law on the Prevention of Discrimination against Persons with Disabilities (2016), a violation of the principle of equal rights and obligations occurs when an individual is unjustly denied rights primarily due to their disability, rights that are not denied or imposed on another individual or group in a similar situation. It is imperative that every citizen can exercise their rights without discrimination. In addition, in 2009 the Republic of Serbia passed the Law On The Ratification Of The Convention On The Rights Of Persons With Disabilities. Article 21 of the Convention (United Nations, 2006), states that the state will take actions that would lead to people with disabilities' freedom to seek and receive information equally to other people by using communication channels of their choice. A part of the defined actions is also a practice of providing information aimed at the general public in accessible ways and formats that would cater to the different variations of disabilities with no difference in time and cost of the obtained information. As of 2024, approximately twelve thousand people are living with visual impairments in Serbia (Union of the Blind of Serbia, n.d.), which accounts for around 0.1% of the total population, based on recent data from the Statistical Office of the Republic of Serbia (2022).

## 2. RELATED WORK

Accessibility encompasses the design and development of websites and tools to ensure usability for people with disabilities. Despite being highly recommended and even mandated by law in some countries, many government portals still face notable accessibility challenges. While web accessibility aims to facilitate website usage for individuals with disabilities, usability extends to ensuring ease of use for all users, irrespective of disability. Multiple studies have indicated a significant positive relationship between usability and accessibility scores. Adhering to the Web Content Accessibility Guidelines (WCAG) improves accessibility for users with disabilities and enhances the experience for all users.

(Hambley et al., 2022) introduced a new framework alongside WCAG Conformance Evaluation Methodology (WCAG-EM). (Bai, 2019) examined 342 US government online portals, finding an average accessibility score of 41/100 and a strong correlation between accessibility and usability. (Król & Zdonek, 2020) examined 182 Polish government websites, which collectively attained 57.23% of the available Aggregate Accessibility Rating points. (Csontos & Heckl, 2021) analyzed 25 Hungarian public sector websites, revealing none fully complied with WCAG recommendations and half exhibited only minimal usability compliance. (Valtolina & Fratus, 2022) investigated Italian municipal websites and developed a web application to aid in addressing accessibility issues, highlighting that solving several issues is not overly complex despite the generally low accessibility of municipal websites. (Kesswani & Kumar, 2022) compared the accessibility of government websites' home pages among G7 and BRICS countries, identifying significant compliance flaws related to robustness.

## 3. RESEARCH OBJECTIVE AND MOTIVATION

This study is motivated by the relatively limited exploration of website accessibility in Serbia. The objective of the research is to assess the accessibility of the Serbian e-government websites for users with visual impairments. The research delves into the fundamental principles essential for ensuring comprehension among blind individuals and those with severe visual impairments. Subsequently, an evaluation of how these principles are implemented on the Serbian e-government website is conducted. By exploring the regulations and guidelines outlined by standards and comparing them with the actual state of the website in the case study, this paper provides an analysis and critique of the applied (or lacking) accessibility principles. Where

violations or misinterpretations of accessibility principles are identified, corresponding advice or commentary will be provided based on the guidelines.

#### 4. TECHNIQUES AND GUIDELINES

The World Wide Web primarily caters to visual interaction, leaving visually impaired users relying on audio methods for accessing content at a disadvantage. While tools exist to assist, they often prioritize adapting content for devices rather than addressing user-specific needs, underscoring the importance of understanding users' behavioral strategies to enhance web accessibility (Lunn et al., 2011). The accessibility point of view should be considered from the start of the analysis and the development process, but it is also possible to upgrade an existing website by adding certain features. As Brown (2024) indicates, content compatibility with screen readers depends on clarity and simplicity, adhering to standard language conventions, and avoiding complex formatting. Additionally, it highlights the intricacies of the English language, where identical spellings can yield different pronunciations.

Designing visual elements with alternative text and descriptive labels is a convenient way of communicating the structure and content of the website to people with visual impairments. As a part of Web Content Accessibility Guidelines, the main principles for ensuring web accessibility are (Kirkpatrick et al., 2023):

- Perceptible - users should perceive information without effort and interface components are supposed to be designed in such a way.
- Operable - the interface should be usable by all users without requiring interactions beyond their abilities.
- Understandable - users need to understand both the information displayed and the functionality of the user interface.
- Robust - content should be reliably interpretable by various user agents, including assistive technologies, ensuring consistent accessibility despite technological advancements.

The guidelines, situated under the principles, offer fundamental objectives for authors to enhance content accessibility for users with diverse disabilities. While not directly testable, they furnish a framework to grasp success criteria and improve technique implementation. There is also a testable success criterion for each guideline in WCAG 2.1 to enable its application in various scenarios, including design specifications, procurement, regulations, and contracts. The defined conformance levels—A, AA, and AAA—cater to diverse needs. The three levels of conformance signify escalating accessibility standards, each tackling more advanced requirements to ensure web content accessibility for users with disabilities. However, enforcing Level AAA conformance for entire sites is discouraged due to practical constraints.

Techniques provide precise instructions for authors and evaluators to meet WCAG success criteria, offering code samples, references, and assessments. According to Kirkpatrick et al. (2023), these techniques are divided into three categories: sufficient techniques, advisory techniques, and failures. Sufficient techniques provide reliable methods to meet success criteria. By correctly implementing these techniques, authors can ensure compliance, contingent upon accessibility support for their audience. Advisory techniques offer recommended approaches to enhance accessibility, catering to various users' needs and providing alternative access methods for certain content types. Authors are encouraged to implement these techniques to ensure inclusivity across diverse user requirements. Failures represent accessibility barriers that cause content to not meet specific success criteria. They serve as valuable guidance for authors, helping them understand what to avoid, and for evaluators, aiding in checking content compliance with WCAG success criteria.

In addition to this, common methods for accessing and interacting with the web include assistive and adaptive technologies. Assistive technologies encompass software and hardware solutions utilized by individuals with disabilities to enhance their web interaction. Examples include screen readers, which audibly relay webpage content, screen magnifiers, and voice recognition software. Adaptive technologies are utilized by individuals with disabilities to enhance their experience on the web. They range from simple adjustments like increasing text size to more complex tactics such as enabling captions. Adaptive strategies may involve standard software, mainstream web browsers, or specialized assistive technologies.

During crises like COVID-19, integrating intelligent personal assistants (IPAs) can notably benefit individuals with intellectual disabilities. Technological advancements and increased affordability have made IPAs more accessible, potentially enhancing overall well-being. Popular options like Amazon Alexa and Google Nest/Home offer diverse input methods and employ machine-learning techniques to improve functionalities such as speech comprehension and usability (Van Wingerden et al., 2023).

WAVE is a suite of evaluation tools aimed at enhancing web content accessibility for individuals with disabilities. It identifies a wide array of accessibility errors while adhering to the WCAG, emphasizing human evaluation to directly address issues affecting end users. Prioritizing user impact and fostering education on web accessibility principles are central to their approach.

Advancements in technology allow us to cater to all users visiting websites or applications. Platforms like Frontend Masters offer comprehensive resources for developers to learn how to address disabilities and create inclusive digital products. Developers find numerous courses on website accessibility, covering topics like color contrast and integration tactics. UX and Product Designers face challenges with vast accessibility guidelines, including clear link text and minimizing color reliance, sometimes lacking clarity on balancing accessibility with aesthetics. The Perkins School for the Blind is committed to ensuring website accessibility for all visitors, including those with visual impairments, by adhering to the WCAG, level AA criteria. Their ongoing efforts focus on enhancing website accessibility for individuals of all ages, abilities, and means of access.

## **5. CASE STUDY OF E-ADMINISTRATION OF THE REPUBLIC OF SERBIA**

Many countries have devoted considerable effort to enhancing accessibility in the IT industry and e-business, reflected in the proliferation of directives and legislation. Detailed guidelines for website accessibility, regularly updated to incorporate technological advancements, are outlined in (Kirkpatrick et al., 2023). Furthermore, the World Wide Web Consortium's Web Accessibility Initiative provides standards and support materials to aid developers in crafting inclusive websites (World Wide Web Consortium, n.d.).

As highlighted, web accessibility is essential for enabling effective internet interaction for individuals with disabilities, yet numerous sites remain inaccessible due to design deficiencies. Despite these challenges, individuals with visual impairments rely on the web daily (Van Deursen & Van Dijk, 2016). For web designers, this implies that approximately 10% of site visitors may encounter difficulties in perceiving colors normally. People with low vision can perceive colors but face challenges such as poor acuity, tunnel vision, central field loss, or clouded vision (Byun & Finnie, 2011). In UX design, catering to users with visual impairments is paramount, with a set of standards derived from WCAG guidelines offering actionable strategies for designers to prioritize assistance and ease of use for them (DeWitt, 2010).

Serbia's e-government website for administrative and governmental activities was approved for development towards the end of 2006 (Vidas-Bubanja, 2011). Since its inception, numerous functionalities have been incorporated, such as scheduling appointments for passports, and ID cards, requesting certificates, electronic signatures, school and kindergarten applications, and tax information, among others. Adhering to the standards delineated in (Kirkpatrick et al., 2023), several measures were undertaken to assess the website's accessibility for all users, including a comprehensive examination of their implementation in Serbian sites to ascertain their effectiveness and applicability within the context. Kirkpatrick et al. (2023) emphasize the importance of catering to individuals with visual impairments, which is particularly relevant to enhancing online government services in Serbia. Within the case study, certain aspects, such as text color and fonts, are consolidated into a single category, mirroring the presentation referenced research.

### **5.1. Logging into the platform**

Information such as legal process descriptions, important dates, or contact numbers can be accessed on the website without requiring users to create an account or sign in. However, most actions are restricted to logged-in users, as they involve private data. The registration process is straightforward and comprehensive. A potential accessibility challenge arises during the account creation process, where users are required to upload a photograph of their identity card or passport, posing difficulties for blind or visually impaired individuals. An alternative solution and suggestion for improvement could involve a secure video call, wherein an agent verifies the user's identity based on system data and information provided during the call, along with video footage of the user displaying their ID.

### **5.2. Text-to-speech option**

Inclusive web design is essential for accessibility, particularly for visually impaired users who rely on screen readers. Clear labeling of links and buttons facilitates easy navigation, and understanding how screen readers convert web content into audio is crucial for compatibility.

While the e-government website has implemented text-to-speech software in Serbian on most pages, it's not consistently available across all of them. For instance, the landing page lacks a text-to-speech button, making it challenging for users to access pages that offer this option. The voice reading of the website's content is

comprehensive, but pronunciation may not always adhere to Serbian grammar rules, and duplicate readings of lines can confuse. Moreover, there's no differentiation between English and Serbian words in pronunciation, leading to comprehension issues, especially for words like "ConsentID." Skipping certain parts of the content without using a mouse is not feasible, posing difficulties for visually impaired users, particularly when navigating lengthy pages with extensive lists of services. Similarly, adjusting playback speed requires accessing a sub-menu, which is only accessible with a mouse, further hindering accessibility. Text-to-voice choices correspond with WCAG success standards connected to offering substitutes for non-textual elements (Success Standard 1.1.1) guaranteeing harmony with assistive tools (for example Success Standard 4.1.2) and aiding in navigation and direction (Success Standard 2.4.5).

### **5.3. Contrast and font adaptability**

In digital design, it's crucial to avoid relying solely on color, as this can pose challenges for colorblind users. Including underlining for alerts, links, and buttons aids in accessibility. Ensuring adequate contrast through careful color and texture selection is vital, particularly for individuals with visual impairments. Integrating textures or patterns into graphs can help distinguish data points, aiding those with color blindness. Limiting the number of colors in the interface improves usability, as an excess of colors can be confusing for users. Adjusting the contrast intensity on a webpage can assist people with partial visual impairments in viewing the content more clearly. Success Criterion 1.4.6 (Enhanced Contrast) mandates a higher contrast ratio of at least 7:1 for most text and images of text, compared to the 4.5:1 requirement in Success Criterion 1.4.3 (Minimum Contrast), which is more stringent for ensuring readability. However, the current version of the website does not support this option, providing the same view for all users.

High contrast intensity may feel unnatural for those with regular vision, so offering an option to adjust this setting in a dedicated place on the page could enhance the experience for people with partial visual impairments. Similarly, font size adjustment is missing from the website, with the only option being to use the browser's zoom feature. Enabling manual font size adjustments, such as through a slider or button, is essential for visually impaired accessibility. This provides a more welcoming experience, especially for older users with declining vision who may not use specialized tools. Offering manual font size adjustments is crucial for enhancing website accessibility on content-heavy pages.

### **5.4. Keyboard as a navigation tool**

Keyboard accessibility, including shortcuts, is essential for facilitating easier navigation, particularly for visually impaired users relying on screen readers. This enhances browsing without necessitating hand-eye coordination. Effective content scanning relies on screen reader support for navigating between headings to access key information, underscoring the importance of descriptive headings to facilitate accurate navigation. Clear page titles benefit all users, as screen readers announce them upon loading, aiding visually impaired users in quickly understanding the page's topic or purpose and saving valuable time typically spent scanning for content details.

It's worth noting that the website enables keyboard navigation, allowing users to select all options on the landing page. However, drop-down menus are inaccessible for selection via keyboard, as the page refreshes when the drop-down menu is chosen. Additionally, the presence of a slider—featuring sliding images with associated buttons, links, or text—is not conducive to keyboard navigation, as users may not have enough time to read the content before it transitions to the next slide, potentially confusing. Keyboard navigation aligns with WCAG Success Criterion 2.1, ensuring that users can access all content functions using only the keyboard without needing to press keys within specific timeframes.

### **5.5. Alternative text for images**

Including alternative text for images is crucial, as screen readers announce them, skipping those without it. Concise descriptions should be used for video and audio content, using clear language in both text and alternative text to effectively convey the message. Describing images in alternative text is essential for communicating the information they represent to individuals who cannot see them clearly or at all and ensuring accessibility.

## **6. CONCLUSION**

Significant progress has been made in the field of human-computer interaction, particularly concerning accessibility, but there's a need for a more thorough application of developed tools and techniques, especially within governmental administration websites. Innovative methods should be mandated by laws and regulations to ensure that accessible design becomes a standard requirement rather than an option. The key principles outlined in accessibility guidelines have been shown to elevate website accessibility levels.



The software solution implemented on the e-government website in Serbia has greatly impacted the daily lives of visually impaired individuals, streamlining administrative tasks that can now be completed from home. While the website developers have adhered to certain accessibility principles during its design, there are still instances where obtaining desired information comprehensively, or at all, remains challenging. The implemented improvements are still not fully utilized. Although the text-to-speech option is available to assist visually impaired users, it is not accessible on all pages. The same applies to keyboard navigation. Additionally, the speech option could be enhanced to include clearer language and better-suited pronunciation for the Serbian language. Introducing color and font size adjustments would benefit not only visually impaired users but also regular users, particularly elderly people with declining vision.

This paper has identified both positive and negative practices on the website and has proposed actionable solutions to enhance its accessibility for users with visual impairments. The research has several crucial implications for enhancing the accessibility of online government services in Serbia. Identifying and addressing existing accessibility issues can create a more inclusive and user-friendly experience for visually impaired users, allowing them to access essential government services without unnecessary barriers. The findings can also inform policymakers about the current gaps in accessibility and the need for stricter regulations and guidelines to ensure all government websites meet accessibility standards. Evaluating the Serbian e-government website provides a benchmark for future improvements of other Serbian websites. The suggested improvements will benefit not only visually impaired users but also the elderly and others with declining vision or reading difficulties. Aligning with international accessibility standards, such as the WCAG, the research helps Serbia move towards global best practices and ensures compliance with potential future European Union directives. Ultimately, the research supports the broader goal of social inclusion, ensuring that all citizens, regardless of their physical abilities, have equal access to government services and information.

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# EDUCATIONAL PATHWAYS TOWARDS SUSTAINABILITY: STUDENT LITERACY IN ENVIRONMENTAL STUDIES

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**Abstract:** *In this paper, the authors investigate the environmental literacy among students at the University of Belgrade - Faculty of Organizational Sciences, Serbia. The reason for this research lies in the fact that the way to a more responsible and sustainable world of today and tomorrow is based on environmentally literate and educated experts and decision-makers who could face the growing environmental problems of nowadays. This research emphasizes the need to include extensive environmental education within Bachelor of Science programs with the goal of increasing students' understanding, accountability, and active involvement in environmental sustainability. The findings enriched the discussion on environmental education and education for sustainable development by providing valuable information for educators and policymakers looking to improve the status of environmental literacy at higher education institutions.*

**Keywords:** *Environmental literacy, environmental education, sustainable development, higher education*

## 1. INTRODUCTION

Thanks to the actions of the human species, the natural balance of Earth is in jeopardy today more than ever (Petrović, 2016). Also, “humanity has become a dominant force in shaping the face of Earth” (Elhacham et al., 2020; Haff, 2014; Krausmann et al., 2009; Matthews et al., 2000; Smil, 2012; Stephens et al., 2019; Zalasiewicz et al., 2019). For this reason, scholars like Crutzen and Stoermer (2000), Steffen et al. (2007), Scholz (2011), and Huang and Xiao (2017) have named the current epoch the Anthropocene (Ha et al., 2021). According to the UN global assessment study, the destruction of nature has accelerated over the past 10 million years, resulting in coral reefs flickering out under the oceans and rainforests drying into savannahs (Watts, 2021). According to the author Robinson (2024), among the most significant environmental issues of our day are “global warming from fossil fuels, poor governance, food waste, biodiversity loss, plastic pollution, deforestation, air pollution, melting ice caps and sea level rise, ocean acidification, agriculture, food and water insecurity, fast fashion and textile waste, overfishing, cobalt mining, and soil degradation”.

Having in mind that environmental education (EE) is one of the most efficient approaches to preparing young people for the world's ever-changing environmental issues (Borojevic et al., 2014; Radaković et al., 2017), the authors of the paper conducted research on the level of environmental literacy (EL) among undergraduate students at the University of Belgrade - Faculty of Organizational Sciences, Belgrade, Serbia. Why is EL so important? This is because establishing integrity in human-nature relationships is critical to the survival and growth of our civilization. As a result, we must learn about life-sustaining ecosystems and how they work, as well as about ecology and environment, which are the bases of EL. It is important to recognize that EL significantly contributes to the SD of global society (Ha et al., 2021).

The presented research in the paper included 265 students aged from 20 to 31 years old. Students were requested to respond to a 32-item online survey. All responses are provided voluntarily and in an anonymous manner. The responses were then tested for assessment using SPSS 26 software package.

The paper is structured into the following subsections. We present a theoretical framework concerning environmental literacy in Section 2. Methods and materials are detailed in Section 3. The survey results are presented and discussed in Section 4, while the conclusions are presented in Section 5.

## 2. ENVIRONMENTAL LITERACY

Etymologically, “literacy” comes from a word used in the eighteenth century to characterize basic reading and writing proficiency (Stibbe, 2009). These days, literacy includes studies in media, politics, and science (Maurer & Bogner, 2020).

Charles Roth (1968, 1992) was the first author to use the term “environmental literacy” for his studies about comprehending environmentally literate individuals. Since then, scholars have extensively examined and undergone significant changes to the definition of EL (McBride et al., 2013; Morrone et al., 2001; Simmons, 1995). The North American Association for Environmental Education (NAAEE) currently provides a widely accepted and frequently applied definition of EL: *EL encompasses skills, knowledge, and a motivation to address current environmental issues to prevent the emergence of future ones* (Education, 2022; Ha et al., 2021; North American Association for Environmental Education [NAAEE], 2004; Scholz, 2011). To the defining of EL should certainly be added a definition of the authors Maurer and Bogner (2020) who “viewed environmental literacy as a concept that integrated cognitive knowledge, environmental values, and ecological behavior” (Liu & Tobias, 2024).

What is certain is that:

- EL is crucial for preventing current and future environmental issues and promoting sustainability (Biswas, 2019).
- EL aims to promote sustainable behavior (Chepesiuk, 2007).
- Environmentally literate citizens are more likely to actively participate in addressing global environmental issues (Moseley, 2000).

When it comes to the components of EL, according to the authors Hollweg et al. (2011), there are four of them: “knowledge, affect, cognitive skills, and behavior”, or according to NAAEE (2011) they are: environmental knowledge, attitude, and environmental concern.

The EL aspects are given in Table 1.

**Table 1:** EL aspects\*

Number	Dimension	Aspect
1	<i>Knowledge</i> (McBride et al., 2013; NAAEE, 2011)	a) <i>Environmental knowledge</i> b) <i>Socio political knowledge</i> c) <i>Knowledge of environmental issues</i>
2	<i>Attitude</i> (Ajzen, 2001; Dunlap et al., 2000; Erdogan & Marcinkowski, 2015)	a) <i>Environmental sensitivity</i> b) <i>Motivation and intention to act in participating actively towards environmental protection and improvement</i>
3	<i>Concern</i> (Hesham & Dajeh, 2011; McBride et al., 2013)	a) <i>Response towards environmental problem</i>

\*Based on the works of Meilinda et al. (2017)

## 3. MATERIALS AND METHODS

For this research, the authors surveyed 256 students at the University of Belgrade – Faculty of Organizational Sciences. The research sample comprised out of 53.1% females and 46.9% males, the youngest participant was 20 years old, the oldest was 31, and the mean value of participant’s age was 22.18, while the biggest portion of participants were 21 (37.1%). Most of the students were in their third year of studies – 63.7%.

The collected data was analyzed using IBM SPSS Statistics 26 to gain insights into the patterns of responses. The primary analytical methods were descriptive statistics, including frequency distributions and crosstabulation. To determine the relationships between categorical variables, the chi-square test of independence was applied. A p value is used to indicate if the difference between two groups (or relationship between two variables) are statistically significant (where  $p < 0.05$  is considered statistically significant at the 95% confidence level). The significance and strength of associations between different variables within the dataset were assessed, thus providing a comprehensive understanding of the survey results.

The first four questions were demographic, the following three were about general environmental behavior, and after that the questions were divided into three sections – knowledge and awareness (13 questions), attitudes and feelings (seven questions), and environmental activism (five questions) – totaling in 32 questions.

## 4. RESULTS AND DISCUSSION

One of the initial questions in the questionnaire was the frequency at which students engage with environmental issues and news, whether it be on a daily, weekly, monthly, rare, or nonexistent basis. Most students (33.2%) said that they read daily, followed by those who do it weekly (30.5%), while just 18.8% of students rarely engage in environmental news. Unsurprisingly this younger generation reported that they mostly inform themselves on social media (41% and more females than males,  $p < 0.05$ ), followed by online portals (33.2%), while only a small portion of students watched documentaries (male students showed an inclination towards documentaries,  $p < 0.05$ ) and listened to podcasts – 13.3% and 9.4% respectively. For these youths, the social media they use the most is Instagram with 60.2% of respondents, then TikTok (18%), while only 7.8% use X (formerly known as Twitter) and 2.3% Facebook. When it came to traditional, and maybe “old school” ways of acquiring information, only 1.6% of students said that they read newspapers and textbooks (no females read textbooks) when wanting to inform themselves on environmental issues.

### 4.1. Knowledge and awareness

This section was comprised of 13 questions meant to evaluate the students' knowledge about environmental issues, ecology in general, and sustainable development. The first question was the students self-reporting and self-evaluating their environmental knowledge on a 1 to 5 Likert scale (1 – very poor, 5 – excellent). Most of the students self-evaluated themselves with a mark of 3 (55.9%), followed by a mark of 4 (27%). This suggests a recognition of some understanding but also an acknowledgment of gaps in their knowledge.

However, even though students felt that they deserved a mark of 3, a mark usually interpreted as “neither here nor there”, 91% of students answered correctly to the question “What is climate change?”. The data indicates a strong correlation between higher self-ratings and the belief that climate change is a result of significant long-term effects in the Earth's temperature (the correct answer). Conversely, less defined, or skeptical views on climate change correspond to lower self-ratings of students.

When asked to rate a series of sentences on their degree of agreement with them, using a Likert scale from 1 to 5 (1 - strongly disagree, 5 – strongly agree), the students gave the following answers:

- “Human actions are contributing to atmosphere and climate change”. The statement received strong agreement (categories 4 – 26.2% and 5 – 61.3%) from most respondents. Among females, there was a particularly high level of agreement with 96 out of 131 respondents strongly agreeing. Most respondents (70.5%) who acknowledge all the mentioned implications of global warming strongly agree that human actions are contributing to it. This suggests a strong connection between their comprehension of human involvement and the wide-ranging effects of global warming. A large majority of respondents who understand climate change also strongly agree (69.4%) that human actions are contributing, showing a clear link in their understanding of human impact on climate.
- “Maintaining biodiversity means maintaining the number and variety of living organisms. This is necessary for sustainable development” - a significant proportion of responses fell into marks 4 (32.4%) and 5 (40.2%). There is a notable disparity in the number of “disagrees” (mark 2) between females and males. Specifically, no females disagreed, whereas 8 males did. Females exhibit a higher prevalence of strong agreement compared to males ( $p < 0.05$ ), indicating a little greater conviction regarding the significance of biodiversity among female respondents.

Other sentences that the students were meant to mark on a Likert scale and their mean values are the following:

- “Reducing the use of internal combustion engines helps reduce air pollution” – 3.86.
- “Using pesticides/fertilizers contributes to air pollution” – 3.92.
- “Human actions are contributing to atmosphere and climate change” – 4.54.
- “Maintaining biodiversity means maintaining the number and variety of living organisms. This is necessary for sustainable development” – 4.12%.

- “Sustainable development requires that individuals reflect on what it means to improve quality of life” – 4.18.
- “Good citizenship and good governance are necessary for sustainable development” – 4.34.
- “The conservation of drinking water is necessary for sustainable development” – 3.99.
- “Sustainable development requires a change in the use of renewable resources as much as possible” – 4.31.
- “Sustainable development requires access to quality education for everyone” – 4.22.

## 4.2. Attitudes and feelings

This section of the questionnaire included a series of 7 questions intended to assess students' attitudes and sentiments toward ecology and the environment to delve into their perceptions, convictions, and affective reactions towards environmental matters.

The students were first asked to rate the current state of the environment in their opinion on a Likert scale of 1 to 5 (1 – very poor, 5 – excellent). The results were a mean value of 2.38. Then they were asked to compare and evaluate the state of the environment 50 years ago on the same Likert scale and their expressed mean value was 3.18, showing that even though they personally feel that the state of the environment a long time before they were born was also poor, they at the same time believe it was better than today. Men were marginally more inclined than women to hold a moderately unfavorable perception of the previous status of the environment (mark 2). Women exhibited a greater prevalence in the neutral category (category 3) in comparison to men. A minority of respondents have a highly favorable perception of the previous environment (5 - excellent), with a higher proportion of males than females holding this perspective.

When asked whether they believed that the activities of an individual can have a positive/negative effect on the future of Planet Earth, most students answered yes – 85.9%, while 6.3% said no, and 7.8% said they were not sure. Interestingly enough, out of these students, the ones who said that they believed one person impacts leave an effect on the future of the Planet also said that they get informed about environmental issues through social media. This potentially means that since they are more exposed to seeing individual environmental activists on social media, they at the same time gain stronger beliefs that activism does matter. At the same time, many students who were unsure about the importance of individuals were podcast listeners.

One of the more important questions were on the feelings that the students felt regarding the environment and the Planet – the level of worry they feel about the environment impacting their future, their perceived pessimism or optimism about the future, and the most important environmental issues of today according to them.

When asked to rate how worried they were about the future of the environment impacting their personal future on a Likert scale of 1 to 5 (1 – not at all, 5 – extremely) the mean value of responses was 3.88 showing a moderate worry. At the same time women exhibit a greater level of concern, as seen by a larger percentage indicating they are “very worried” (51.9%) or “extremely worried” (34.35%). Males are also “not worried at all” or “slightly worried,” which was not reported by females.

Regarding the students' pessimism or optimism about the future of the Planet on a Likert scale (1 – pessimistic, 5 –optimistic), the mean value of responses was 2.49 showing a very pessimistic outlook of the younger generation. Females generally exhibited a higher inclination towards pessimism compared to men, with a majority falling into the “very” and “somewhat pessimistic” categories (64.9% of females,  $p < 0.05$ ), while males exhibit a higher propensity for being categorized as “very optimistic”, in stark contrast to the relatively smaller percentage of females who are very optimistic (15.7% men versus 3% women,  $p < 0.05$ ).

According to students, air pollution is the number one pressing environmental issue of today (32%).

## 4.3. Activism

The final section of the questionnaire was meant to determine the scale of environmental activism among the students. Out of the surveyed students, 19.7% of them said that they feel that they are environmentally active, 60.9% said they are somewhat active, and 19.4% said they are not active. Out of these answers,

more females answered that they are active than males ( $p < 0.05$ ). As the level of their worry for the future of the Planet increases, there appears to be a trend toward higher activity levels.

When asked whether they recycle – 17.9% students said that they do, 70.7% said that they recycle sometimes, and 11.4% said that they do not recycle. When comparing the students who said that they believe that the activities of an individual matter when it comes to the future of the Planet with the students who recycle, the results showed a strong correlation between belief in power of an individual and proactive recycling habits.

Asking the students to report the environmental actions they participated in the last year and asking them to circle multiple answers (in this case total percentage goes over 100%) these were their answers: recycling – 76.3% of students, attending protests or rallies – 16.5% of students, donating to environmental organizations – 17% of students, and volunteering for environmental causes – 26.3%.

It is evident that students do not participate in environmental activities enough, but when posed with the question why, they said that it was because of lack of time (40.2%), lack of information (33.5%), skepticism about effectiveness (13.4%), and financial reasons (12.9%). When compared by genders ( $p < 0.05$ ), the primary reason mentioned by females for not engaging in environmental activism is a lack of time, but males commonly cite skepticism regarding effectiveness as their main reason.

When asked what types of support or resources would encourage them to participate more in environmental activism, the students said the following (multiple choice, percentage  $> 100\%$ ): more information and education – 60.3%, organized events and activities – 50%, community support groups – 32.5%, incentives (tax reductions, subsidies) – 28.4%.

## 5. CONCLUSION

Unsurprisingly this younger generation reported that they mostly inform themselves on social media way more than they use traditional ways of acquiring knowledge. At the same time, almost no students used textbooks when wanting to find out more about environmental issues. This means that the future of higher education is somewhere between using social media and traditional ways of learning. For the educators to better appeal to younger generations they must accompany this shift to social media and the youth's way of thinking.

The students surveyed for this research gave themselves a mark of 3 when self-evaluating their environmental and sustainable development knowledge. Does this mean that the students' objective knowledge is somewhere in the middle – passable but not perfect? Does this mean they do not value themselves high enough subjectively? This is an issue that needs to be addressed in future research that will get to the bottom of this phenomenon. Positively, almost all students knew precisely what climate change was and what its consequences on the environment were.

The results indicate that students' minimal involvement in environmental activism is primarily a result of time constraints and restricted access to information. To enhance their level of participation, they express a need for additional educational opportunities and well-structured events that promote active involvement in environmental initiatives. Curiously, financial incentives are deemed unnecessary, perhaps because many students do not have substantial financial obligations. This suggests that the emphasis in promoting student involvement should be on providing educational assistance and well-organized programs rather than offering financial incentives.

As a conclusion, the authors would like to point out again that the students who used Instagram for their environmental news, believed more that the actions of individuals impact the state of the environment, and that environmental activism is making a difference. Is this because they watched videos of people working hands-on on environmental issues? This is a topic that opens many doors to educational opportunities as well as a means for inspiring the younger generation to make this world a better place, which, after all, is the most important thing we can strive to do.

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# ENHANCING BUSINESS AND ENERGY EFFICIENCY WITH ENERGY PERFORMANCE CONTRACTING

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**Abstract:** *Energy Performance Contracting (EPC) is a goal-driven strategy that facilitates the financing and implementation of energy-efficient technology to enhance business efficiency. The paper examines the main factors that affect the success of a project in the EPC business, including future maintenance and operating expenses, the performance of energy-saving methods, and shifting energy prices. The highlighted concept is a contractual agreement between energy service providers and clients in which one or more energy-related functions are delegated to a third party. The role of Energy Service Companies as undertakers of projects' energy efficiency is presented. The paper proposes that the primary objective of EPC is to minimize the cost of delivering energy services, allowing clients to cut energy expenses and even guarantee service levels at a lower cost. Furthermore, the paper stresses that realizing expected energy performance under actual operating circumstances is crucial to the overall balance of EPCs.*

**Keywords:** *Energy Performance Contracting, Energy Service Companies, Energy Efficiency, Business Performance*

## 1. INTRODUCTION

Energy Performance Contracting, also known as "Energy Management Contracting", is a results-oriented approach that enables the funding and execution of proven energy-efficient technology to improve the energy efficiency of organizations (Zhou et al., 2016). An Energy Performance Contract (EPC) is essentially a mutually agreed upon agreement between an Energy Service Provider (Qin et al., 2017). The entity referred to as the Energy Service Company (ESCO) is a company that provides energy services to consumers. In an (EPC) project, ESCO primarily functions as a service provider that assists its clients in enhancing energy efficiency.

The EPC, which emerged in response to the oil crisis of the 1970s, was developed as a novel financing model primarily aimed at lowering energy consumption by covering the expenses associated with the installation and maintenance of energy-saving equipment (Zhang & Yuan, 2019a). EPC projects have demonstrated the ability to create favorable environmental outcomes. Specifically, the Energy Service Company (ESCO) and its client both benefit from the shared energy cost savings, making the Energy Performance Contract (EPC) comparable to revenue sharing agreements in supply chains (Zhou et al., 2016). Global EPC markets have experienced significant growth over the last ten years, driven by the implementation of laws and standards that promote EPC. Nevertheless, the level of market maturity varies across different regions (Zhang & Yuan, 2019a).

EPC is also a comprehensive service that offers clients a broad assessment of energy efficiency, renewable energy, and distributed generation methods, all of which come with guaranteed energy savings (Zhang & Yuan, 2019a). EPC projects entail the involvement of an Energy Service Company as a service provider, assisting clients in enhancing their energy efficiency. While EPC contains some similarities with standard performance-based contracting, like a long contract time and uncertainties regarding performance, its unique feature lies in the way it evaluates and allocates risks, particularly in terms of the guarantee of cost savings (Deng et al. 2015). One of the specific areas of expertise in EPC is the estimation of future cost savings. This process considers the uncertainties related to both energy prices and the amount of energy savings. Energy performance contracting (EPC) is as well a market-driven approach, used to implement energy efficiency initiatives. The ESCO recoups the costs of the project, including the initial investment expenditures, by utilizing the money generated by the project (Carbonara & Pellegrino, 2018).

## 2. EXPLORATION OF ENERGY PERFORMANCE CONTRACTING

Given the increasing complexity of energy systems, the modern energy economy necessitates the use of more sophisticated models to accurately evaluate future developments in the energy sector (Backović et al., 2024). Although energy services have a lengthy history, they are still marked by a lack of clear definitions, a wide range of products, and a multitude of suppliers. The terminology used in relation to Energy Service Contracts encompasses many phrases, such as: *Energy Performance Contracting*, *Energy Savings Performance Contracting*, *Facility Contracting*, *Chauffage*, and *Contract Energy Management* (Pătări & Sinkkonen, 2014).

Due to the lack of a globally recognized standard, there is no consensus on how to define the duration of a contract in the EPC market (Deng et al., 2014). The EPC establishes a legally binding and exact objective for the preservation of energy. The ESCO offers energy-efficient approaches, finance, deployment, as well as service through an appropriate business model to achieve the goal of energy conservation (Qin et al., 2017). ESCOs typically choose for more long-lasting contracts to generate more profit over time. The owners may decrease the contract time to protect their project interests and rights after the transfer of the well-equipped facility. To win the bid, ESCOs must present a competitive offer for a shorter contract period (Deng et al., 2014).

The primary attributes of EPCs could be succinctly described as follows, as outlined by Giretti et al. (2018): (1) The EPC provider offers comprehensive services for developing and implementing an entire cost-effective project at the customer's location. (2) The expenses incurred for improving energy efficiency are directly repaid by the reductions in energy costs and associated financial benefits. (3) The EPC provider assumes the agreed-upon risks concerning the project's performance. (4) The EPC provider guarantees the attainment of the mutually agreed-on level of savings and is responsible for compensating any shortfall in savings.

The energy user (EU) and energy service company (ESCO) are considered key participants in EPC projects, and their actions and choices have a significant impact on the total energy-saving results (Zhang & Yuan, 2019b). Customers and ESCOs should establish the energy efficiency investment and calculate the return on savings depending on the success of the project (Deng et al., 2014). For example, for a 15-year contract, ownership transfer occurs at the end of the 15th year. There are four major types of EPC projects (Qin et al., 2017):

- 1) *Savings Share Model*: Before beginning the EPC project, the ESCO and client must reach an agreement on the benchmark and reduction in energy consumption. The energy consumer and ESCO collaborated throughout the project. The advantages of the undertaking will be distributed in accordance with defined proportions. When the project is completed, employ energy-saving equipment. Energy customers will get free transfers. The energy user reaps the full benefits of energy savings. The ESCO bears both performance and credit risk in this arrangement. Once the project's revenue stream ends, energy users stop using it, placing the ESCO at risk.
- 2) *Guaranteed Savings Model*: Energy users finance EPC projects internally via financial institutions, financing businesses, and transportation planning firms. ESCOs provide energy savings in return. Energy consumers will receive compensation from the ESCO for any savings that fall short of the minimum threshold. Otherwise, the ESCO and the energy consumer will share the surplus in accordance with the contract proportions. The energy consumer can avoid performance risk, however, they cannot exclude risk to their credit from repayments.
- 3) *Energy-cost Trust Model*: The ESCO manages the client's energy. Clients pay a charge to complete this transaction. Energy cost savings help to mitigate this tax. This method to energy supply contracting is known as high-level energy management outsourcing. With the lower bill, ESCO may profit entirely at the end of the contract.
- 4) *Finance Lease Modeling*: The ESCO uses an EPC project's expected energy savings to secure money from a finance lease company. After investing into the EPC initiative, the leasing company will provide the ESCO with technology. However, the leasing company owns the equipment for the duration of the contract. Energy consumers pay for equipment through cost savings. Contributions are made on an agreed-upon basis. After the work is completed, the energy user is free to acquire possession of the equipment.

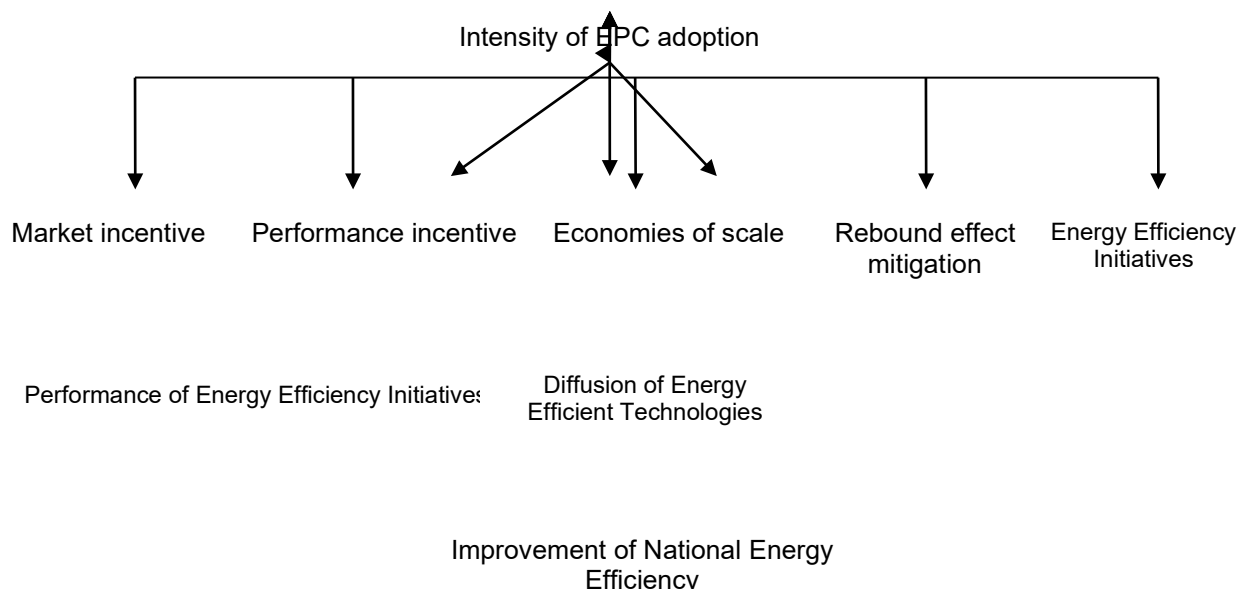
The primary differentiation resides in the following elements: revenue sharing contracts primarily serve to coordinate the activities of downstream and upstream enterprises within a supply chain. Furthermore, within the framework of revenue sharing contracts, the moral hazard problem develops due to the lack of observability between firms and the uncertainty surrounding the outcomes of their actions (Zhou et al., 2016). EPC is a performance-oriented approach that necessitates diligent monitoring and verification of project performance and savings by both parties involved. The primary uncertainties that impact the success of a

project in the EPC industry are the future maintenance and operation costs, the performance of energy-saving measures, and the fluctuating energy price (Deng et al., 2014).

Consequently, a range of theories and approaches have been utilized to examine the behaviors and decisions of stakeholders. The performance of an Energy Service Company (ESCO) plays a crucial role in evaluating the real performance of Energy Performance Contract (EPC) projects (Zhang & Yuan, 2019b). In addition to risk assessment, the allocation of risk is another important matter to consider while managing the tradeoffs between conflicting and cooperative contracts among rational decision-makers. Hence, game theory is a valuable tool for addressing the challenge of risk distribution (Deng et al., 2015).

EPCs might not be the most cost-effective alternative, depending on capabilities, capacities, and relationships (Polzin et al., 2016). ESCOs are directly involved in most of the operation and management activities in EPC projects, as stated by numerous studies (Zhang & Yuan, 2019b). Research on ESCO is crucial in the field of EPC. Furthermore, the profit-sharing ideologies between the owner and the ESCO diverge from typical performance-based contracts, particularly in cases where there is a surplus beyond the guaranteed amount (Deng et al. 2015). In a traditional “turnkey” energy efficiency project, the contractor assumes responsibility for the design, specification, construction, and commissioning of the project. The contractor gets compensated upon the completion of the project. The contractor lacks both the motivation and the resources to enhance the effectiveness of the energy efficiency projects after it had been delivered (Capelo, 2011).

Often, it is more profitable to maintain a cost-inefficient power plant using conventional energy than to shut it down, indicating the need for cost management (Backović & Ilić, 2023). This is where EPCs can also help, considering one of their main goals is to minimize the overall cost of providing energy services (Capelo, 2011). The transaction costs of EPC contractors are influenced by the specificity of client assets, which in turn depends on the nature of the technologies needed to deliver the essential energy services. The size and learning benefits offered by the contractors are also affected by this factor (Capelo, 2011). The inclusion of both the collaborative and competitive dynamics between energy users and ESCO greatly complicates the decision-making challenges in EPC projects (Zhang & Yuan, 2019b). However, it is crucial to consider and analyze this aspect in future EPC research, with the aim of enhancing stakeholder decision-making and minimizing transaction costs throughout the execution of EPC projects. The general equilibrium of Energy Performance Contracts (EPCs) is heavily contingent on the successful attainment of the anticipated energy effectiveness under operating circumstances, just like investments made in energy efficiency get refunded solely through energy savings (Giretti et al., 2018). Therefore, it is important to achieve the energy efficiency values established during the design phase.



**Figure 1:** Economic effects of adopting EPC  
Source: Capelo (2011)

Zhou et al. (2016) propose that policymakers should thoroughly evaluate the consequences of incentive measures prior to their implementation. Their model investigates various expansions of the fundamental scenario, demonstrating that EPC may result in higher overall energy consumption when the market is

limited in size and the ESCO possesses minimal energy-efficiency superiority over its client. Despite that, the model is subject to some drawbacks, such as its reliance on assumed beginning energy intensities, its failure to account for uncertainties, the involvement of many ESCOs, and its assumption of perfect substitution of goods. Additionally, most contractors lack the same level of proficiency in particular process technologies, necessitating the ESCO to invest significant resources in recruiting and training personnel, as well as gaining practical experience (Capelo, 2011). A study of drivers and barriers to EPC solutions in German municipalities indicated that existing relationships, missing financial resources, staff capacity, and financial constraints increase EPC consideration (Polzin et al., 2016). According to these results, the interpretation is that ESCOs and lawyers as consultants may enhance EPC consideration, whereas energy consultants may decrease it. Hence, EPC contractors should have specialized knowledge in generic technology (Capelo, 2011). Previous literature indicated that the selection of an ideal EPC business model would depend on several criteria, including the stage of the project, the organization of the contract, and the financial standing of the energy users.

The energy efficiency expenditures and their payback are categorized into two distinct phases. Owners prioritize the second stage, but ESCOs prioritize the first. Owners retain the balance of energy cost reductions and operational and maintenance expenditures. For instance, the EPC suggested by Deng et al. (2014) typically achieves the anticipated rate of return for the 13-year agreement, however there is a possibility that it may not. If the business model is implemented appropriately, it will recoup the initial investment and generate a reasonable return (Qin et al., 2017). In such situations, the Energy Performance Contracting (EPC) arises as a mutually advantageous model for both the energy customer and the Energy Service Company (ESCO).

Energy Performance Contracting enables the client to minimize energy expenses and potentially ensure specific service levels. EPCs for public sector retrofitting minimize carbon emissions and energy dependency while saving money. Business transparency and the governmental ability to rationally choose among in-house and outsourcing alternatives are needed for efficient retrofitting. Support schemes should allow EPC models to maximize participation by the private sector and reduce budgetary restrictions (Polzin et al., 2016). When choosing an EPC business model, managers should consider the complexity of the decision, which involves multiple elements. It is important to evaluate managers' preferences articulated in terminology to select an appropriate and practical EPC business model (Zhang & Yuan, 2019a).

### **3. CONCLUSION**

Energy performance contracting as a strategy aims to enhance energy efficiency by installing energy-efficient technologies through agreements that are mutually agreed upon by Energy Service Providers (ESCOs) and companies that provide energy to customers. In other words, EPC is a method that is based on performance as its primary motivation. The global EPC projects have undergone significant expansion, which has resulted in the incorporation of a wide variety of models, including energy-cost trust, financing leasing, savings share, and guaranteed savings. In order for EPC projects to be successful, they require careful monitoring, risk assessment, and the distribution of risks among the various parties involved. During the execution of EPC projects, it is essential to take into consideration a number of important elements, including transaction costs, the dynamic between collaboration and competition, and the achievement of the anticipated energy performance. It is the responsibility of policymakers to evaluate the effectiveness of incentive measures, and it is essential for contractors to have specialized knowledge in technological areas.

The aforementioned contracting strategy offers a number of benefits, including the reduction of carbon footprints, the reduction of energy expenses, and the achievement of financial savings. Energy performance contracting is a form of modern contracting that makes it possible to easily digitize the tasks of energy companies. The intended purpose of EPC is to make the observation of all business activities that are negotiated between business parties more efficient. There is a clear demonstration of the significance of openness, energy efficiency, and the reduction of total costs in the context of such complex business tasks. It is without a doubt that energy companies will achieve higher business efficiency over the long term with the appropriate application of EPC. This will enable all processes to be followed by service users, which will ultimately lead to cost efficiency, standardization of contracting between energy companies on an international scale, and the utilization of even more cutting-edge technologies for the utilization of energy sources.

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# THE IMPACT OF DIGITAL TRANSFORMATION ON THE DIGITAL LABOR MARKET AND THE FUTURE OF EMPLOYMENT IN COMPANIES: CHALLENGES OF FUTURE HUMAN-TECHNOLOGY INTERACTION

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**Abstract:** Companies currently operate in a VUCA environment (Kaufman and Srića, 2020), characterized by rapid changes in competition, demand, technology, and regulations, creating additional pressure on management to align their business processes and models with the adoption of disruptive technologies, for competitiveness and value creation (Savastano et al., 2019; Teichert, 2019). However, according to (Schneider et al., 2021), it is important not to forget that technology-oriented companies fail to recognize the procedural nature of digital transformation and the substantial impact of the transformation occurring in business unless they encompass sociological, cultural, and economic factors such as vision, strategy, culture, HR skills, resources, and infrastructure (Leao et al., 2021; Kraus et al., 2022).

Due to global crises such as the Covid-19 pandemic and the current war in Ukraine, digital transformation significantly develops and innovates the conditions in the labor market. There is an increase in the number of digital jobs, non-standard forms of employment, changes in the requirements of labor market actors, innovative employment practices, greater mobility, flexibility, and much more detailed demands for education and job enhancement (DigitalCxo, 2023). The use of digital technologies such as robotics, artificial intelligence, machine learning, the Internet of Things, advanced analytics, virtual reality, 3D printing, has completely changed the way employees perform tasks and communicate with customers. On the other hand, the negative effects of digital business transformation and its consequences on the labor market relate to problems of imbalance between national and international labor markets, then between regulatory frameworks and the need for education, as well as insufficient social element and investment in human capital, but also procedures in the digital labor market, and security level (Zub, 2023).

In the global labor market, competitiveness over many job positions now involves "Chat GPT," an open AI technology based on advanced machine learning algorithms, which allows for simulating human interaction with users and thus enables sophisticated responses and reactions to clients based on training with large amounts of data (Božić, 2023).

**Keywords:** Digital transformation, human resources, digital technologies, HR disruption, VUCA time

## 1. INTRODUCTION

The need for business transformation demands disruptions in business operations. There are multiple factors, which focus on innovating business processes to enhance competitiveness (Gokalp and Martinez, 2021; Barbosa et al., 2019), and digital business strategy to boost productivity and create new value for customers (Hanelt et al., 2021). An ongoing trend is the digital business transformation, where additional value is created through the integration of social and economic dimensions of operations (Attaran, 2020). Regarding the use of digital technologies, an IBM study shows that 42% of companies are considering the use of artificial intelligence, while 35% are already implementing it in their operations (ECM, 2023). Although digital technologies bring numerous benefits, they also pose challenges for companies, employees, and individuals. The contribution of artificial intelligence (AI) in business is reflected in customer communication services and problem-solving. On the other hand, challenges arise as well, particularly in the labor market. According to

Forbes estimations, the use of AI solutions may eliminate nearly a billion jobs in the next 10 years, also with the loss of up to 375 million of the different job positions (Zub, 2023).

According to current studies, the size of the digital transformation market in the US alone was \$594.5 billion in 2022. Estimates suggest that this figure will grow annually by 21% until 2027, reaching \$1,548.9 billion in 2027, with the USA, Europe, and China being the largest investment areas in the coming years (Zub, 2023). Simultaneously, one of the key drivers of instability in the labor market will be the digital transformation market and the aforementioned parameters. Disruptive changes in the labor market have partly emerged due to the emergence of the digital labor market, which is part of the global labor market where supply and demand are formed digitally within the digital ecosystem, resulting in labor market outcomes due to the application of digital technologies (Azmuk, 2020).

One of the results of Covid-19 pandemic has been a dominance of the digital labor, which has increased remote business processes, new investments in IT infrastructure, employee education, and more flexible work relationships. These events have led to a global transition towards remote and flexible business models, motivating companies to consider the need for office reorganization, hybrid business models with lower costs, fewer new investments, and higher satisfaction of employees. The impact on the digital business transformation of companies and the labor market in Europe has been significantly influenced by the war in Ukraine, leading to, according to the International Organization for Migration (IOM), 7.8 million refugees in Europe in 2022, significantly affecting migration development in the global labor market (Zub, 2023). Specifically, the war has caused problems in the global market due to the reduction in the working population, increased professional gap among employees, decreased labor productivity, increased migration at local and state levels, decreased real wages, increased informal employment, and greater discrepancies in labor supply and demand in regional labor markets.

In a digital environment, work positions have significantly improved through agile working methods, the use of cloud computing, virtual reality, and IoT solutions (Cotrino et al., 2020). On the other hand, new work models bring both positive and negative circumstances, opportunities, and challenges for both employers and employees (McFadden et al., 2021; Chang et al., 2021). The positive circumstances include greater satisfaction, flexibility, process control, and organization of working hours, which allows employees the opportunity to work where, when, and how they want to achieve their daily targets. Additionally, digital workplaces provide greater autonomy and control, improving employees' personal characteristics and abilities, like goal-setting, efficiency self-monitoring, anticipation of challenges, more decision-making, and other factors (Wang et al., 2020; Miron et al., 2021). However, flexibility in the digital environment can sometimes bring a certain degree of pressure and invasion into employees' private lives, leaving individuals with little personal space and interests. This concept, known as "technostress," highlights the dark and negative aspects of digital technology use, as well as the inability to keep pace with the dynamics of computer power and needs.

Therefore, when creating and implementing a digital transformation plan, it is important to define the relationship between technology and humans within the company and based on that, define an education and adaptation plan for employees to effectively manage new work models. Research questions:

- Does digital transformation require educating and raising awareness among employees about the importance of digital business, as an opportunity for improvement and creating competitiveness?
- Digital anthropology – can the application of technologies result in strategic business development, but not in replacing humans, in order to achieve performance and also better business outcomes?

## 2. RESULTS

Does the implementation of ICT (artificial intelligence and robotics) reduce or increase the level of employment by introducing many new jobs in distribution, services, and production activities? There are three possible scenarios for the reaction of employees: 1) "end of work" - a major social uprising due to the fact that technological development (robotics and AI) directly causes mass unemployment, 2) "structurally lower" - a scenario where business positions are directly replaced by robots and 3) "rebound" - a scenario in which, after a state of shock and structural changes during transformation, employment returns to regular levels. As can be concluded, in all three scenarios, the key outcomes are dictated by education and the willingness of employees to change their habits and improve business skills (Pyka, 2019).

Also, business digital transformation involves reengineering, reinvention, and in some cases, complete destruction of existing organizational work segments (Mendling et al., 2020). When it comes to the negative impacts of digital transformation on the development and transition of job positions (Feliciano-Cestero et al., 2023), challenges and threats to cybersecurity, compliance with international standards and laws, and negative effects on communication channels (Ameen et al., 2021; Hannibal and Knight, 2018) are included. In addition,



insufficiently developed ICT infrastructure, employee knowledge, cultural factors, and problems that limit professional and social development, even with optimal use of ICT tools, stand out (Nambisan et al., 2019; Biggiero, 2006).

In the HR sector, it is important to consider and organize the mentioned development directions independently within the company. According to (Mao et al., 2019), the development of the ICT/digital sector in the company leads in two separate directions, one dealing with improving the existing ICT infrastructure and the other, agile and experimental, which levels the use of digital technologies towards creating new business models and meeting consumer needs (Su et al., 2016; Haffke et al., 2017). In the field of ICT infrastructure, the necessary skills are already known in advance, while in digital professions, new positions necessary for various stages of digital transformation application in the company are continuously developing, namely: chief technology officer, chief digital officer, chief transformation officer, digital innovation officer, head of digital strategy (Mansfeld et al., 2010; Singh and Hess, 2017; Singh et al., 2020).

What are the real possibilities and business scenarios that HR management can offer to employees? One dark side of use is the dedication to digital technology that requires the use of human performance, abilities, and characteristics at a very low level, while on the other hand, it requires knowledge of new skills and knowledge that employees still do not know enough about. If the highlighted advantages are not balanced adequately, most employees will quickly return to old working methods, which have traditional values opposed to "remote working," which suppresses humans (Toscano et al., 2022). The use of digital technologies, in addition to bringing social challenges, also poses challenges for the mental development of employees as humans, such as the need to transition from physical to mental efforts at work and the transition from "work control to work liberalization" (Loang, 2022). Therefore, HR departments and management face an increasingly greater challenge to adapt working methods to young professionals who will further develop skills in data analytics, artificial intelligence, and online learning to enhance the effectiveness and efficiency of their positions, without being compromised by cyber attacks and many other risks to the security and quality of business operations (YuLing et al., 2023).

Digital talents increasingly demand autonomy, purpose, control, and flexibility in their workplaces. Therefore, the entire ecosystem needs to build a flexible work environment that provides ICT and digital experts with enough "freedom accompanied by control" because only through flexibility they can motivate and retain talents - material conditions are becoming less crucial in the decision-making and choice of employees (Alam and Joshi, 2021). Hence, companies should establish centers of excellence or high-performance teams where employees learn from each other, compete, and empower themselves to solve problems and develop new solutions (Jacobs et al., 2020), as "Great people want to solve really hard problems; if not, they get bored and leave" (Fernandez-Vidal et al., 2022).

When it comes to the application of artificial intelligence in the workplace, solutions like OpenAI's ChatGPT provide the possibility of simulating human interaction with users through technology, thereby questioning a large number of customer-facing positions and understanding their needs without additional development of the capabilities of all employees (Božić, 2023). Therefore, companies approach testing the efficiency of these solutions in their business, which often causes significant pressure and stress among employees due to the fear of losing their positions. However, technology can hardly replace the efficiency, productivity, and quality of products and services of a company, but it can certainly improve the quality of communication with customers, delivery of products or services, as well as understanding customer needs and predictive abilities regarding new strategic decisions. What can be the best relationship-collaboration, between digital technologies and employees?

It is important to consider customer satisfaction as the ultimate goal of business, which can most effectively be achieved through the collaboration of employee efficiency and performance on one side, and ChatGPT and digital solutions on the other (Acemoglu and Johnson, 2023). The competitiveness of the workforce versus the efficiency of technological solutions can always be strengthened by national or international regulations, but on the other hand, this cannot prevent companies from developing digital solutions that will replace a large number of business positions in order to increase their profits. That is why the solution can be a combination of 1) predictive power of artificial intelligence and digital solutions to understand customer needs and propose innovative solutions, and 2) performance and capabilities of employees to utilize the given recommendations in order to create concrete value for the company, through innovation of offerings, market acquisition, or other decisions in the company's business (Mamoon, 2023).

Regardless of the industry a company operates in, what customers expect is a sense of brand and exclusivity in collaboration, which can best be offered by a combination of digital solutions that search basic customer preferences, create recommendations, and then give employees the opportunity to make decisions with emotions, exclusivity, and to satisfy customer needs (Acemoglu and Johnson, 2023). In this way, the application of digital technologies directly increases productivity, performance, knowledge, and benefits of

employees, thanks to the increased quality of the company's products and services, as well as meeting the needs of an increasing number of customers from the economic class, with whom employees previously collaborated as a group, but now through technology, employees can establish a sophisticated, 1:1 relationship.

In order to achieve a combination and utilize the advantages of techno-socialization in business, it is necessary for company management to develop creative and critical thinking, while employees need to strengthen their reputation, soft skills, and technical knowledge about offerings, so that their competitiveness is not solely tied to communicativeness or some mechanical operations they previously performed (Mamoon, 2023). If companies invest resources in acquiring skills and competitiveness of their employees, the use of ChatGPT and other digital solutions would give the HR sector an opportunity to increase the number of employees and conquer new markets continuously, instead of market downsizing.

### 3. DISCUSSION

The new digital space enables the creation of new cultures. Action in the digital world increasingly resembles the real world - by entering any of the virtual worlds, each user refines it according to their experience, knowledge, and needs, intersecting it with their own interests and everyday life. Also, in the real world, robots that resemble humans, perform human tasks, or are intelligent in a way that approaches human intelligence, are increasingly used. By giving emotions to robots, they become beings that have a soul; now the question is How does this robot differ and what does it want from humans? (Gavrilović, 2011).

The modern human operates in a society with a high degree of social stratification, partly due to the relationship with and access to digital technology and the manner of its use, which is explained by the concept of the digital divide (Čejko, 2019). The rate and level of a society's digital divide are influenced by the standard of living, economy, education, and culture of the people, making it logical that some social communities better respond to the challenges of the digital, specifically having a less pronounced digital divide. How humans accept technologies and what they can "extract" from them depend on the cultural elevation of society, because culture consists of the products of a group that can be material and mental.

Jacques Ellul (1954) believes that "separating mental activities from the physical movements of man at work leads to a reduction in fatigue since, unfortunately, man no longer needs to participate or make any decisions." When a person is no longer responsible for his job and does not play a role in it, he feels spiritual violence is being exerted upon him, which is why, according to Ellul, "escape becomes a logical choice". Technology offers solutions to all problems and sends a message that all humans need is a bit more technology (Zerzan, 2004). This view contrasts with the perspective of Boellstorff (2008), who claims that the digital world is characterized by creativity becoming a form of value exchange, not just value consumption. According to this logic, work begins to be viewed from the perspective of exchange and use value, blurring the clear boundary between work and play - production is slowly turning into a game. People are increasingly involved in immersive marketing, based on the idea of "don't sell me, play with me."

### 4. CONCLUSION

After more than two decades of steady development, the question of digital consumerism has gone into hyperproduction due to the COVID-19 pandemic, which began to change the reality around it. In the world, digital consumers dominate, who are not only focused on digital collaboration but also on emotional fulfillment and depletion, fear of consequences such as pandemics, anxiety, and concern (Solis, 2020). All business and life activities are directed towards digital platforms, creating new digital habits that do not necessarily motivate consumers, as they only partially aim to replace traditional habits with digital ones. Therefore, the success of employees and the company, and the ability to navigate the waves of disruption (Vukotić, 2020), will depend on companies' ability to recognize the impact of the digital and adapt offerings.

As smart generalists and creatives rather than specialists, the ability to adapt to market conditions with a wider range of knowledge and skills needs to be developed, instead of a guarantee that a person will learn and work exclusively in a specialized field throughout their life. Therefore, today's giant companies seek to employ multifunctional employees who are agile and ready to function from team to team, adapt, and learn in a given environment. Creatives also possess general cognitive abilities that make them aware of how quickly a company needs to evolve and explore new jobs in the digital age. They are smart generalists (Lisa Stern Hayes, Google).

Instead of skills that once created value, skills that lead us to attention and success are now crucial. Integrating digital technologies, along with operational agility, culture, and digital leadership, leads to fundamental transformation, as opposed to using only ICT technologies. It is necessary to adapt to the digital mindset, develop an innovative approach and philosophy of thinking that will help employees establish a culture of

continuous learning and utilize skills to create value and opportunities (Lukito et al., 2022). The only certainty for the future is that uncertainty is guaranteed. Therefore, the survival depends on the strength of individuals to awaken their spirits.

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# SUSTAINABLE DEVELOPMENT IN ADDRESSING CONTEMPORARY ENVIRONMENTAL CRISES

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**Abstract:** *The modern era is characterized by a whole series of ecological challenges that disrupt the delicate balance of the Earth's ecosystems, biodiversity and the well-being of current and future generations. These crises are the result of human activities and various industrial processes. Excessive, unsustainable use of resources, polluting and waste generation are highly associated with the requirements of reaching desired rates of economic performance set by industrialization. Traditional economic models and patterns of unlimited production and consumption must be replaced. Achieving sustainable economic growth based on the wise use of natural resources is facilitated by integrating green transformation components into all facets of society. The main components of transition to environmentally friendly economy include the transformation of a linear economy to a circular economy, the adoption of renewable energy and technology, and the advancement of environmental awareness through education which are all presented. This study aims to explicate the potential of sustainable development in mitigating the underlying causes of environmental degradation and laying the groundwork for a more sustainable future.*

**Keywords:** *environmental crises, sustainable development, green transformation*

## 1. INTRODUCTION

The modern era is characterized by a whole series of ecological challenges that disrupt the delicate balance of the Earth's ecosystems, biodiversity and the well-being of current and future generations. Climate change, pollution, depletion of resources, etc. are key environmental crises affecting our planet (Cortes, 2023). These crises are the result of human activities and various industrial processes. They have multiple negative environmental, social and economic impacts on society and the economy (Al-Taai & Al-Dulaimi, 2021) and represent a significant threat to sustainable development.

In order to preserve the long-term sustainability of our planet and the well-being of future generations, these questions require immediate and creative answers. The idea of sustainable development has emerged as a framework for balancing social justice, economic growth and environmental protection in response to these current crises. Ideally, all elements of a complex socio-economic-ecological system are interconnected and interdependent systems that influence and rely on each other (Mensah, 2019). However, the industrial revolution, social progress and economic development have degraded the environment and depleted natural resources, and therefore the need to find alternative development paths and change human behaviour is initiated (Mamipour et al., 2019). Managing environmental sustainability and maintaining a balance between environmental protection and consumerism in a capitalist society (Panizzut et al., 2021) is a growing challenge. Achieving sustainability requires balancing economic prosperity, social well-being and environmental stewardship to ensure a harmonious relationship between human activities and the world of nature.

With aim to address the environmental issues of modern era, this study investigates the ideas and methods of sustainable development. A more robust and peaceful coexistence between humans and the natural world can be achieved through sustainable development, which takes a comprehensive approach that incorporates social, environmental, and economic factors.

Through analysis of policy and theoretical frameworks, this study aims to explicate the potential of sustainable development in mitigating the underlying causes of environmental degradation and laying the groundwork for a more sustainable future.

The paper is structured as follows. The first part, after the introduction, offers a review of the literature, provides a more detailed insight into contemporary environmental crises, the impact of economic development on the environment (disrupted ecosystem balance) and the concept of sustainable development. The central part of the work (Green transformation) focuses on solving environmental crises. It will explain the impact that different environmentally sustainable practices can have on overcoming crises. Efforts will be made to combine all theoretical knowledge in order to propose concrete ways to overcome environmental crises through the synergy of concepts of sustainable development, circular economy, use of renewable energy sources and cooperation of various actors of interest. Finally, concluding considerations will be presented in the last part of the paper.

## **2. LITERATURE REVIEW**

### **2.1. Contemporary environmental crises**

As already pointed out in the introduction, we are witnessing increasingly visible manifestations of environmental crises. Due to the seriousness of the consequences they carry and as a significant threat to achieving sustainability, they require immediate solutions (Mravcova, 2024). First, it is necessary to explain the main ecological crises that characterize modern civilizations.

Climate change (global warming) is the most dangerous threat of the modern age. There has been a global temperature increase of 1.1 °C over the last 150 years (IPCC, 2023). It results from the buildup of greenhouse gases in the atmosphere, mostly as a result of human activity like deforestation and the combustion of fossil fuels. This raises the sea level and causes extreme weather events like storms and droughts, which disturb ecosystems, agriculture and have an impact on the survival of humans and animals worldwide. Beyond climate change, human activity is the root cause of other environmental catastrophes, such as pollution, overexploitation of resources, and biodiversity loss. They all affect and are influenced by one another. According to Banks-Leite et al. (2020), the current biodiversity catastrophe is caused by pollution, biotic exchange, overexploitation, habitat modification (conversion to agriculture), and climate change. The Living Planet Report (WWF, 2022) reveals an average decline in biodiversity of 69% over the past 50 years. Deforestation is closely related to climate change and loss of diversity. Deforestation, as a tool of agriculture and urbanization, causes loss of habitat, threatens the survival of countless species and promotes climate change, since forests appear as carbon sinks. (Lawrence et al, 2022).

In addition to human activities, various industrial processes lead to the deterioration of the environment we live in. Industry, transportation, agriculture, as well as household waste are responsible for multiple pollutions of air, water and soil (Awewomom et al, 2024), which results in the ecosystems destruction, damage of human health, threatens the survival of species and thus hinders the development of society (Al-Taai & Al-Dulaimi, 2021). The production processes of various industries (Wen et al., 2024), power plants and mining emit pollutants such as heavy metals (Hanfi et al., 2019), poisonous gases such as sulphur dioxide, nitrogen oxides, carbon (Ghorani-Azam et al., 2016) and particulate matter (PM). Transportation pollution that occurs as a result of vehicle emissions, shipping and maritime activities; cars, trucks, airplanes and other vehicles emit pollutants such as carbon monoxide, nitrogen oxides, volatile organic compounds and particles into the atmosphere (Krupnick et al., 1997), as well as when boats and ships emit sulphur and nitrogen oxides and particles into water or oil is spilled (Airclim). Agricultural pesticides, herbicides and fertilizers should also be highlighted (Li, 2011). All in all, pollution comes in many forms, from heavy metals and hazardous chemicals to plastic trash and agricultural waste water that contaminate air, water and soil. A phenomenon associated with air pollution and deforestation is ocean acidification. An increase in (CO<sub>2</sub>) levels in the atmosphere due to deforestation and fossil fuel burning, accompanied by agricultural activities, causes a large increase in (CO<sub>2</sub>) levels in seawater,

creating an acidic environment that is dangerous to marine life, especially corals and shellfish (Doney et al., 2020). Therefore, ocean acidification can negatively affect fisheries, marine ecosystems, the food chain, and indirectly, coastal populations.

It is important to mention the depletion of limited natural resources. Back in the 70s of the last century, environmentalists took this problem seriously, warning of the consequences of unsustainable excessive consumption (Kirsch, 2020). Earth's limited resources, such as fossil fuels, minerals and arable land, are being extracted and consumed at an unsustainable rate, threatening the integrity of ecosystems, exacerbating social injustices and geopolitical tensions over access to resources.

## 2.2. Impact of Economic Growth on the Environment

The nexus between economic development and environmental protection has been extensively studied by the scientific community. The focus is on identifying the interdependence of these two phenomena essential for social progress. Raising living standards, combating poverty, enhancing competitiveness in the global economy, building infrastructure, encouraging creativity and social cohesion all depend on economic development. On the other hand, the industrial revolution, rapid economic development, social progress and urbanization are responsible for the degradation of the quality of the environment.

Excessive, unsustainable use of resources, polluting production processes are highly associated with reaching desired rates of economic performance (Liu et al., 2021). The primary economic model of most countries is currently unfortunately a linear model characterized by reckless patterns of production and consumption where the final product is discarded after use, generating a huge amount of garbage around the world (Milanović, Jovović & Petrović, 2020). Although it is often considered that economic growth negatively affects the environment and that it is necessary to make a trade-off between economic growth and environmental protection (Jayachandran, 2021), economic prosperity can also encourage environmental protection and push the planet towards sustainable development. For this purpose, the Environmental Kuznets Curve model (Mazurek, 2011) presented in Figure 1 has been implemented.

The Environmental Kuznets Curve (EKC) is used to define the turning point where growth does not negatively affect the environment (Ekonomou & Halkos, 2023). With the growth of income, deterioration of the environment also increases until it reaches a certain threshold, after which it displays a diminishing trend. This hypothesis dictates that when the necessary level of economic prosperity and environmental awareness is reached, environmental degradation is gradually reduced at the expense of the use of new, cleaner technologies, the promotion of sustainable practices, etc. (Wang et al., 2024).

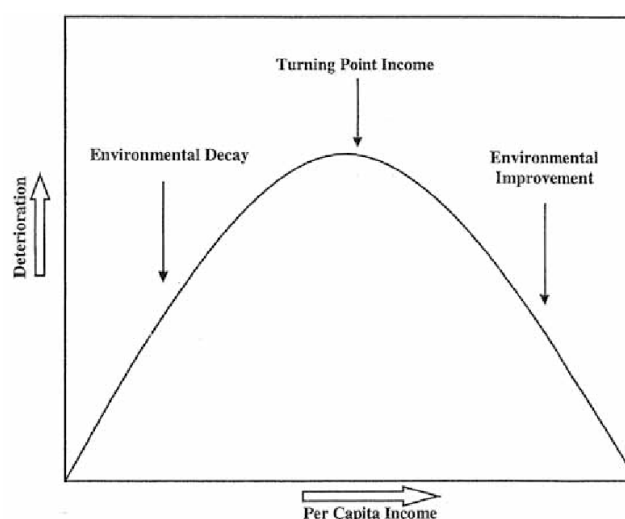


Figure 1. Environmental Kuznets Curve (Mazurek, 2011)

Despite numerous criticisms of the model, it can have useful implications and be applied to the formulation of the most sustainable strategies that will neutralize negative environmental impacts by reducing emissions and increasing the use of renewable energy sources in order to achieve identical economic outcomes (Ekonomou & Halkos, 2023).

### **2.3. Concept of sustainable development**

The concept of sustainable development seeks to bring together environmental protection, social equity and economic development to create a balanced and sustainable future (Mensah, 2019). Sustainable development was defined in 1987 by the United Nations World Commission on Environment and Development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987)."*

The Sustainable Development Goals (SDGs) were adopted 2015 by the United Nations Sustainable Development Agenda (Weiland et al., 2021). There are 17 goals (UN), each with specific sub-goals to be achieved by 2030. These goals address the most important global challenges and include social, economic and ecological dimensions of development that focus on building a more sustainable and fairer world. This concept, with its integrated approach, targets problems (goals) such as the suppression of poverty, hunger, promotion of education and gender equality, which are all intertwined.

## **3. GREEN TRANSFORMATION**

In recent decades, there has been an increasing demand to replace traditional economic models to address the environmental crises of modern civilization. An alternative economic model is called "Green Economy" and implies economic growth compatible with environmental protection (Söderholm, 2020).

The vision of green transformation is a shift from resource-intensive and environmentally harmful activities to more sustainable lifestyle and business models. It is based on a major change to the use of sustainable technologies and sustainable patterns of production and consumption (Batrancea et al., 2021). Green transformation is a long-term initiative that aims to integrate sustainable development concepts into all facets of society by using a comprehensive and systematic approach, creating a harmonious relationship between the ecological and economic systems (Pietras, 2023).

The main components of a transition to environmentally friendly economy include transformation of a linear economy to a circular economy (Oliveira et al., 2021), the adoption of renewable energy and technology (Batrancea et al., 2021), the encouragement of sustainable environmental practices (Cheba et al., 2022) and the advancement of environmental awareness through education (Li et al., 2023). All these elements will be explained individually, as well as their role in the green transformation, and finally potential of their interaction and the expected impacts on environment will be presented.

### **3.1. Transformation from Linear to Circular economy**

The concept of a circular economy has recently acquired popularity as a means of achieving sustainability in corporate and political discourse worldwide (Oliveira et al., 2021). The circular economy is a model of development that tends to neutralize negative impact of human activities by applying the "3R" principle: reduce, reuse, and recycle, in order to maintain the highest utility value of products at all times (Scarpellini et al., 2019).

As mentioned earlier, dominant economic model of production and consumption is linear. The linear model paradigm is: extract-produce-discard (Arruda et al., 2021). The economic process and use of our planet's resources takes place in a straight line in stages: extraction of natural resources, their processing, shaping into semi-finished products or finished products, distribution to consumers, consumption-use and finally their disposal-rejection. In this way,



consumption increases, the use of resources and energy increases in parallel, and thus the amount of generated waste.

This model does not take into account the limitation of resources, generated waste cannot be reused, and as such is unsustainable in the context of environmental protection. For this purpose, the concept of a circular economy was created, which integrates the economy and the waste management system, targeting the problems of huge amounts of waste, pollution and limited resources (Upadhayay et al., 2024). Figure 2 illustrates the distinction between a linear economy and a circular economy. A component of the "green transformation," which attempts to reduce environmental harm and dependence on finite resources, is a shift toward a circular economy model.

This approach changes the function of resources in the economy. What is waste from one factory becomes a valuable raw material in another production process (Milanović, Petković & Jovanović, 2019). Products themselves can be repaired, re-purposed, reused, improved, instead of being discarded. Concept is designed to lead to the restoration of the ecosystem, with a large number of innovations and with a significant impact on the habits of society as a whole. The circular economy prioritizes activities that have a positive impact on the environment. It implies the "use of recyclable packaging, the promotion of ecological products; the reduction of emissions and waste, the assessment of renewable and alternative energies, energy conservation, adoption of consumer goods with minimal environmental impact, eco-design, waste recovery (recycling of trash) and de-materialisation (Scarpellini et al., 2019)."

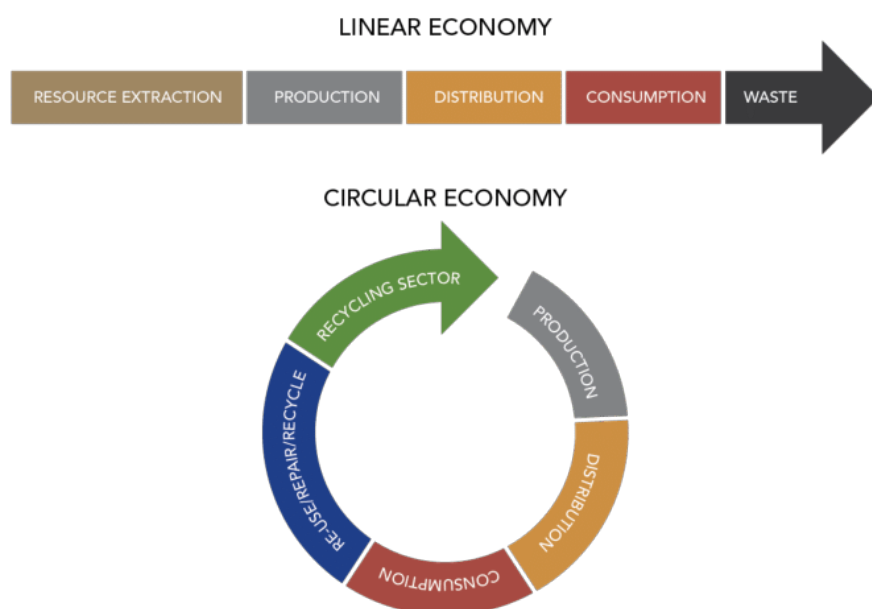


Figure 2. Linear economy vs circular economy (Unterfrauner et al., 2018)

### 3.2. Transition to Renewable Energy and Technology

Sustainable energy solutions are becoming more and more important due to the urgent problems of climate change and the depletion of non-renewable energy sources (Lv, 2023). One important aspect of the green transformation is the transition from fossil fuels to renewable energy sources. Renewable energy (RE) is necessary for producing power in an economic and environmentally sustainable manner. They include the use of wind, water, solar, bioenergy and geothermal energy (Ang et al., 2022). According to Gielen et al. (2019), these clean energy sources "*can provide two thirds of the world's energy demand while reducing emissions by up to 94%*". Using renewable energy not only reduces greenhouse gas emissions, but also increases resistance to climate change. Energy transition is a useful tool in reaching the goals set in the Paris Agreement, with the aim of limiting the average global surface temperature increase to 1.5 °C above pre-industrial levels (Skjærseth et al., 2021).

In general, the use of renewable energy is critical to accomplishing objectives of sustainable development, which include lowering greenhouse gas emissions, boosting energy security, generating employment, enhancing public health, protecting natural resources, encouraging equitable access to energy, assisting with rural development, and encouraging innovation and technological advancement. Building a sustainable and resilient energy future requires incorporating renewable energy into the energy mix.

### **3.3. Education and development of environmental awareness**

The term "environmental awareness" describes the degree of awareness and concern that individuals, groups, and society have regarding the condition of the environment and how human activity affects it (Cheng et al., 2023). It entails being aware of environmental problems and being prepared to take action to save the environment. Development of environmental awareness is an initial step in solving environmental issues and a prerequisite for sustainable development. It ensures both environmental protection and economic development. Environmental awareness is an important tool in the process of green transformation, as it encourages the manifestation of various forms of sustainable behaviors (Pinho & Gomes, 2023). Ecologically conscious individuals apply eco-friendly consumption patterns, while conscious organizations modify and establish sustainable production processes and business practices.

Basis for pro-environmental, sustainable behaviour is education. Education makes people informed and concerned about environmental problems. Higher education contributes to the reduction of household energy consumption (Li et al., 2023) and have significant impact on renewable energy utilization (Özbay et al., 2022). Furthermore, it boosts economic expansion. Additionally, highly educated human capital makes creative and effective use of technology to create clean and green products. Education contributes to the promotion of green innovation and raises human capital's awareness of the nation's ability to uphold environmental norms.

## **4. CONCLUSION**

This study aims to explicate the potential of sustainable development in mitigating underlying causes of environmental degradation and laying the groundwork for a more sustainable future. Since the long-term social and economic benefits of sustainability are outweighed by dangers associated with the effects of environmental crises, the ecological dimension of sustainable development may be its most important component (Mravcova, 2023). It won't matter whether sustainability is achieved in the social and economic spheres if we cannot ensure that humanity has a place to live and survive in the future. Therefore, linear economic models and patterns of unlimited production and consumption must be replaced by new ones, compatible with environmental protection.

Achieving sustainable economic growth based on the wise use of natural resources is facilitated by integrating green transformation components into all facets of society. The main components of the shift to an environmentally friendly economy include the conversion of a linear economy to a circular economy, the adoption of renewable energy and technology, the encouragement of sustainable environmental practices, and the advancement of environmental awareness through education.

Overcoming crises requires concentrated, coordinated efforts of individuals, organizations and structures at the local and global level. Policy makers must implement different strategies and approaches that target environmental protection with an emphasis on resource conservation, pollution reduction and promotion of sustainable environmental practices, in order to restore disturbed balance of ecosystem to its original state.

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# **CREATIVITY, INNOVATION AND SUSTAINABLE MANAGEMENT**

# EXPLORING THE IDEATION ROADMAPPING FRAMEWORK

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**Abstract:** *The starting point of successful innovation is the generation of creative ideas. Managing ideas is imperative for organizations to save on research costs, shape future developments and maintain their unique capabilities. Idea management is recognized as a critical component of the Fuzzy Front End (FFE) process, helping organizations capture and evaluate a wide range of innovative ideas. By employing idea management tools and procedures, organizations can manage the FFE in a more structured manner, reducing the risk of spending resources on ideas that do not align with their strategic objectives or customer needs. The significance of the FFE and idea management is exceptional in academia (numerous publications) and in practice (application of various software solutions). This paper aims to explain general steps of an ideation roadmapping framework based on a literature review and interpretation of existing idea management systems. The approach should serve as the foundation for developing a comprehensive algorithm for idea management, functioning as a support tool for both the FFE and subsequent stages of innovation projects.*

**Keywords:** *Innovation, Fuzzy Front End, Idea Management*

## 1. INTRODUCTION

Modern organizations face constant competitive pressure to maintain their market position, enhance product variety, improve efficiency, and reduce costs. One solution to these challenges is innovation (Trott, 2021). Organizations that successfully leverage knowledge, skills, and experience to create novel products, services, processes, marketing strategies and way of organization gain competitive advantage. It is crucial to identify a set of relevant factors that can serve as the foundation for determining whether an innovative solution can be considered successful or not (Cooper, 2017, 2019).

One of the recognized factors for successful innovation is the effective management of the “Fuzzy Front End” (FFE) or early stages of innovation. FFE is a very important phase of the innovation process, which can be a factor that determines manufacturers’ innovation performance and sustainable growth. It is often considered as the base of successful innovation. The term Fuzzy Front End of innovation was first introduced in the work of authors Reinertsen & Smith (1991). They described this part of the innovation process as the time between the moment of spotting an opportunity in the market and the moment when a significant effort should be made to develop the project. De Brentani & Reid (2011) described the FFE as the early stages of innovation projects which involve the generation and evaluation of ideas and concept creation. According to Koen et al. (2001), the early stages of the innovation process encompass activities that precede the formal, structured innovation process, from idea generation and evaluation to concept development and approval for further development.

This stage of the innovation process is often considered one of the most challenging to manage, due to the degree of uncertainty, equivocality, and complexity involved (Stevens, 2014). Experts assert that the FFE has a significant impact on both the process and the outcome of innovation, as it greatly influences the innovative solution’s design and overall costs. However, in practice, companies often execute the FFE in an unstructured way with limited resources. As the quality of FFE implementation has a substantial influence on the success of innovation, organizations can effectively manage this impact by implementing structured idea management processes (Gassmann & Schweitzer, 2014).

Efficiently generating, evaluating, and selecting ideas through the idea management process is crucial for successful FFE management, thereby driving innovation within businesses (Gerlach & Brem, 2017). Idea management systems are particularly important in this regard, as they help companies manage the large number of ideas generated and ultimately lead to more successful innovation behavior. Although the concept of idea management systems (in that time suggestion box) originated in the manufacturing industry back in 1872, it has continuously evolved to adapt to changing contextual conditions. While traditional suggestion systems are typically focused on generating incremental improvements, modern ones may encourage the pursuit of radical innovation (for example, Shall GameChanger). Idea management system is an important

aspect of corporate management that utilizes employee creativity to generate ideas. It represents a system that provides a systematic, manageable process of idea management (Mikelsone & Segers, 2022). Ignoring this source of ideas would be a waste of organizational resources. Expert reviewers evaluate the ideas submitted, and if deemed appropriate, they are put into practice. These systems could also embed open innovation for capturing external ideas.

Identifying and evaluating opportunities, generating ideas, and creating concepts are all essential components of the FFE, making it challenging to optimize the entire process. However, it can be possible to start by improving individual stages, such as the idea management process. Boeddrich (2004) suggests that to create successful innovations (1) the innovative ideas should be aligned with companies' strategic goals in early stages of the innovation process, and (2) the idea management process should be structured and conducted systematically. Many authors have explored this issue (Table 1).

**Table 1:** Idea management process

Authors	Phases of the idea management process
(Thom, 1980)	Idea generation, acceptance and realization
(Wood, 2003)	Idea gathering, idea development, implementation, measuring results, recognition and rewards
(Summa, 2004)	Ideation, idea gathering, idea evaluation, idea development, idea implementation, idea follow-up and rewarding the innovator
(Iversen et al., 2009)	Inspiring and involvement, generation and capturing, development and enrichment, evaluation and selection, implementation, post-implementation learning and feedback
(Westerski et al., 2011)	Ideation, idea improvement, idea selection, implementation, deployment
(Malik, 2014)	Idea genesis and gathering, idea evaluation and selection, idea feedback and recognition, idea implementation, idea bank

Based on previous research, the aim of this study is to define a general approach for idea development through all stages of the process. This approach may serve as a basis for defining comprehensive algorithm of idea management process functioning as a support tool for both the FFE and subsequent stages of innovation projects. The framework is grounded not only on a literature review but also on an examination of idea management systems from the well-known platforms, such as Innovation cloud, HunchBuzz, Sopheon, IdeaWake, IdeScale, Wazoku, Shall GameChanger, OpenIDEO, etc.

## 2. THE KEY ELEMENTS OF ROADMAPING FRAMEWORK

This section of the paper outlines identified key elements of managing ideas, which can be considered as a roadmap for understanding and implementing this part of the innovation process, describing a conceptual model of idea management derived by interpreting various theory and practice within the field.

### 2.1. Innovation strategy and objectives phase

The first step should be defining the innovation strategy aligned with the corporate strategy and the company's specific knowledge and capacity to exploit it (Kerka et al., 2009). Many authors claim that effective idea management can contribute to the success of a company, if the setup is strategically planned and operated (Gerlach & Brem, 2017; Westerski et al., 2011). This step helps define the strategic focus and research field, which should be attractive and built upon existing knowledge and experience from the market and production. The goal is to clearly define the boundaries for the quest of new ideas (PDMA, 2020; Tidd & Bessant, 2021). One of the key issues in defining the innovation strategy is determining the sources of ideas, whether they are internal, external, or a combination of both. According to Harland & Nienaber (2014), an almost equal number of ideas come from both internal and external sources. For example, Proctor & Gamble's innovation strategy in the early 2000s aimed to have 50% of the company's future innovations come from external relations, highlighting the importance of engaging external knowledge and innovative solutions.

In addition to complying with the innovation strategy, ideas must also align with the organization's defined goals and objectives. These goals determine what a potential innovation should achieve in terms of revenue, costs, market share, etc. They should be clearly defined, feasible, and understandable. Performance metrics are important to track innovation and allow an organization to measure the impact of process improvements over time. These measures can include aspects of the process, such as time to market and duration of particular process stages, as well as outcomes such as the number of new products commercialized per year and percentage of sales due to new products (Tidd & Bessant, 2021).

The next step of the framework is to identify and define the criteria that will be applied in the idea evaluation phase. This step is closely related to defining objectives, with the difference that these objectives/criteria are related to the specific field of idea evaluation (Boeddrich, 2004; Gerlach & Brem, 2017). The evaluation phase represents a great challenge because ideas carry insufficient information and great uncertainty. Therefore, it is very difficult to prioritize ideas (as there are usually many ideas) and to make the right decision about which idea should advance and enter the further development process. Studies have shown that the failure rate of new products is very high. The percentage varies from industry to industry. In the literature, different failure rates of new products ranging from 40% to 90% can be found (Haller, 2013; Tidd & Bessant, 2021). Based on this range, it can be said that there are different opinions among researchers and practitioners, but this big range implies that this kind of research cannot enable precise results.

## **2.2. Idea generation**

Idea generation, also known as ideation, is the process of creating new and creative ideas. Therefore, creativity is essential during this phase and is determined by the ideator's proficiency, imaginative thinking abilities, and drive (Amabile, 1997). This phase is typically depicted as a wide funnel, with the goal of collecting as many ideas as possible to increase the value obtained from a structured idea management process (Cooper, 2017). Idea generation begins with gap identification which represents opportunities or chances that exist within the organization or in the market. A gap can take the form of an innovative product/service, a new need, a new technology, or a rough assessment of how to overcome a perceived challenge. As gaps are uncertain, they can also be seen as hypotheses of potential future values and ways to achieve them (Toubia, 2006; Ulrich et al., 2020). Once the gaps are identified, it is essential to define the approach for collecting ideas. The framework should include both internal and external sources of idea generation. While some organizations rely solely on internal sources to safeguard intellectual property, a combination of internal and external sources can yield a significantly greater number of ideas (Hallerstede, 2013; Kohler & Chesbrough, 2019).

## **2.3. Idea improvement**

The process of idea generation is followed by a very important step, which involves the improvement of the proposed creative ideas. This step can be considered as an intermediate part of the idea management process since it occurs before the formal evaluation process (Gerlach & Brem, 2017; Westerski et al., 2011; Iversen et al., 2009). During this phase, the ideas are reviewed and corrected, if necessary, to achieve an adequate improvement. Commenting and discussing the proposed ideas are the most commonly used mechanisms. Game mechanisms like badges and points can also be used to promote collaboration (Milutinović et al., 2018, 2020). Westerski et al. (2011) highlighted stakeholder workshops and scenario planning as valuable tools and methods for identifying weak points or providing incentives for an idea. Idea improvement enables the idea contributor to enrich their idea by gathering additional information, for example, through market studies or scientific experiments, for parts where they lack expertise or access to information. Feedback and insights from different sources can help contributors assess the feasibility of their ideas and identify areas that require improvement (Fairbank et al., 2003). This phase usually does not consume too much time.

## **2.4. Idea evaluation**

A common mistake is to believe that idea generation is the sole focus of innovation. Although it is an important part of the process, the evaluation of those ideas is equally critical in ensuring that innovation processes deliver positive results (Todd et al., 2023). The evaluation process represents a tool for decision-making which aims to determine whether an idea should progress or be rejected. In essence, the evaluation acts as quality assurance for innovation, ensuring that resources are not wasted on ideas that provide no value (Soukhoroukova et al., 2012; Wazoku, 2023). Once the idea improvement period is complete, the idea enters the evaluation process, which is carried out by evaluators or experts from the field (Figure 2). The first step in the evaluation process involves preliminary assessment, which is typically based on the individual opinion of the expert who is responsible for this stage. This initial review (performed by the expert) assesses the sense, quality, and clarity of the idea and provides feedback. Depending on the given review, ideas may either progress, be sent back or be rejected. The preliminary evaluation is designed to ensure that duplicate or incomplete ideas do not progress (Gerlach & Brem, 2017; Wazoku, 2023). If the idea progresses to the next stage, evaluators are selected based on the area or areas it affects. Experts are usually from different functional units such as marketing, research and development (R&D), production, etc. (Soukhoroukova et al., 2012). The criteria are then chosen from a predefined pool of criteria based on the area where the generated ideas will have an impact. The output of the evaluation phase is a prioritized list of ideas based on the total score of all proposed ideas. The position of an idea on the list indicates its potential for implementation and the possibility of transforming it into an innovation.



In cases where idea generation is based solely on external sources and knowledge, different evaluation mechanisms (such as those applied in Wazoku Platform, Quirky, Open Innovation Platform, etc.), are employed (Milutinović et al., 2018, 2020). Even in such cases, a group of experts may make the final decision about advancing an idea. Open evaluation, on the other hand, involves all stakeholders by utilizing technology-based mechanisms (for example, voting on the Threadless platform or combining voting and comments on the My Starbucks Idea platform).

## 2.5. Idea selection

Once the evaluation process is complete, the ideas are reviewed again to ensure alignment with the organization's innovation strategy and goals. Based on this, a list of prioritized ideas is created, and the selected ideas are then moved forward for implementation in the execution phase. This involves creating concepts, prototypes, and final innovations. Usually, a reward system is implemented in this phase to incentivize individuals and teams to work towards the successful execution of the selected ideas (Mikelsone & Segers, 2022; Valdati et al., 2020). Offering rewards to stakeholders is crucial for maintaining their motivation and sense of value within the organization (Wilson et al., 2010).

## 3. CONCLUSION

Innovation has long been a strategic focus of most organizations, especially those operating in markets where constant changes occur. This situation has led to the need for identifying multiple sources of ideas to increase the number of creative ideas, as well as the need for finding new solutions that apply cutting-edge approaches and methods for managing ideas. Having in mind the fact that there are not so many papers that explain and describe the structure of the idea management process and considering the nature of the FFE (degree of uncertainty, equivocality, and complexity), the proposed roadmapping framework may be of big importance in further interpretation of this part of innovation process for both academy and practice. It can be said that the proposed approach could serve as roadmap for understanding and implementing the idea management process. As for academy this research could serve as the foundation for further structuring of other parts of FFE and for in-depth analysis of its individual segments. When it comes to practice, different stakeholders might follow the framework for better understanding the process. It also may serve as the base for software developers and companies for understanding the process and creating a tool, that is, an idea management system. Such a systems have proved to be a useful tool for gathering a large number of quality ideas that have a greater potential to grow into successful solutions.

The roadmapping framework allows the complete process to be viewed in steps, defined according to the identified stages of the idea management process. This level of transparency is crucial for all participants in the system. Therefore, the presented framework could be an ideal starting point for anyone planning to introduce such an approach as part of their innovation management system. Future research will focus on elaboration of the details enabling defining the algorithm for idea management process. There is also a possibility of expanding this concept by connecting it to other segments of the early stages of innovation. and incorporating contemporary approaches (for example, artificial intelligence)

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# STRENGTHENING ENTREPRENEURIAL ECOSYSTEM – A COMPARATIVE STUDY

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**Abstract:** *There are numerous factors that impact the success of entrepreneurial ecosystems. Successful ecosystems create conditions that encourage talented entrepreneurs to start their own business. The objectives of the research are to identify key environmental factors important for the improvement of entrepreneurial activity, to analyze developed entrepreneurial ecosystems in selected countries and to identify key factors of their success. Based on the results, and comparative case study, the paper presents guidance for improving entrepreneurial ecosystem in the Republic of Serbia. One of the conclusions is that Serbian entrepreneurial ecosystem can develop its competitiveness by specializing in industries like blockchain and gaming, as they have proven to be driving forces of the growth in the past few years. Also, specific recommendations are listed as directions for strengthening the competitive power of entrepreneurial ecosystem in Serbia.*

**Keywords:** *entrepreneurship, ecosystem, comparative study, Serbia*

## 1. INTRODUCTION

Entrepreneurial ecosystem represents a social and economic environment that encourages entrepreneurial activity. It is accepted that more developed ecosystems provide better opportunities for rise of startup companies. Given the impact of entrepreneurship and innovation on economic growth (Srikanth et al., 2021), a lot of attention is given to supporting entrepreneurial activities.

The objectives of the research are to identify key environmental factors important for the improvement of entrepreneurial activity, to analyze developed entrepreneurial ecosystems in selected countries and to identify key factors of their success. Based on the results of the research, and comparative study of Slovenia, Hungary, Romania and Serbia, recommendations for the improvement of startup ecosystems in Serbia will be formed.

## 2. ENTREPRENEURIAL ECOSYSTEM

Entrepreneurial activity is manifested through the growth of the number of innovative startups, fast-growing startups and the number of entrepreneurs. The key elements of the environment necessary for the success of entrepreneurial startups are (Kende, 2015):

- knowledge, i.e. education and research activity;
- competent employees, capital, access to infrastructure, etc.;
- mentoring and collaboration that are necessary for startups to overcome the initial challenges and achieve sustainable growth.

According to Spigel and Kitagawa (2020), entrepreneurial ecosystems can be defined as “regional collection of actors and environmental factors that contribute to creation and survival of high-growth ventures”. This definition stresses a variety of subjects and processes involved in the development of the entrepreneurial ecosystem, as well as specific geographical context. Entrepreneurial ecosystems emphasize the impact of environmental factors on entrepreneurial activity in a certain territory and interactions between various subjects needed to support new ventures appearance and success (Andonova et al., 2019).

Ecosystems do not focus solely on start-ups (Isenberg, 2011), despite the fact that high-growth start-ups are more innovative and effective (Shwetz et al, 2019). All new companies contribute to employment growth, it is only a fraction of these firms that create the majority of employment growth and are able to scale up (Acs et al., 2014). Thus, ecosystems are supportive environments for entrepreneurial activity, all potential

entrepreneurs, start-ups, growth-oriented innovative firms and larger corporate entities (Brown & Mason, 2017).

Technology startups, that focus on creating technology products and services, are “temporary organizations that are designed to easily search for repeatable and scalable business models” (Blank & Dorf, 2012). Their survival depends on cooperation and innovation, entrepreneurial culture and organizational agility of their founders (European Commission, 2021). Founders of innovative startups face a higher risk than entrepreneurs - they do not know who their target customers are, they do not know the characteristics of their market and cannot research it, because these introduce products and services that did not exist before. The founders of startups cannot use past data to forecast the future sales. Startup founders usually do not have the experience needed to manage a company's development. That is why entrepreneurial ecosystems are important - they enable the sharing of experiences and information that are necessary for the founders of startups to successfully overcome the problems in the realization of their ideas.

## 2.1. Key success factors

According to the contemporary approach to entrepreneurship, individual entrepreneurs cannot succeed if a business context does not support development and commercialization of entrepreneurial ventures (Stam & van de Ven, 2021). Successful ecosystems create conditions that encourage talented entrepreneurs to start their own business. According to research by the World Economic Forum (2020), entrepreneurs perceive market access, human capital and financing as key elements of successful ecosystems. Access to the domestic market is just as important as access to foreign markets. The value of human capital is primarily manifested through the possibility of hiring talented workers who possess the skills necessary to build a competitive advantage. Most entrepreneurs cite access to finance as a key success factor (World Economic Forum, 2020).

There are numerous factors that impact the success of entrepreneurial ecosystems. Since entrepreneurial ecosystems can operate on local, regional or national level, it is difficult to identify key success factors (Stam & van De Ven, 2021). For example, according to the World Economic Forum (2020), key success factors include access to human capital, markets, and finance.

Given that entrepreneurial ecosystems are considered to be “entrepreneur-centric hubs of activity, focused on a specific sector or market opportunity in a given city or region” there are several approaches to factors that facilitate their success. Factors that support entrepreneurial ecosystem development include (Viktoria Solutions, 2015):

- consistent intellectual property protection frameworks,
- technical standards that support innovative business models
- access to affordable and diverse funding sources,
- presence of role models - successful entrepreneurs who inspire and support new entrepreneurs,
- government and non-government organizations celebrating success stories and protecting entrepreneurs' interests,
- market open to innovative products, technologies, services, and business models,
- educated and skilled workforce,
- private and public sector that serve both as buyers and suppliers,
- cooperation with corporate sector through incubator, partnerships, sponsorship, corporate venture capital and similar.

Entrepreneurial ecosystems require several committed entrepreneurs who will create networks and engage other stakeholders. For example, large companies, incubators, investment funds, accelerators, and service suppliers provide mechanisms that support entrepreneurial activity but they will not create a network on their own. They need encouragement to become mentors or investors. Similarly, governments design policies needed to facilitate entrepreneurial ecosystems growth through venture funds, incubators and similar, and through education, private sector empowerment, investment and intellectual property protection mechanisms, fundamental scientific research and similar, but they can only complement and boost entrepreneurial activity (World Economic Forum, 2020).

Although entrepreneurial ecosystems are predominantly a local or regional phenomenon, entrepreneurs usually have to compete globally for financing and customers. Especially in early stages of growth, entrepreneurs need access to funding. Later, they need access to labor markets and customers. Therefore, local investors play crucial role in the early stages of entrepreneurial ventures. Culture also plays an important role in development of entrepreneurial ecosystems – overconfidence and ambition can be equally damaging to entrepreneurs as lack of confidence and risk aversion. Finally, power of industry incumbents and the timing of the entry to the market are important factors of entrepreneurial ventures success (Aaltonen, 2016).

### 3. COMPARATIVE ANALYSIS

For the purpose of the analysis, several relevant and comparable countries in the South-east Europe were chosen. Based on the data in Table 1 (*Startup Genome, 2020, Startup Blink, 2021, Yushkevich, 2020, European Commission 2020, OECD, 2020*), it can be concluded that:

- Slovenia ranks best in terms of innovation, ease of doing business, national competitiveness and innovativeness, despite being the smallest market in size. However, since Slovenia is the member of the European Union, start-ups have access to more than 400 million consumers;
- Entrepreneurial ecosystems in the chosen countries specialize in different industries which allows them to specialize and grow without direct competition in the region;
- Serbia ranks better in Doing Business report, but worse in other global indexes. Still, it has a significant number of startups, especially given the size of the market and the fact that all other countries are members of the European Union.

**Table 1:** Comparison of relevant indicators of selected ecosystems

Groups	Serbia	Slovenia	Hungary	Romania
Total early-stage funding (million US\$)	38	-	211	116
Ecosystem value (million US\$)	677	-	1600	-
Ease of doing business (rank 2020)	44	37	52	55
Global competitiveness index (rank 2019)	72	35	47	51
Global innovation index 2021 (rank)	54	32	34	48
Number of ecosystems	Belgrade, Nis, Novi Sad	Ljubljana, Novo Mesto, Maribor	Budapest, Debrecen, Szeged, Pecs (6)	Bucharest Cluj-Napoca, Timisoara (8)
Population (million)	8.7	2.4	9.6	19
Top industries	Marketing & Sales, Software & Data, Health	Foodtech, Transportation, Education	Education, Foodtech, Transportation	Social & Leisure, Hardware & IOT, Fintech
Number of start-ups	219	131	233	233
Networks (number of coworking spaces, accelerators, organizations etc.)	28	5	31	24

*Source: Authors, based on the data available (Startup Genome, 2020, Startup Blink, 2021, Yushkevich, 2020, European Commission 2020, OECD, 2020)*

Hungarian startup ecosystem was established in 2006, and its growth has been supported by Joint European Resources for Micro to Medium Enterprises which facilitated the appearance of many startups. Government support is also significant as one of the long-term development goals is developing entrepreneurial ecosystem. Government offers tax incentives to business angels and organizes numerous conferences, events, meetings and similar gatherings (Yushkevich, 2020).

Romanian entrepreneurial system is in the early stage of development. According to the report by the European Commission (2020), environmental factors are not favorable for entrepreneurial ecosystem growth – economic and political instability, lack of access to funding and education and limited government support are the main barriers. The birth rate of all firms, including entrepreneurial ventures, motivated primarily by the opportunity of self-employment, is low, and survival rates are about 40 to 60%. Finally, innovativeness of Romanian companies is below the average of the European Union.

Slovenia has become a startup hub and a superb ecosystem for crypto currency and Fintech. Besides geographical advantage, Slovenia offers excellent conditions for startups in terms for administrative procedures for foreign investors, government support and access to financing (Startup Blink, 2021). Slovenia ranks high in terms of skills and knowledge, but entrepreneurs face challenges in terms of financing. One of the challenges for Slovenian entrepreneurial ecosystem is the shortage of labor and depend on hiring foreign workers (OECD, 2020).

The most important subsectors in Serbian are gaming and blockchain-based product development. Serbian ecosystem is attractive primarily due to (Startup Genome, 2020):

- access to skilled workforce – there are more than 40000 employees in IT sector, and every year about

30000 engineers graduate at local universities and colleges. Additionally, programming is compulsory in primary schools, and numerous high schools offer specialized IT courses.

- tax incentives – founders of start-ups enjoy various incentives and tax credits. Additionally, Serbian government offers fund-of-funds mechanism through Serbia Ventures program.

Unicorns, or startups that reach 1 billion US\$ in funding, are not common in the region. The majority of European startups come from Sweden, UK and Estonia. Although European companies raised about 21 billion US\$ in 2021, which is three times more than the year before, cumulative capital invested in South-East Europe is well below than in the West and North Europe. For example, in South-East Europe, cumulative capital invested per capita reached 70US\$ compared to 1000 US\$ in the west (Ionita, 2022).

In 2018, robotics startup from Romania became unicorn. This helped other startups and in 2021, Elrond, digital wallet innovator, became the second unicorn from this ecosystem (Ionita, 2022). First Hungarian unicorn is Prezi, highly popular presentation tool. After Prezi, several more startups attracted more than 1billion US\$, including LogMeln, Ustream and AIMotive. There are still no unicorns from Slovenia and Serbia.

Based on the analysis on the chosen European entrepreneurial ecosystems it can be concluded that:

- business environment is important for the ecosystem growth, given the success of Slovenia, but it is crucial – Romania and Hungary are below Serbia and Slovenia in terms of the ease of doing business, but have more unicorns;
- appearance of unicorn is important and seems to be crucial for the generation of other unicorns, as cases of Romania and Hungary prove. This is consistent with the conclusion of both Startup Genome and World Economic Forum – networks and mentoring have significant impact on the entrepreneurial ecosystem growth;
- in all ecosystems, entrepreneurs are facing the challenge of financing their ventures. Although important, it can be overcome by expanding to international market and using new technologies such as crowd funding. This also confirms the importance of infrastructure – entrepreneurs need access to Internet in order to attract investors;
- role of government is confirmed – Slovenia, Serbia and Hungary support their entrepreneurial ecosystems, while Romanian government lags behind.
- technology appears to be an important factor for the growth of entrepreneurial ecosystems– all ecosystems operate in ICT sector, or industries based on the use of new technologies,
- access to market is confirmed to be an important factor of the success of entrepreneurial ecosystems – Hungary and Romania have bigger domestic markets than Slovenia and Serbia,
- access to labor have medium impact on the success of entrepreneurial ecosystems – Slovenia lacks skilled workforce but employs workers from abroad.

Collected data were used for conducting the SWOT analysis of Serbian entrepreneurial ecosystem. Start-up founders stated financing, acquiring customers and staffing as the major obstacle to growth.

<b>Strengths</b> <ul style="list-style-type: none"> <li>- access to technical and management talent,</li> <li>- government support,</li> <li>- ease of starting business,</li> <li>- mentors and advisors,</li> <li>- incubators and accelerators,</li> <li>- business friendly regulations</li> </ul>	<b>Weaknesses</b> <ul style="list-style-type: none"> <li>- small domestic market</li> <li>- access to financial markets</li> <li>- cultural support</li> </ul>
<b>Opportunities</b> <ul style="list-style-type: none"> <li>- access to foreign markets,</li> <li>- the role of universities is changing,</li> <li>- network of entrepreneurial peers is growing,</li> <li>- available workforce with pre-university and university education</li> <li>- digital transformation</li> <li>- infrastructure improvement</li> </ul>	<b>Threats</b> <ul style="list-style-type: none"> <li>- competition in the South-East and Central Europe, with better access to European Union market</li> <li>- reliance on internal sources of financing</li> <li>- lack of skilled workforce</li> <li>- lack of unicorns – success stories and role models.</li> </ul>

**Figure 1: SWOT analysis of the Serbian entrepreneurial ecosystem**

*Source: Authors' summary*

SWOT analysis of Serbian entrepreneurial ecosystem shows that identified weaknesses could be overcome by supporting entrepreneurs to expand to international markets, as well as through popularization of entrepreneurship through formal and informal education. Further improvements in access to more diverse funding sources are expected due to the change in relevant laws, as well as due to the stable macroeconomic

environment. Digital transformation of public and private sector will increase demand in domestic market.

#### 4. CONCLUSION

Serbian entrepreneurial ecosystem can develop its competitiveness further by specializing in industries like blockchain and gaming, as they have proven to be driving forces of the growth in the past few years. At the same time, ecosystems in the neighboring countries are focusing on other industries. Increasing number of opportunities for formal and informal education in digital skills and entrepreneurship will resolve the lack of skilled workforce. Specialization will hopefully result in the appearance of unicorns, which will further support the growth of entrepreneurial ecosystem.

Based on the analysis, recommendations for managers and entrepreneurs are:

- encourage potential entrepreneurs to start their ventures it is necessary to provide entrepreneurial education as well as opportunities for understanding the business environment,
- develop networks within the entrepreneurial ecosystem and beyond it,
- explore various sources of funding and ensure their accessibility and regulation,
- include representatives of universities into meet-ups, conferences and other forms of networking,
- strengthen the connections between formal education institutions and entrepreneurs – mentorship and coaching can contribute to closing skills gap,
- promote industry-institute partnerships,
- make sure that patent commercialization is transparent and user-friendly process,
- ensure that entrepreneurs understand the benefits of accelerators, incubators and co-working spaces, and have access to them,
- develop a database for high-tech start-ups that contains important data on multilateral and bilateral agreements, grants and other investment sources and stages of investment, employment opportunities, and other to support scaling up and internationalization.

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# CIRCULAR ECONOMY AND SUSTAINABLE HUMAN DEVELOPMENT- A COMPARISON OF SERBIA AND NIGERIA

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**Abstract:** *This paper explores Serbia and Nigeria are implementing circular economy practices. It examines the current state of sustainable practices in both countries. specifically in the areas of waste management, renewable energy and sustainable agriculture. It also shows how each country is adapting to changes related to sustainability and opportunities available within its own social, economic, and environmental landscape. By making a comparison between Serbia, an emerging European economy, with Nigeria, a developing African nation, insight is gained into the different strategies and results of adopting circular economy principles. The study in the process also highlights key barriers like policy gaps, technological limitations, and social constraints. Moreover, this study gives an understanding of how practices supporting circular economy can aid economic growth, healthier environments, and social well-being in diverse developmental settings.*

**Keywords:** *Circular Economy, Sustainability, Waste management, Renewable energy, Sustainable agriculture*

## 1. INTRODUCTION

The United Nations Sustainable Development Goals (SDGs), introduced in 2015, caused a worldwide push for a more sustainable future, particularly focused on how we consume and produce. This paper explores how Serbia and Nigeria are approaching this challenge by adopting circular economy practices. We will look into how these two countries, with their unique social, economic, and environmental situations, are making this transition. Serbia is an emerging European economy, while Nigeria is a developing African nation – each faces its own distinct hurdles and potential rewards. This study aims to: Analyze the current progress of circular economy practices in both countries. We will look specifically at waste management, sustainable resource use, and eco-friendly production methods. By comparing Serbia and Nigeria, this research offers a look at the different paths countries can take towards a circular economy, depending on their level of development. This side-by-side analysis reveals the delicate balance between economic growth, environmental protection, and social progress.

## 2. CIRCULAR ECONOMY PRACTICES IN SERBIA: AN EXPANDED OVERVIEW

### 2.1 Overview and Current Status

Serbia has faced challenges, in developing an economy due to political factors. Unlike countries such as Denmark which has taken steps, Serbia has focused on rebuilding its market economy after the communist era and addressing issues stemming from conflicts and international sanctions (Rajaković, 2021).

Ristanović (2022) found that this has led to a lack of emphasis on matters causing Serbia to fall behind European nations in terms of sustainability. However, as Serbia aims for EU membership it must adhere to standards.

## 2.2 Waste Management

Poor waste management in developing nations suggests that the amount of waste generated is mostly influenced by the economic status of a society, their weak social economic factors affected by lack of robust environmental laws, financial control, and administrative capabilities (Ilić & Nikolić, 2016).

Josimović et al. (2022) believe that Serbia has made strides in improving its waste management systems, with a focus on reducing landfill use and enhancing recycling processes. While the Waste Management Strategy from 2010 to 2019 made some headway by introducing updated rules and new infrastructure it lacked aspects such as waste collection, recycling practices, and the closure of unsanitary landfills. In line, with the principles of circular economy Serbia acknowledges the importance of waste management. Recent studies have highlighted that embracing the concept of an economy involves utilizing resources to their potential. One proposed solution is to incorporate practices that facilitate the reintegration of waste into the production cycle encompassing sectors of the economy (Milanović et al., 2022). This strategic approach is crucial as Serbia advances towards implementing waste management strategies crucial, for enhancing environmental sustainability and economic effectiveness. The launched Waste Management Program spanning from 2022 to 2031 recognizes these shortcomings showcasing Serbia's understanding of the hurdles involved in translating policies into effective measures (Ministry of Environmental Protection, Republic of Serbia, 2022). Bjelić et al. (2024) noted that this new approach in line, with the objectives of the EU highlights the importance of reducing waste production and optimizing resource use. It signifies a change in Serbia's waste management strategy moving away, from disposing of waste to appreciating resources in a sustainable cycle.

## 2.3 Renewable Energy

Korhonen et al. (2018) state that the Utilization of renewable energy plays a key role, in creating circular products and resources encompassing the entire process from designing and manufacturing components of renewable facilities to their construction, operation, and eventual disposal.

Kosanović, Miletić, & Marković (2021) noted that the shift towards renewable energy is pivotal in Serbia's circular economy strategy, and for that happenings such as Investments in solar, wind, and biomass energy to reduce the country's reliance on fossil fuels and decrease carbon emissions. Khajuria et al. (2022) stated that renewable energy sector not only contributes to environmental sustainability but also presents opportunities for economic development and job creation. According to Knäble et al. (2022), sustainable development and circular economies can only be achieved by promoting and adopting renewable energy since the economy relies on energy as a fundamental input for goods and services. Challenges such as financing renewable energy projects and the need for policy support are being addressed through partnerships with international organizations and the European Union (Renewable Energy Association of Serbia, 2021).

## 2.4 Sustainable Agriculture

Serbia is faced with an issue of food wastage posing both a challenge and an opportunity to enhance its agriculture industry (Vukelić et al., 2023). Reports show that around 770,000 tons of food are wasted yearly with most of it ending up in landfills and contributing to greenhouse gas emissions (UNECE, 2022). Given the crucial role agriculture plays in Serbia's economy, where food production makes up 10.4% of exports and 6% of the GDP. Addressing this problem through a circular economy approach is seen as a priority (Gajić et al., 2021). The UNECE offers Serbia support in terms of guidance and tools to measure and tackle food loss and waste along the supply chain (Joshi, 2022).

### **3. CIRCULAR ECONOMY PRACTICES IN NIGERIA: AN IN-DEPTH EXAMINATION**

#### **3.1 Overview and Current Status**

The population of Nigeria has been approximated at 229.2 million people as of 2024, calculated with 2.39% growth index from 2023 (Macrotrends, 2024). Onungwe et al. (2023) noted that the nation's abundant natural resources have somehow played a role, in driving its economic growth leading to its consistent ranking as one of the top economies in sub Saharan Africa since 2004. Nigeria is still new to exploring the possibilities in waste management and the circular economy sector which offers a chance for progress (Ezeudu & Ezeudu, 2019). Ogunsanwo & Ayo-Balogun in their research work stated that, to make the most of this opportunity Nigeria requires a defined plan for embracing the economy. Steps should be outlined, practices should be endorsed, and economic growth should be stimulated.

#### **3.2 Waste Recycling and Management**

The environmental challenges faced by the Sub-region are significant and Nigeria is no exception when it comes to managing municipal solid waste (MSW) (Adedara et al., 2023). In Nigeria, there is a major problem with waste collection with an estimated average collection rate of 44% across African nations (Adedara et al., 2023; Kaza et al., 2018). 80% of components of MSW end up in dumpsites while only 12% are actually recycled (Kehinde et al., 2020). The management of MSW in Nigeria and other developing countries is characterized by a lack of data on waste generation, absence of waste sorting systems, limited service coverage, inefficient operations, low recycling rates, and poor practices (Wikurendra et al., 2022; Nnaji, 2015).

Although there have been some improvements in landfill infrastructure and private partnerships (PPP) related to MSWM in Nigeria recent challenges such as urban migration, insufficient funding for the waste sector lack of infrastructure development and absence of innovative technologies continue to hinder progress (Nwosu & Chukwueloka, 2020; Aliu et al., 2014). This situation has resulted in a subpar state for the MSWM system. Similar issues have been observed in the past due to policies, inadequate funding, and lack of data, on waste collection that have negatively impacted the MSWM system.(Nwosu & Chukwueloka, 2020; Aliu et al., 2014)

#### **3.3 Renewable Energy Transition**

In Nigeria, the transition to renewable energy within the framework of a circular economy is progressing, but challenges remain. The country, rich in solar, wind, and biomass potential, has taken steps towards leveraging these resources to reduce dependency on fossil fuels and promote environmental sustainability. Recent initiatives focus on integrating circular economy principles into sectors like solid waste management, which is seen as a crucial component for sustainable energy production, particularly in biomass (Onungwe, Hunt, & Jefferson, 2023). However, the transition is hindered by infrastructural deficits, financial constraints, and a lack of widespread technical expertise (Ezeudu & Ezeudu, 2019).

To combat these challenges, strategies are being implemented to foster better resource management and waste reduction, which are central to the circular economy model. Efforts include promoting recycling and the reuse of materials in various industries, including construction, which significantly contributes to sustainability and resource efficiency (Bello & Idris, 2023). The government, along with private sector partners, is increasingly recognizing the importance of digital technologies in enhancing the effectiveness of these strategies, driving the country closer to a circular economy that supports renewable energy transition (Olaghere, Inegbedion, & Osiobe, 2023).

#### **3.4 Sustainable Agriculture**

The agricultural sector, which plays a role in Nigeria's economy by providing food and employment opportunities has the potential to lead the way in sustainable practices (Omodero, 2021). However issues like soil salinity and degradation pose challenges to productivity and sustainability (Kayode et al., 2021; Usman et al., 2018).

While efforts to embrace circular economy principles in Nigeria show promise, they also encounter obstacles such as lack of infrastructure, weak regulations and limited professional involvement (Onungwe et al., 2023). The shift towards a circular model in areas like solid waste management and construction is essential for sustainable agriculture since these sectors offer crucial resources and infrastructure for agricultural development (Aremu et al., 2019; Bello & Idris 2023).

Innovative approaches like leveraging technologies in service delivery are starting to transform the agricultural sector by enhancing supply chain efficiency and reducing wastage thereby supporting the circular economy initiatives, in Nigeria (Olaghere et al., 2023).

In addition educating agricultural extension workers on methods can speed up the acceptance of these principles, in regions boosting food security and reducing poverty by enhancing agricultural productivity (Alabi & Ajayi 2018).

4. ANALYSIS

Table 1 presents a side, by side analysis of waste recycling and management practices in Serbia and Nigeria. According to a report, by EU za Tebe (2024) Serbia produces around 2,950,000 tons of waste each year with 79.45% of it not managed and disposed of in landfills indicating significant waste management challenges. The recycling rate in the country is currently at 15.45% suggesting there is room for improvement in waste processing practices. On the other hand, Agbo (2023) highlights Nigeria's pressing waste management issues. With a waste generation of 32,000,000 tons about 25% is recycled in Nigeria while a staggering 75% of the waste remains unmanaged and ends up in landfills. These statistics underscore the need for waste management systems, in both countries to address environmental concerns and encourage sustainable practices.

Table 1: Waste recycling and management

Metrics	NIGERIA	SERBIA
Total waste produced yearly	32,000,000	2,950,000
Unmanaged waste/disposed in landfills	75%	79.45% <sup>""</sup>
Recycled rate	25%	15.45%

SOURCES: European Union Delegation to Serbia (2024); Agbo (2023).

Table 2: Sustainable Agriculture

Metrics	SERBIA	NIGERIA
Organic Farmin hectares	23,527.03	58,028,000
Renewable energy utilization	60% of agricultural waste used for biomass (2020)	Emerging efforts in bioenergy, no specific percentage available
Increase in agricultural output	11.7%	3.58 %
Impact on nation's GDP	6.29%	24.17%

SOURCES: Milovanović et al. (2022); Willer et al. (2023); Škrbić et al. (2020); Ministry of Agriculture; Nature and Food Quality of the Netherlands (2021); National Bureau of Statistics, Nigeria (2023); (O’Neil, 2024).

In Table 2 you will find a comparison of metrics related to sustainable agriculture practices in Serbia and Nigeria. In their examination of farming practices, Milovanović et al. (2022) found that Serbia has dedicated 23,527.03 hectares to organic cultivation demonstrating a strong commitment, to environmentally friendly agriculture. In contrast, Nigeria has taken an approach with the research by Willer et al. (2023) indicating that 58,028,000 hectares are under farming. Further enabling sustainability efforts, Škrbić et al. (2020) highlight the progress in renewable energy utilization in both Serbia and Nigeria through the conversion of agricultural waste into biomass for energy production with Serbia utilizing 60% of agricultural waste. This transition is reflected in agricultural outputs by Ministry of Agriculture, Nature and Food Quality of the Netherlands, (2021), where Serbia saw a 11.7% increase while Nigeria experienced a 3.58% growth rate (National Bureau of Statistics, Nigeria, 2023) showcasing significant improvements in agricultural productivity, for both nations. These advancements also contributed to the GDP; agriculture contributes 6.29% (O'Neil, 2024) to Serbia's GDP and influences 24.17% of Nigeria's GDP underscoring the vital role of agriculture in their respective economies.

### **Key Challenges**

- Both countries face infrastructure challenges, albeit in different contexts. Serbia's challenges lie in enhancing its waste management infrastructure and transitioning to renewable energy, while Nigeria struggles with basic waste collection services and energy access.
- Public awareness and participation are common hurdles. Despite Serbia's progress, increasing public engagement remains crucial. Nigeria, too, must enhance awareness to encourage participation in recycling programs and sustainable practices.
- Financial and technical resources are significant barriers. Serbia needs investment to modernize its infrastructure and adopt green technologies, whereas Nigeria requires substantial investment to develop its circular economy initiatives and renewable energy projects.

### **Opportunities for Growth**

- EU integration offers Serbia opportunities for funding, technical assistance, and policy guidance in circular economy practices. For Nigeria, international partnerships and investment in circular economy startups present significant opportunities for sustainable growth and innovation.
- Both countries can leverage education and capacity building to overcome challenges related to public awareness and participation. Fostering a culture of sustainability through education can drive long-term changes in attitudes and behaviors towards the circular economy.

### **Insights and Recommendations**

The analysis reveals that while Serbia and Nigeria are at different stages of circular economy implementation, they share common goals of sustainable development, environmental protection, and economic resilience. Both nations can benefit from:

- Enhancing policy frameworks to provide clearer guidelines and incentives for circular economy practices.
- Investing in technology and infrastructure to improve waste management, recycling, and renewable energy capabilities.
- Fostering public-private partnerships to mobilize resources, share knowledge, and innovate in circular economy solutions.
- Prioritizing education and awareness campaigns to build public support and participation in circular economy initiatives.

## 5. CONCLUSION

This research compares how Serbia and Nigeria are embracing circular economy principles despite being, in stages of growth and facing unique challenges on their path to sustainable development. Serbia has made progress in waste management and renewable energy aligning itself with European Union standards. The country's efforts to incorporate practices span sectors, supported by policy driven initiatives and infrastructure upgrades aimed at reducing environmental impact and boosting economic efficiency.

On the other hand Nigeria in natural resources faces obstacles primarily due to infrastructure deficiencies and gaps in policies. The nation is still evolving its approach to the economy with potential for advancements in waste recycling renewable energy and sustainable agriculture. Nigeria's advancement relies on strong policies implementation increased investments in technology and infrastructure as building partnerships locally and globally.

For both countries advancing involves not expanding initiatives but also deeply embedding circular economy principles into policymaking processes and community involvement. This entails promoting a sustainability culture across society levels and utilizing support, for knowledge exchange to tackle challenges effectively.

The results of this comparison highlight the importance of creating customized approaches that address the situations of each country guaranteeing that the concepts of an economy result, in real advantages for nature, finances and communities as a whole.

While Serbia and Nigeria confront their obstacles their journeys provide lessons on the complex and diverse process of integrating circular economy tactics on a worldwide scale. The dedication, to enhancement and adjustment is vital as both countries aim for more enduring futures.

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# EXPLORING UNCONVENTIONAL IT PRACTICES: RISKS AND OPPORTUNITIES FOR INNOVATION

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**Abstract:** *In the contemporary digital landscape, understanding the distinctions and overlaps between Workarounds, IT consumerization, and Shadow IT is important for organizations navigating the complexities of technology adoption. These concepts reflect the dynamic relationship between employees and technology, shaping how individuals interact with IT resources to meet their needs and enhance productivity. By comprehensively analysing these phenomena, organizations can harness the potential for innovation while mitigating risks associated with unauthorized technology usage. Moreover, recognizing the significance of these concepts underscores the importance of adaptability and agility in responding to evolving technological trends. Elucidating the phenomena facilitates organizations in optimizing their technological ecosystems to drive efficiency, innovation, and overall performance in the digital era. This paper delves into distinguishing relevant terms, highlighting both their similarities and differences, while also examining their impact on organizational performance metrics such as risk management, innovation, and overall efficiency. Through a comprehensive literature review, it seeks to clarify the nuances among these terms and their implications for organizational performance.*

**Keywords:** *workarounds, shadow IT, IT consumerization, literature review*

## 1. INTRODUCTION

Contemporary information technology (IT) surrounding is characterized by easy and simple usage, focused on user experience and broad accessibility at affordable prices. Its users have continuous access to versatile personal information systems that provide an intuitive consumer experience of creating and reproducing multimedia, easily searchable, user-generated content, ideas, and knowledge shared via social networks and the cloud. In line with the rapid development of the digital environment, which has shown no signs of stopping for more than a decade, digital native workforce often seeks innovative tools and technologies to increase productivity and meet their specific needs (Peppard, 2016). As a result of dissatisfaction with the information systems (IS) available within organizations and the drive to enhance individual performance, many users turn to utilizing technological resources and systems not provided by their organization's IT department (Ostermann et al., 2020). This reliance on alternative systems and solutions is a common occurrence after the initial adoption of IT within organizations, while achieving optimal utilization of the organization's systems remains an ongoing challenge (de Vargas Pinto et al., 2023).

Scientific literature abounds in different terms that describe the mentioned occurrences. For example, *Shadow systems, Shadow sourcing, rogue IT, Workarounds, Grey IT, Unofficial IT, Feral systems, Feral practices, Bolt-on systems, End-user development, Citizen development, End-user computing, Hidden IT, Un-enacted project, IT consumerization*, etc (Raković et al., 2020). However, although they are similar or used as synonyms, and often directly related, there is a difference in the phenomena that some of them describe. In general, using the systems under the radar of IT departments to increase efficiency and productivity (Sillic, 2019), or adopting alternative solutions to perform a task when the designated path is obstructed (Ejneffäll & Ågerfalk, 2019), which is typical for the mentioned phenomena, can be considered from two aspects. On the one hand, it leads to information security risks, consistent business logic, inefficiencies, and errors in tasks and activities throughout the organization (Đorđević Milutinović et al., 2023a; de Vargas Pinto et al., 2023; Raković et al., 2020b; Klotz et al., 2019). On the other hand, it highlights the efforts of employees to find new, innovative tools and technologies that can improve their productivity, efficiency, and processes. In this way, this phenomenon becomes a source of new ideas and solutions that can be applied in the organization. This connection can have a positive impact on organizational innovation and agility (Đorđević Milutinović, 2023b;

Junglas, 2019). Therefore, there is a need to examine these workarounds, shadow tools, solutions, and systems that are outside the scope of the IT department, to increase their efficiency and productivity, as well as management improvement.

This study aims to differentiate between the concepts of Workarounds, IT consumerization, and Shadow IT, which frequently overlap in practice and are challenging to distinguish. Additionally, it aims to analyse the influence of these phenomena on risk, innovation, organizational and employee performance. Furthermore, this research should establish the foundation for structuring a questionnaire to investigate the impact of workaround and shadow concepts on employee and organizational performance. Following the aims of the study, two research questions are defined:

*RQ1: How do the phenomena of Workarounds, Shadow IT, and IT consumerization relate to each other, and what are the key distinctions between them?*

*RQ2: What is the impact of the aforementioned phenomena on the innovation, risk management, and overall performance of both employees and organization?*

Correspondingly, research goals will be realized through a systematic review of the literature.

## 2. LITERATURE REVIEW METHODOLOGY

A systematic literature review is conducted following the methodology outlined by Xiao & Watson (2019). Two citation databases, Scopus and Web of Science (WoS) are searched using the keywords: “IT consumerization” or “Shadow IT” or “Workarounds” and “innovation”. The total number of hits for the specified keywords is 116 in the WoS and 106 in the Scopus databases. After analyzing titles, keywords, and abstracts, 25 papers from WoS and 19 papers from the SCOPUS citation database are included for further analysis. After removing duplicates, 37 papers remained. In the next step, the selected papers are fully analyzed. The inclusion criteria for selecting papers encompassed several aspects. Papers needed to exceed a length of more than 4 pages, not solely represent research announcements, and be relevant to addressing at least one of the research questions posed. Fourteen papers are selected, after which forward and backward searches are conducted.

**Table 1:** Key considerations about Shadow IT and related terms

Manuscript	Phenomenon	Key considerations
Mallmann et al., 2016	Shadow IT	Knowledge sharing influences innovation, organizational learning, and enhances productivity.
Klotz et al., 2022	Shadow IT, Business-managed IT	Shadow IT and Business-managed IT can be a source of innovation.
Tambo & Baekgaard, 2013	Feral Information Systems	These systems create space for low-cost innovations and rapid responses to changes.
Györy et al., 2012	Shadow IT	The potential for user-driven innovations facilitated by Shadow IT is highlighted.
Junglas et al., 2019	IT consumerization	IT consumerization by end users turns employees into innovators.
Köffer et al., 2015	IT consumerization	In companies that allow privately owned IT, there is a positive impact on individual IT innovation behavior.
Godefroid et al., 2021	Lightweight IT, Shadow IT	A key advantage of Shadow IT is cited as increased productivity and innovation.
Zimmermann et al., 2014	Shadow IT	The adaptability and innovative potential of Shadow IT.
Haag & Eckhardt, 2017	Shadow IT	The use of Shadow IT can lead to higher levels of innovation within the organization.
Urbach & Ahlemann, 2019	Shadow IT	Shadow IT is associated with a high rate of innovation.
Fuerstenau & Rothe, 2014	Shadow IT	Powerful drivers of innovation.
Silic et al., 2016	Shadow IT	An important source of innovation in organizations.
Soffer et al., 2023	Workarounds and Shadow IT	Source of innovative ideas for the development of processes and applications.
Bartelheimer et al., 2023	Workarounds	Mechanisms for bottom-up process innovation.

## 3. RESULTS AND FINDINGS

The following section presents summarized responses to the research questions, obtained through a detailed analysis of selected papers. Due to page limitations, the paper doesn't include a list of the selected papers that met the search criteria.

### 3.1. Distinction of concepts

Workarounds are frequently observed within organizations, involving deviations from formally established and authorized work procedures. These deviations may stem from various reasons, either positive or negative (Malaurent & Karanasios, 2020; Wibisono et al., 2022). Positive reasons for workarounds typically involve their perceived benefit to the organization or their necessity for achieving organizational objectives, such as bypassing resource shortages or overly complicated processes. Conversely, negative reasons for workarounds contribute to inefficiency and harm, often arising from employees' inadequate capabilities or their lack of motivation to adhere to established procedures. Recognizing and addressing workarounds can significantly enhance process quality as part of a continuous improvement initiative (Wijnhoven et al., 2023).

Alter (2014) identifies two primary reasons for workarounds: (1) difficulties encountered in executing work processes as desired, and (2) discrepancies between goals and incentives, the former concerning process execution and the latter involving crucial resources. Weinzierl et al. (2022) differentiate between process-oriented workarounds and information-systems-related workarounds, focusing on deviations from formal scripts and mental models of process execution. Wibisono, Sammon, & Heavin (2022) define differences in formal script deviations from deviations based on mental models, where individuals make professional judgments regarding process execution. Alter (2014) points out that challenges to preferred work methods can emerge due to insufficient IT functionality or irregularities in established routines and processes. In response to these obstacles, individuals may resort to various strategies such as bypassing them, implementing quick fixes, enhancing existing routines, replacing resources, or even establishing alternative systems like shadow systems. Moreover, workarounds can also originate from discrepancies in goals and incentives within the work environment, leading to behaviors such as feigning compliance, deception, or dishonesty. Weinzierl et al. (2022) characterize information systems-oriented workarounds as instances where individuals breach their responsibilities by utilizing others' system privileges or manipulating data, which differs from fraudulent activities or hacking attempts. On the other hand, process-oriented workarounds involve a range of actions including cross-checking, substituting tasks, reorganizing task sequences, skipping steps, and introducing unnecessary tasks. In summary, workarounds arise due to problems in process execution, deficiencies in information systems, and inadequacies in formal process scripts or guidelines.

Most methods for detecting workarounds rely on qualitative approaches, which involve techniques such as interviews, discussions, and observational data analysis. However, researchers in process mining have begun to explore quantitative analysis of process data in this area as well. According to (Weinzierl et al., 2022), existing research focuses on explaining the reasons behind employees' engagement in workarounds, while an automated detection method could uncover additional insights not accessible through qualitative means and mitigate biases that may restrict their effectiveness.

Shadow IT refers to the adoption of technologies and systems developed by business areas within an organization without the support of the IT department (Kopper et al., 2018). It includes all software (Software/Platform/Infrastructure as a Service), hardware, or IT service processes that are used or created by business units without alignment with or awareness of the IT organization (Raković et al., 2020). There are varying opinions regarding the relationship between workarounds and shadow IT. Some authors differentiate between the two based on the duration of their use, considering workarounds as short-term solutions and shadow IT as longer-term solutions (Rentrop & Zimmermann, 2012). However, (Alter, 2014) describes that a shadow system is a form of workarounds. The accurate connection between workarounds and shadow IT has not been empirically studied. Thus, it remains unclear whether users who resort to workarounds also tend to utilize shadow IT.

Despite differing opinions on their relationship, there is a consensus that both workarounds and shadow IT stem from a mismatch between user task requirements and the technology supporting them (Lund-Jensen et al., 2016). In Information Systems research, the concept of task-technology fit is crucial for individual performance. Users perceive workarounds and shadow IT as a means to overcome this misalignment, thereby enhancing productivity and fostering creative problem-solving (Alter, 2014; Ejnefjäll & Ågerfalk, 2019).

The consumerization of IT entails individuals utilizing personal IT resources, like laptops, tablets, smartphones, social media, or cloud storage, for professional tasks. This phenomenon, also referred to as the integration of consumer IT in the workplace, involves the introduction of personal hardware entitled Bring Your Own Device (BYOD) and software, social media platforms, and cloud storage solutions into a business environment. As consumer IT tools permeate organizations, they reshape how employees leverage technology in their work routines (Sadiku et al., 2018). IT consumerization unfolds in two keyways. Firstly, employees are increasingly engaging with a range of IT technologies like broadband, wireless networks, multimedia, social media, digital cameras, smartphones, and computing. This user-centric approach is termed the consumerization of IT. Secondly, it involves a shift from the IT department's control over device selection to employees choosing their

own devices, marking a shift from top-down to bottom-up innovation in IT. The phenomenon of IT consumerization cannot be considered precisely defined. General interpretation can be made more specific by considering the legality, in terms of corporate rules and procedures, of using personal devices and applications for business purposes. If done covertly, without the company's approval and awareness, it falls under IT consumerization covered by the term shadow IT, while a form regulated by formal rules for the use of consumer IT artifacts for business tasks is often referred to BYOD, which, although containing only the word device, encompasses the semantic and software found on devices (Sadiku et al., 2018; Dang-Pham et al., 2019; Junglas et al., 2019).

### 3.2. Performance influencing factors

Contemporary IT tools have become ubiquitous, largely due to the phenomenon of IT consumerization, which has had a profound impact on organizations. It has enhanced convenience and compatibility across various devices with different operating systems, boosting employee productivity, collaboration, and multitasking while reducing hardware ownership costs for companies. Additionally, it brings potential cost savings, increased job satisfaction, improved recruitment, bottom-up innovations, heightened IT workload, and enhanced customer engagement. Technology-savvy employees who choose their own IT tools can benefit the company by reducing IT staff burdens and fostering innovation partnerships (Sadiku et al., 2018; Dang-Pham et al., 2019).

IT users often resort to workaround behavior and shadow IT utilization to overcome system anomalies and constraints that hinder complete and effective task performance. Employees require tools that empower them to execute tasks to the best of their abilities. Workaround practices are primarily viewed as enhancements to the work system, facilitating the completion of urgent or complex tasks and leading to greater efficiency. These practices help mitigate some of the negative consequences of organizational systems. Consequently, users tend to improvise in their work when encountering problems, adjusting the system to achieve better performance. As a result, workaround behavior and shadow IT usage are anticipated to boost user productivity (Alter, 2014; de Vargas Pinto et al., 2023).

All the above concepts encourage, imply, and include innovative work behaviors, which are recognized as vital for organizational innovation and long-term survival. They involve intentionally generating, promoting, and realizing new ideas within a work role, group, or organization, aiming to enhance performance. Organizational innovation is fundamentally linked to these behaviors, as individual employees explore, develop, and implement ideas, ultimately driving innovation. At the individual level, such behaviors lead to more effective task performance, changes in work processes, or the introduction of new methods (Junglas et al., 2019). According to (Đorđević Milutinović et al., 2023b), key positive effects of the phenomena on innovations can be grouped as: alternative solutions that improve the process or meet specific needs that the official information systems do not cover; identification of technologies or tools that help employees be more efficient and productive; a source of innovative practices that can be extended to the organization as a whole; potential for organizational development. The same source states some of the negative aspects that can be singled out: (1) security risks related to unauthorized technology or software can create openings for potential attacks, data leaks, or information misuse. Lack of control and security measures jeopardizes data integrity and confidentiality; (2) compliance issues or more precisely non-compliance risks with internal and external rules, regulations, and standards that the organization must adhere to. This can lead to legal and regulatory issues, as well as sanctions from regulatory bodies; (3) support and maintenance challenges describe that using unauthorized software or technology can make it difficult for the IT department to provide adequate support, troubleshoot problems, and update systems. This can result in decreased productivity and efficiency; (4) IT infrastructure fragmentation may occur since different teams or individuals use different tools and technologies, hindering integration, collaboration, and information sharing. This can reduce operational efficiency and impede innovations requiring an integrated approach; (5) lack of transparency and control results in difficulty in tracking, managing, and planning IT resources that affect efficiency, budgeting, and innovation strategy; (6) financial risks may arise from using unauthorized technologies and software can lead to unforeseen costs. Licenses, subscriptions, or implementing new tools may exceed the organization's budget.

When employees use their own devices, workarounds, and shadow systems several challenges arise, including security, compatibility, and data-sharing issues. Managing diverse platforms becomes more difficult for the IT department. The proliferation of IT products and bandwidth requirements adds to the confusion. Increased heterogeneity in IT can result in knowledge gaps among individuals. All the concepts bring security risks such as data integrity, confidentiality, and authentication concerns. Managers must balance employees' desire to use described phenomena at work with the need to prevent security breaches and data loss (Junglas et al., 2019; Ostermann et al., 2020; Đorđević Milutinović, 2023b).

#### 4. CONCLUSION

Within this study, the concept of shadow IT, workarounds and IT consumerization are examined, analyzing their implications on innovation and organizational performance. Given the limited representation of this topic in Serbia, authors were additionally motivated to popularize and advance the field, contributing to the further development of theory by establishing a foundation for future researchers. Through a systematic literature review, the advantages and challenges were identified, along with an analysis of their effects on different types of innovation. The phenomena can be a double-edged sword, with the potential to stimulate innovation but also pose risks and challenges requiring careful management. Addressing the concepts issues relies on improving communication between IT departments and business users, educating, and raising awareness about risks, and adapting IT policies and procurement processes.

It has long been considered that workaround behavior typically results in adverse effects on the organization, potentially leading to additional work by disregarding the efficiency offered by the system, which could otherwise benefit the organization. Similarly, the utilization of shadow IT may elevate security risks and complicate managerial control. However, many contemporary studies consider insight into phenomena significant benefits. Hence, a comparative study evaluating the potential advantages and drawbacks of workaround behavior and shadow IT usage is strongly recommended. Further research on this topic involves conducting primary research in the territory of the Republic of Serbia, as the number of such studies is notably low. Additionally, an analysis of selected papers shows that the applied methods are mainly qualitative, suggesting potential for enhancing research on the topic through the application of, for example, structural equation modelling techniques. In the context of applying this knowledge in practice, it is desirable to define a methodological framework and conceptual model for managing described concepts to avoid risks and stimulate innovation.

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# INTEGRATED HEALTH SERVICES REPORTING IN CROATIA

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**Abstract:** In 2016, the World Health Organization developed a global strategy on integrated people-centred health services 2016-2026 (IPCHS). One of the main objectives of the IPCHS strategy is to strengthen governance and accountability. The aim of this paper is to analyze which form of non-financial reporting should be applied to achieve better accountability and governance. Using a qualitative approach and examining secondary data, the paper examines how the Republic of Croatia has responded to the challenge of the integrated health services strategy and approached the process of reporting. The results show that the strategy of integrated health services based on people's needs has not yet taken root in the Republic of Croatia, although some steps are being taken. In addition, no additional reporting has been introduced in public health organizations in the Republic of Croatia to improve accountability and governance. Therefore, the work of politicians and policy makers is needed to recognize the importance of additional reports and to start producing them, all with the aim of improving accountability and governance and achieving better communication with citizens.

**Keywords:** IPCHS strategy, accountability, governance, non-financial reporting, Croatia

## 1. INTRODUCTION

To improve accountability, public sector entities are expected to deliver services and create value in line with the principles of economic, environmental and social sustainability (Argento et al., 2020, Kaur & Lodhia, 2019). The term public sector entities refer to public sector entities at the state and local level, state-owned enterprises, higher education institutions and public health organizations. It is important to know how the results they achieve impact the community and the environment (Biondi & Bracci, 2018, Manes Rossi, 2019). Therefore, in addition to financial reports, various forms of non-financial reports have recently been produced. Indeed, studies have shown that financial reports are not sufficient to govern with public entities due to the particular nature of the activities and the type of funding (Manes Rossi et al., 2023). Therefore, non-financial reports are recognized as new tools to improve the communication of public sector entities with external users (Jorge et al., 2021).

Public health organizations face a particularly significant challenge. Public health organizations are faced with the problem of maintaining funding levels. Current funding levels cannot keep pace with technological innovations, demographic and epidemiological trends and growing expectations. In response to this, the World Health Organization developed the Global Strategy on Integrated People-Centred Health Services 2016-2026 (IPCHS) in 2016. This strategy serves as an instrument for a paradigm shift in the financing, management and provision of health services. The goal of IPCHS is to provide people with access to health services that meet their needs and preferences and are coordinated through the continuum of care in a safe, effective, timely, efficient and fair manner. The strategies proposed in the IPCHS are: engaging and empowering people and communities, strengthening governance and accountability, reorienting the model of care, coordinating services within and across sectors, and creating an enabling environment (WHO, 2016).

The UN has also drawn attention to the issue of sustainability and published the 2030 Agenda in 2015. This agenda contains 17 global Sustainable Development Goals (UN SDGs) relating to people, planet, prosperity, peace and partnership. One of the goals is to ensure healthy lives and promote well-being for all at all ages (SDG 3). Therefore, public health organizations are faced with the need to align their activities with the mentioned goal, but also with other goals, and to report on the committed efforts and results achieved in the implementation of the goals (Sobkowiak et al., 2020). Research has shown that public sector entities publish information on sustainable development goals in various formats, mainly on their websites (Manes Rossi et al., 2023).

The Sustainable Development Goals are also endorsed at European Union level. Indeed, the WHO (2016, 19) advocates "establishing and continuously improving a sustainable and fair system of long-term care".



Therefore, the WHO conducted a study for Europe to support the implementation of the “European Framework for Action on the Delivery of Integrated Health Services”. The study was based on a literature review, interviews with experts and conducting case studies in 6 countries (Croatia, Denmark, Germany, Portugal, Romania, Turkey) providing different systems of long-term care to identify barriers, drivers and success factors under different systematic conditions. However, the report for the Republic of Croatia is not available. But in response to the WHO strategy, the Republic of Croatia has developed the National Plan for Healthcare Development until 2027.

From all this, it can be concluded that public health organizations are facing the challenge of sustainability and sustainability reporting to improve accountability and better governance. Therefore, this paper presents different forms of reporting that public health organizations can adopt. It also shows how the Republic of Croatia has responded to these challenges.

## 2. BACKGROUND

To improve accountability and sustainability, public sector entities, including public health organizations, have begun to report on sustainability, with a focus on social and environmental reporting (Biondi & Bracci, 2018). As separate reports or parts of financial reports, sustainability reports are beginning to be seen as complementary to the production of financial reports (Jorge et al., 2021). Indeed, it has been observed that providing additional information has a positive impact on public sector entities as well as internal and external users (Manes Rossi et al., 2023). By producing additional reports, public sector entities involve stakeholders in the definition of relevant information and an open dialogue with users is achieved. Furthermore, the use of different languages and means of communication increases the comprehensibility of the public sector entities' activities. Internal users can better understand the results and outcomes of the public sector entities' activities and make better use of the information in decision-making and performance evaluation. On the other hand, external users have transparent and comprehensive information on financial and non-financial results and can better understand strategies, plans and actions. Most importantly, they are able to make decisions and participate in public management based on the information provided.

There are numerous alternatives for improving the reporting of public sector entities, such as integrated reports, sustainability reports, reports on the UN Sustainable Development Goals or SDG reports (Manes Rossi et al., 2023). The aim of sustainability reports is to inform users about social, environmental and economic impacts as well as the effects of management. The aim of SDG reports is to inform all users about the progress made towards the defined sustainable development goals through narrative reporting and quantitative indicators for each relevant sustainable development goal. Meanwhile, integrated reports provide users with integrated financial and non-financial information on the performance of public sector entities and give an outlook on future trends.

As public sector entities, including public health organizations, play a central role in achieving the Sustainable Development Goals, a trend towards integrating different types of information into one report has been observed in recent years (Montesinos & Brusca, 2019). Integrated reports present financial and non-financial information in one document, including information on all forms of resources that are important for the long-term survival of public sector entities (Cohen & Karatzimas, 2015). The integrated report is a form of concise communication on how the strategy, management and performance of the organization's operations lead to value creation in the short, medium and long term in the context of the external environment (IIRC, 2013). Integrated reports enable greater accountability to stakeholders and interest groups and serve as a guide for the delivery of sustainable services and enable long-term management alignment (IIRC & CIPFA, 2016). The above is particularly relevant for public sector entities and public health organizations as they strive to strengthen the relationship between managers and stakeholders, stakeholder engagement in strategic management and the value creation process, which is key to effective accountability, transparency and successful governance of public services, i.e. healthcare services (Montesinos & Brusca, 2019).

The need to achieve sustainability was also recognized by the UN, which published the 2030 Agenda in 2015, i.e. adopted the Global Development Program for 2030. The aforementioned agenda contains 17 global goals. The first 6 goals relate to people, goals 7, 8, 9 and 10 relate to prosperity, goals 11 to 15 relate to the planet, the 16th goal relates to peace and the 17th goal relates to partnership. The goals mentioned relate to international organizations, the corporate sector, non-governmental organizations, individuals, public sector entities and public health organizations. With the development of the SDGs, the need to report on the efforts made and the results achieved in reaching the goals emerged, and the sustainability strategies of public sector entities are gradually being linked to the SDGs (Manes Rossi et al., 2023). Čičak (2022) concludes that non-

financial reporting in public entities is or should be used on a voluntary basis due to the requirements to achieve the Sustainable Development Goals and is expected to become mandatory in the near future.

The Global Strategy on Integrated People-Centered Health Services 2016-2026 (IPCHS) was developed for the organization of the public health system. The strategy was developed to improve the quality of life and healthcare, patient satisfaction and the efficiency of the system. This is because traditional models of healthcare focus on the disease and do not recognize the patient's ability to be an expert on their own life based on their own life experiences (IAPO, 2020). In contrast, when treatment focuses on the person and the approach is personalized, a positive and stimulating environment is created, both for service users and service providers (Pirhonen et al., 2019). Person-centered care recognizes patients as individuals who have resources and abilities despite their illness (Ekman et al., 2011). This leads to a partnership and agreement between patients and healthcare professionals regarding healthcare activities, which has an impact on shorter hospital stays, lower readmission rates, higher quality of care and satisfaction with healthcare (Gyllenstein et al., 2019). On the other hand, public healthcare organizations get to know users better and can better integrate services and methods to provide personalized solutions, resulting in higher healthcare value and additional revenue (Pirhonen et al., 2019). For this reason, policy makers have shown interest in the introduction and implementation of person-centered care. Research by Rosengren et al. (2021) has shown that person-centered care is most prevalent in the west of the United Kingdom and the north of the Scandinavian countries. This is followed by Central Europe, while person-centered care is least represented in Southern and Eastern Europe. Countries with a developed healthcare system (the UK) have recognized that the problem of healthcare system administration can only be solved by better management within the healthcare system. Therefore, they have accepted the concept of management that increases the positive impact on health and the positive impact on the organization, i.e. limiting the excessive growth of healthcare expenses.

The above strategy aims at empowering people, strengthening governance and accountability, redesigning an efficient and effective healthcare system, coordinating the various services according to the needs of the people and creating a stimulating environment that respects all stakeholders. The second objective of the strategy relates to strengthening governance and accountability. This requires a participatory approach to policy formulation, decision-making and performance evaluation at all levels of the health system. Good governance is transparent, inclusive, reduces vulnerability to corruption and makes optimal use of available resources and information to achieve the best possible results. Good governance refers to the mutual accountability of policy makers, managers, service providers and users, as well as incentives aligned with a people-centered approach (WHO, 2016). Creating a strong policy framework and narrative for reform is important to develop a shared vision and define how this vision will be achieved. Governance refers to the establishment of participatory governance where communities are involved in policy formulation and evaluation (WHO, 2016). Governments should take responsibility for protecting and improving the wellbeing of their populations and build trust and legitimacy with citizens through effective governance. The role of the Ministry of Health is key to good health governance and involves identifying and engaging community stakeholders so that voices are heard and consensus is reached. Therefore, accountability primarily refers to the responsibility to make decisions and provide information on performance. Strengthening the accountability of health systems requires collective action at all levels to improve the organization and delivery of services. Under the above strategy, there are no universal indicators to measure progress in establishing integrated, people-centered health services. Therefore, it is suggested that research and development of indicators to monitor the global progress of integrated people-centered health services be undertaken, as the development of indicators will facilitate the development of medium and long-term targets needed to monitor progress in the implementation of the framework at global, national and regional levels (WHO, 2016).

At European level, the concept of integrated care has been recognized since 2016 and was instrumentalized by the European Framework for Action on the Provision of Integrated Health Services (WHO Regional Office for Europe, 2016). It involves linking different services, providers and institutions within the care system through new partnerships between local organizations, their mutual coordination in service delivery and planning (to reduce inequalities) for the health of the population (WHO, 2016). However, looking at different European countries, the value of the concept is not uniquely recognized, as the study by Rosengren et al. (2021) shows.

Both the global and European concept of integrated care should be linked to the SDG goals, i.e. SDG 3 Ensure healthy lives and promote well-being for all at all ages. Public health organizations are required to report on both the stated goal and the implementation of the goal. Since the reports submitted are not standardized because there is no legal obligation to publish them, and since the indicators for the achievement of the strategies' objectives are not uniform, the reports and the results achieved for the objectives may appear in different forms, which can make it difficult to compare results between public health organizations and also between other public sector entities (Manes Rossi et al., 2023). It can be concluded that public health organizations face a major challenge when it comes to implementing the concept of integrated care and

improving reporting to enhance accountability, transparency and governance. The next section describes how the Republic of Croatia has responded to the requirements of the integrated care strategy.

### 3. DISCUSSION

In response to the IPCHS strategy, the Republic of Croatia has adopted the National Health Development Plan for the period from 2021 to 2027. The national plan is a medium-term act of strategic planning that sets specific goals with the basic objective of improving the health system and health outcomes of the population. The Republic of Croatia, like other countries, faces health challenges that burden the system and have a negative impact on the health of citizens. This concerns the weak results of health promotion and disease prevention measures, unequal outcomes of care and the financial unsustainability of some forms of care. As far as the EU is concerned, the healthcare system does not collect and analyze enough data, which makes it difficult to monitor the effectiveness of the system and health outcome indicators. E-health projects and activities have been a priority for the healthcare system in the Republic of Croatia for more than 15 years, but the information systems are not fully integrated to enable integrated healthcare that puts the patient at the center. Furthermore, the human resources for the development and management of these systems have not been developed. Therefore, the goal is to improve health outcomes and reach the level of developed Western European countries by 2027.

The National Plan identified certain priority areas and actions as well as specific objectives, namely: 1. improve healthy living habits and disease prevention, 2. improve the health system, 3. improve care models for key health challenges, 4. make the healthcare system a desirable place to work, 5. improve the financial sustainability of the healthcare system. The indicator for the outcome of improving the financial sustainability of the healthcare system is the proportion of hospitals that do not have an annual deficit. The proportion of hospitals in the total number of hospitals whose total annual expenses does not exceed total annual revenue is monitored. In 2020, the baseline value was less than 1%, and the target value by 2027 is that 40% of hospitals do not have an annual deficit.

The National Plan is in line with the National Development Strategy of the Republic of Croatia until 2030. The National Development Strategy considers the health sector under the strategic goal 5: healthy, active and quality life, and specifies an increase in the expected number of healthy life years to over 65 years for both genders as a performance indicator.

On the other hand, the financial basis of the health system is chronically strained, as the financial obligations of the last twenty years show when it comes to the management of financial resources. The Republic of Croatia must work to increase revenues based on economic growth, improve the revenue collection model and rationalize and better manage health expenses. Health expenditure per capita in Croatia is lower than in most other EU countries and has been relatively stable in recent years. However, the public share of total spending was 81.9% in 2019, higher than in most EU countries with comparable spending levels. The share of public funding was higher than the EU average in all care areas, particularly in the areas of dental care and pharmaceuticals (OECD / European Observatory on Health Systems and Policies, 2021). It is necessary to improve the quality of healthcare in order to achieve the greatest return on resources invested in the health of the population.

Improving governance at all levels is another basic prerequisite for the financial sustainability of the healthcare system. Guidelines for the financial and clinical management of healthcare facilities will be developed and an IT solution implemented. This will enable the monitoring and evaluation of the success of hospital management. To this end, five measures are defined in the National Plan: 1. creation of a strategic framework for sustainable healthcare financing 2. improvement of the unified public procurement system. 3. Improve the hospital management system; 4. introduce a pricing system for healthcare services that reflects the cost of effectively provided treatment; 5. improve the payment model for healthcare services. In the strategic framework, it is necessary to analyze the revenue and expenses side of the healthcare system and define short- and long-term steps to balance the financing of the healthcare system. The current financing system is not sustainable in the short or long term, as the system structured by compulsory, supplementary and complementary insurances has not been improved since its introduction. A unified public procurement system will increase the transparency of spending, achieve savings and standardization and allow for more efficient control of public procurement. It is also necessary to improve the governance of hospitals by applying guidelines and monitoring the financial and clinical management of hospitals and holding management accountable for results. Therefore, professional and responsible management is required.

The Ministry of Health, as the holder of the Strategic Planning Act, will establish mechanisms for monitoring and evaluating the National Plan in accordance with the provisions of the regulations that govern the deadlines

and procedures for monitoring and reporting. When examining the websites of public health organizations in the Republic of Croatia, it was found that public health organizations do not prepare or publish on their websites additional reports, such as sustainability reports or SDG reports, in addition to financial reports. This is due to the fact that the preparation of additional reports is not provided for in the national legal framework. There is also no legal obligation at EU level for public sector entities to produce additional reports. The Ministry of Health has also not issued any instructions or recommendations for the preparation of additional report forms. This is also in line with previous research in the Republic of Croatia, which has shown that apart from large listed companies and state-owned enterprises, other reporting entities do not prepare additional or other forms of non-financial reports (Čičak et al., 2021). Everything indicates that the system of non-financial reporting and the provision of additional information beyond financial in the public sector, including public health organizations, has not yet been developed. The Republic of Croatia needs to carry out many activities to develop the reporting system of public sector entities including public health organizations, which will lead to improved accountability and governance.

#### 4. CONCLUSION

Public sector entities, including public health organizations, face the problem of sustainability and sustainability reporting. The problem of sustainability is also recognized by world organizations, so that numerous strategies and agendas have been created in the last 10 years. The UN has drawn up the 2030 Agenda with the Sustainable Development Goals. These goals apply to all public and private sector entities. In fact, it is necessary to take the Sustainable Development Goals into account when carrying out activities and to report on their implementation. In the health system, the problem of health system management was also recognized and the WHO developed the IPCHS strategy. The strategy aims at an integrated health system that puts people at the center. This strategy is in line with the SDG goal. In response to the WHO strategy, a framework for a sustainable healthcare system was also developed in the European Union. The aim of all strategies is to achieve effective governance of healthcare organizations and improve accountability. It also seeks to achieve the participation of all stakeholders in decision-making. To address this issue, additional forms of reporting have been advocated in recent years as new tools to improve communication with all stakeholders and to improve accountability, transparency and governance. For example, individual countries produce sustainability reports, SDG reports, integrated reports. However, research has shown that these reports are more talked about than actually adopted by public sector entities, including public health organizations (Biondi and Bracci, 2018). The reason for this is that there is no legal framework that prescribes the production of the aforementioned reports. In addition, public sector entities often face a lack of political and management support for sustainability issues, a lack of resources for implementation and a lack of organizational capacity (Giacomini et al., 2018).

In the Republic of Croatia, the situation is similar to that in other jurisdictions. The Republic of Croatia is facing the problem of sustainability of the health care system, which is why the National Health Development Plan for the period 2021 to 2027 was drawn up. It defines strategic long-term and short-term goals to make the healthcare system more efficient, qualitatively better and more sustainable by 2027. Major efforts are being invested in the development of e-health and measures have been defined to improve financial and clinical management at all levels. The Ministry of Health is responsible for monitoring the achievement of results according to the defined plan and certain indicators have been set. The aforementioned plan is somewhat in line with the IPCHS strategy, as it is also focused on improving the health system, improving the care model for the main health challenges and improving the financial sustainability of the health system. Currently, no single entity of the public health system in the Republic of Croatia reports on the results achieved according to the mentioned health system development plan, nor does it produce additional reports that would provide insight into economic sustainability and serve as tools for improving accountability and governance.

When analyzing the environment in the Republic of Croatia, it was found that one of the challenges in the healthcare system is the competence of healthcare staff and public administration. This was also found to be in line with previous research, which emphasized that the education of healthcare and other staff is key to improving the healthcare sector (Rosengren et al., 2018). Therefore, the training and professionalization of public administration in the health sector is necessary to improve the skills of employees and to achieve better organizational and management skills. At this stage, the collaboration of policy makers and politicians is therefore necessary to recognize the importance of investing in education in the health sector. In addition, it is necessary to understand the importance of producing additional reports that can be critical to the decision-making and successful management of healthcare organizations. Which form of reporting to choose is a difficult question to answer. There is no best solution, and each public health or organization must determine the most appropriate reporting format to reach all stakeholders and provide users with all relevant information, resulting in a better management system for public health organizations.

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# THE USE OF SIMULATION MODELS FOR ANALYZING COSTS IN ADDITIVE MANUFACTURING FACILITIES

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**Abstract:** *In the current market environment, characterized by volatility and uncertainty, informed decision-making is crucial for the sustainability and success of entrepreneurial and business ventures. This paper explores the practical application of simulation models as analytical tools, demonstrated through the creation and analysis of a simulation model of an additive manufacturing facility. Simulation models are effective tools for gaining a deeper understanding of real-world systems. Additive manufacturing, as a sustainable alternative to traditional methods, is gaining traction, with fused deposition modeling being particularly notable for its safety, widespread adoption, and cost-effectiveness. By simulating a small to medium-scale manufacturing operation, this paper aims to provide practical insights into the integration of simulation models and small-scale manufacturing facilities that implement additive manufacturing methods. These insights are designed to assist decision-makers in making informed decisions, weighing alternatives, and mitigating unnecessary waste and risk when initiating an entrepreneurial venture.*

**Keywords:** *Sustainable management, Simulation models, Additive manufacturing*

## 1. INTRODUCTION

The turbulent and dynamic state of today's market requires modern management to, for the most part, make informed decisions whilst tackling growing uncertainty. The quality of informed decisions will directly affect the health, longevity, and sustainability of entrepreneurial ventures and long-standing organizations. The uncertain market state makes educating new and up-and-coming personnel in using simulation analysis tools paramount. Simulation models, created using simulation analysis computer programs, play a crucial role in combating market uncertainty by allowing users to replicate observed real-world systems and experiment within those systems in an environment of massively reduced risk. Parallel to the increasing market uncertainty, an old challenge comes to light – the need for more responsible, sustainable, and just-in-time production. As we move forward in today's hyper-productive era, our effects on the environment become ever-present. As new challenges emerge, so do new manufacturing techniques in the form of additive manufacturing methods.

This paper is dedicated to exploring the potential of integrating simulation models and additive manufacturing techniques. To illustrate this, we present a simulation model of a small-to-medium-scale manufacturing operation using readily available additive manufacturing technology. Our aim is to provide a practical demonstration of how simulation models can be effectively used in the context of additive manufacturing, thereby offering valuable insights for decision-makers in small-scale manufacturing ventures.

## 2. ADDITIVE MANUFACTURING

Additive manufacturing refers to one of three categories of manufacturing methods: formative, subtractive, and additive manufacturing. Formative manufacturing methods create desired geometric shapes by using molds and raw materials (usually in a liquid state) capable of conforming to the shape of the cavity created by the mold. Subtractive manufacturing methods create desired geometric shapes by intentionally removing material from a raw piece of chosen material. With the advent of CNC (computer numerically controlled) lathes in the '50s at MIT (Massachusetts Institute of Technology), highly precise, repeatable, and predictable CNC subtractive manufacturing became possible (Smid, 2003; Xu, 2009). AM (Additive Manufacturing) methods create desired geometric shapes by applying successive layers of raw material, building the desired shape up layer by layer (Wong & Hernandez, 2012). Contemporary AM methods use CNC technology to control

machines equipped with tools that implement an array of manufacturing technologies. Notable additive manufacturing methods include SLA (stereolithography), SLS (selective laser sintering), and FDM (fused deposition modeling) (Danut Mazurchevici et al., 2020). For the purposes of this paper, our focus was on additive manufacture by FDM, as FDM has reduced health risks in comparison to SLA, a smaller barrier of entry compared to SLS and overall higher adoption rate and user support in comparison to both SLA and SLS (Chan et al., 2020; Danut Mazurchevici et al., 2020; Huang et al., 2020). Manufacturing using FDM can be performed by following this process (Jumaah et al., 2018):

1. Creating a 3D model of the desired shape using CAD (Computer Aided Design) software,
2. Creating a *.stl* file from the created 3D model,
3. Slicing, or creating a series of commands for the CNC machine to execute (*.gcode* file containing toolpaths and other miscellaneous commands) using slicing software,
4. Configuring machines and importing the *.gcode* file,
5. Surveilling the execution of the commands in the *.gcode* file,
6. Removing, processing, packing the finished units, and preparing the machine for future use.

Advantages of FDM include the use of stable and safe to handle raw materials, simple post-processing operations, low barrier of entry, serviceable and upgradable machinery, the ability to produce highly complex geometries as well as embedded components, scalability (both quantity and size) and just-in-time production (Antic et al., 2023; Danut Mazurchevici et al., 2020). Disadvantages of FDM include low manufacturing speeds for complex geometries, embedded failure points due to layered construction, structural compromises (for parts with less than 100% infill), complications when designing overhangs, surface roughness and exposure to VOC's (Volatile organic compounds) (dependent on chosen material) while machines are in operation (Chan et al., 2020; Li et al., 2017). All three manufacturing methods produce some amount of scrap material. However, scraps created by FDM serve as structural supports for overhangs or supports for better adhesion to the build plate and can be recycled for future use. Parts meant to be manufactured can be designed around these constraints in such a way as to eliminate or at least minimize the amount of necessary support material, which would later become scrap (Paris et al., 2016).

## 2. MODELING REAL-WORLD SYSTEMS

Modeling serves as a method for comprehending and learning from and about real-world systems, which consist of any number of interdependent elements whose interactions influence their changes and observed outcomes of the system as a whole (Radenković et al., 2009). Models are constructed by observing such systems, identifying elements impacting outcomes, and specifying their relationships, attributes, and rules to replicate reference outcomes. The level of detail in a model is determined by abstraction, a process where the relevance to an outcome of specific details is determined (Grigoryev, 2022). Models can be physical or conceptual, depending on the tangibility of the system. Physical models represent tangible objects, while conceptual models illustrate relationships between intangible concepts. This paper focuses on simulation models, which enable users to simulate real-world systems in a risk-free environment, providing control over attributes and, in some cases, passage of time (Борщев Андрей, 2013). Simulation models are crucial for decision-making when real-world experimentation is costly or impractical. They can be digital and depict physical or conceptual systems. For example, Computational Fluid Dynamics (CFD) models can simulate aerodynamics, while conceptual simulation models can depict logistics, product adoption, organizations, or environmental impacts (Grigoryev, 2022). Digital simulation models offer advantages such as a digital environment, control over resources and time, scalability, and dynamic system representation. Simulation models are executable and require running in order to conduct experiments. Each run provides feedback based on parameters, variables, dependencies, and rules. Modelers can adjust details and inputs for comparison. Three distinct methodologies, System dynamics modeling, Agent-based modeling, and Discrete event modeling, are used to build simulation models, chosen based on the required level of abstraction for a faithful representation of the observed system. In this paper, agent-based modeling combined with discrete event modeling was employed to simulate a 3D printing workshop.

## 3. MODELING A 3D PRINTING WORKSHOP

To create a simulation model, it is necessary to describe the system being modeled as well as choose the appropriate software to use. In our research, a model of a 3D printing workshop has been created to analyze which combinations of salary, number of machines, number of employees, level of margin, and price per spool of material are optimal for which printer. The simulation model of a 3D printing workshop has been created using the AnyLogic software, utilizing the Analysis, Controls, Agent, and Process Modeling libraries (Grigoryev, 2022). The created simulation model offers visualizations of an income statement, expense structure, the distribution of prices per unit per project, and the distribution of time spent on various activities during the manufacturing process over the course of three simulated years. The model consists of the following agents: Main, Project, Worker, and Printer.



### 3.1. Agents Worker and Printer

The Worker and Printer agents define two inexhaustible resources that make manufacturing possible. The worker agent is defined by their speed, set at two meters per second. The printer agent is defined by the following parameters listed in Table 1 (*Bambu Lab A1*, 2023; *Original Prusa XL Semi-Assembled Single-Toolhead 3D Printer*, 2023).

**Table 1:** Parameters defining the Printer agent

Parameters	Unit of measurement	Data type	Short description
BuildX	mm	double	Build plate size of a specified printer in the X-axis
BuildY	mm	double	Build plate size of a specified printer in the Y-axis
BuildZ	mm	double	Build plate size of a specified printer in the Z-axis
PrintSpeed	mm <sup>3</sup> /min	double	Volumetric flow rate
PrintArea	mm <sup>2</sup>	double	Area within which a printer can print
PrintVolume	mm <sup>3</sup>	double	Space in which a printer can print
EIConsumption	kWh	double	Electric consumption of a printer during operation

### 3.2. Agent Project

Projects are defined by a population of Project agents. The Project agent represents the projects requested by clients. Several parameters and variables define the Project agents. Some variables refer to common attributes found in publicly available .stl files (*Printables*, 2023), while others refer to derived attributes necessary for multiple calculations regarding cost and manufacturing time (Ellis, 2023). The variables and parameters defining projects are listed in Table 2.

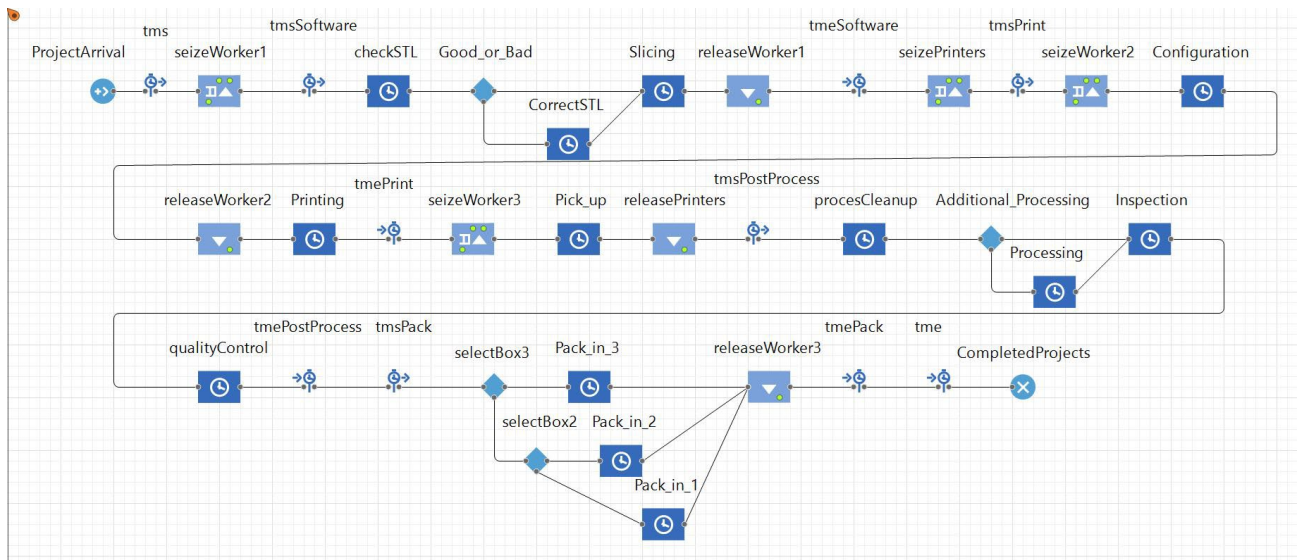
**Table 2:** Project agent parameters and variables

Type	Name	Unit of measurement	Short description
Parameter	wc	mm	Thickness of a unit's shell.
Parameter	Infill	%	Percentage of unit's infill.
Variable	x	mm	Size of unit in the x-axis.
Variable	y	mm	Size of unit in the y-axis.
Variable	z	mm	Size of unit in the z-axis.
Variable	q	q	Quantity of requested units.
Variable	Areaq	mm <sup>2</sup>	Area of a unit on the build plate.
Variable	Shellq	mm <sup>3</sup> /q	Volume of a unit's shell.
Variable	Infillq	mm <sup>3</sup> /q	Volume of a unit's infill.
Variable	VolumeMat	mm <sup>3</sup> /q	Volume of material per unit.
Variable	VolumePiece	mm <sup>3</sup> /q	Volume taken up by a unit.
Variable	VolumeProject	mm <sup>3</sup>	Volume of material spent for all units of the project.
Variable	AreaProject	mm <sup>2</sup>	Area taken up by all units of the project.
Variable	Box1,Box2,Box3Count	box	Number of boxes used for the project.
Variable	PackMaterial	mm <sup>3</sup>	Volume of packing material used for the project.
Variable	MachineCount	machine/s	Number machines required for the project.
Variable	MatProject	mm <sup>3</sup>	Material used for the project.
Variable	TimeProject	h	Time spent on project.
Variable	Work Software, ConfigPostPack, Time	min	Time spent on individual activities.
Variable	Material,Electric,Box,PackMaterial,Worker Cost	RSD	Associated costs of materials and activities.
Variable	CostProject	RSD	Cost of entire project.
Variable	ValueOfProject	RSD	Market value of the project.
Variable	PricePerUnit	RSD/q	Price per unit of the project.

### 3.3. Agent Main

The agent Main, serving as the work surface, contains several parameters defining the dimensions of the packing boxes best suited for a chosen printer, the salary for the workers as well as their hourly rate. Aside from these parameters, Main contains several parameters defining the minimum and maximum size of the units requested in projects, number of boxes, amount of packing material, amount of filament, number of spools

used during the simulation run, as well as elements of the simulated income statement. Main also contains the visualizations mentioned above and controls for choosing which printers, paygrade, percent of margin, and cost of material are to be simulated. Most importantly, Main contains the modeled process flow of production and packaging using FDM, which has been built using elements from Anylogic's Process Modeling Library (Figure 1).



**Figure 1:** Process flow of a 3D print shop

#### 4. SIMULATION EXPERIMENTS

Upon running the simulation, the user is prompted to choose a desired number of machines and workers, salary for the workers, percentage of margin, price of a spool of material, and type of printer they want to simulate. Each run is limited to 3 years of simulated time.

Projects upon arrival have their  $x$ ,  $y$ , and  $z$  values determined via triangular distribution bounded by the minimum and maximum allowable values defined upon choosing a printer type (the minimum values are always 10mm, and maximum values are defined by subtracting 10mm off from the dimensions of a printers build area). A uniform discrete distribution bound between 1 and 20 defines the number of requested units. The volume of a unit is defined as a product of the  $x$ ,  $y$ , and  $z$  values. After the project has arrived, a worker is seized. The worker examines whether the attached *.stl* file is suitable for FDM manufacturing. If the file is suitable for printing, it is forwarded; if not (which has been defined as the case for 10% of arrivals), it is corrected by the worker. After the examination/correction process, the worker will take the *.stl* file and process it using slicing software (such as Cura, Prusa slicer, Orca slicer, etc.). During this process, several attributes listed in Table 3 are calculated.

**Table 3:** Attributes calculated during the slicing process

attributes	Unit	Description
Shellq	mm <sup>3</sup> /unit	Sum of volumes of individual sides, where $w_c$ is the height of the cubes.
Infillq	mm <sup>3</sup> /unit	Product of the infill percentage and difference between the unit's volume and their shell.
VolumeMat	mm <sup>3</sup> /unit	Sum of the shell and infill volumes
VolumeProject	mm <sup>3</sup>	Product of $q$ and the material necessary for a single unit (VolumeMat)
Areaq	mm <sup>2</sup> /unit	Product of $x$ and $y$
AreaProject	mm <sup>2</sup>	Product of the area of a single unit (Areaq) and $q$
MachineCount	units	Ceiling of the quotient of the AreaProject value and the area of build plate

Once the file is sliced and the *.gcode* is generated, the worker will seize the necessary number of printers and configure them for the current project. The printers are now ready for manufacturing. During this step, the amount of material spent on the project is calculated, as well as the time needed to manufacture the requested units as a quotient of the volume of material to be printed and the chosen machine's volumetric flow rate (the volume of material, the machine is able to extrude per unit of time). After printing, a worker retrieves the finished pieces from the printer/s, a process during which the costs of material and electric power spent for the project are calculated.

Material and electrical costs associated with that specific project are tallied up with the costs of other projects during the run, forming TmaterialCost and TElecCost. Upon releasing the printers used for the project, the number of spools spent during the simulation is calculated, as well as the time spent printing that specific project. Following the printing process, a worker assesses whether additional processing is required (it is simulated to be necessary for only 10% of arrivals). The project is then processed (if necessary) and inspected by checking whether the shape of the resulting units complies with the attached digital model file. Post inspection, a worker conducts a quality control check, during which units are checked for defects or faults, after which packing can commence. The box size to be used is determined by checking multiple conditions. These conditions effectively check whether the units can fit in a specific box size in any orientation. During the packaging process, the number of boxes used is recorded as well as the amount of packaging material used (as the product of q and the difference between the volume of a box and the volume of a unit) and the cost of the boxes spent on packaging the finished units of the project is calculated.

After packaging, costs related to labor and packing materials put into the project are calculated, and following this, the total costs of the project. Upon releasing the worker, the project is considered complete, and the entire project's value is calculated by multiplying the entire project's cost by the selected margin. After calculating the price for that specific project, the simulated balance sheet elements are calculated by calculating fixed and variable costs, total costs, and marginal and simulated profit. Simulation runs will pause at the break-even point (if applicable). This pause, if the break-even point is achieved, can offer the user information on when the break-even point could be achieved in the real world, or after how many completed projects, as well as all the other indicators in Figure 2, such as the average manufacturing time or average price per unit.



**Figure 2:** Break-even point for 9 Ender3 printers, where workers are paid the Median salary, margins are at 50% and the material used costs 2600 RSD/spool.

#### 4.1. Possible application

The results gathered from the simulation experiments can assist the users in determining which scenario would best suit their means. In other words, a simulation experiment can give them a glimpse of what's to come if they were to pursue an specific combination of attributes. An example of which is given in Table 4.

**Table 4:** Simulated Profits across all combinations of workers and printers, where the margin is at 25%, the workers are paid a median salary, and the cost per spool is 2400 for the Creality K1 machine/s

Profit [RSD]	3	6	9
1	3,088,785.26	2,923,987.71	2,300,800.10
2	430,741.15	-70,790.59	-1,087,969.75
3	-2,704,360.34	-4,046,217.61	-3,445,197.36

Table 5 shows that employing more than two workers is unprofitable. Furthermore, profitable combinations given in Table 4 have different break/even points, as demonstrated.

**Table 5:** Break-even points of all profitable combinations of the K1 printer with 25% margins and material priced at 2400 RSD/spool

Number of workers	Number of machines	Profit	Break/even point is achieved after
1	3 machines	3,088,785.26	57 days
1	6 machines	2,923,987.71	112 days
1	9 machines	2,300,800.10	286 days
2	3 machines	430,741.15	263 days

## 5. CONCLUSION

Today's uncertainty, paired with a global need for sustainable production methods, poses a new and complex challenge, necessitating a novel approach to production and analysis. This paper emphasizes the importance of informed decision-making in a sustainability-oriented market by showcasing a simulation model built to focus on the manufacturing cost analysis of a 3D printing workshop. By utilizing Anylogic's Process Modeling Library, it has become possible to increase the accuracy of entrepreneurs' and managers' predictions when making decisions regarding the acquisition of different means of production, the structure of costs, the necessary time to achieve the break-even point, etc. Through simulation experiments, decision-makers can assess not only the potential outcomes of their chosen strategies but also what to expect until they reach their desired outcomes. This can offer decision-makers a competitive advantage while budgeting and a sustainability advantage when considering the fact that the resources used in simulation models are fictitious.

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# APPLICATION OF THE STRATEGIC THREE-DIMENSIONAL 3D MATRIX IN THE AUTOMOTIVE INDUSTRY

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**Abstract:** *Following the global crisis of 2008, COVID-19, and the war in Ukraine/Israel, the automotive industry is facing two major issues: a) rising oil prices and b) legal mandates on emissions (transition to zero emissions by 2035). The question is no longer, whether the automotive industry should invest in "green technologies", but rather how the strategy of ecological sustainability correlates with brand value and financial-market outcomes. This paper aims to demonstrate, using a strategic tool from 2010, how the automotive industry has responded since the 2008 crisis by employing a threefold approach that simultaneously measures the impact of three(3) factors: 1) ecological sustainability strategy (Z-axis); 2) brand value (Y-axis); and 3) financial-market results (X-axis). Using the strategic tool of the three-dimensional (3D) matrix and a holistic approach, we provide insights into the position automotive manufacturers have taken, the solutions presented before them, and the associated risks.*

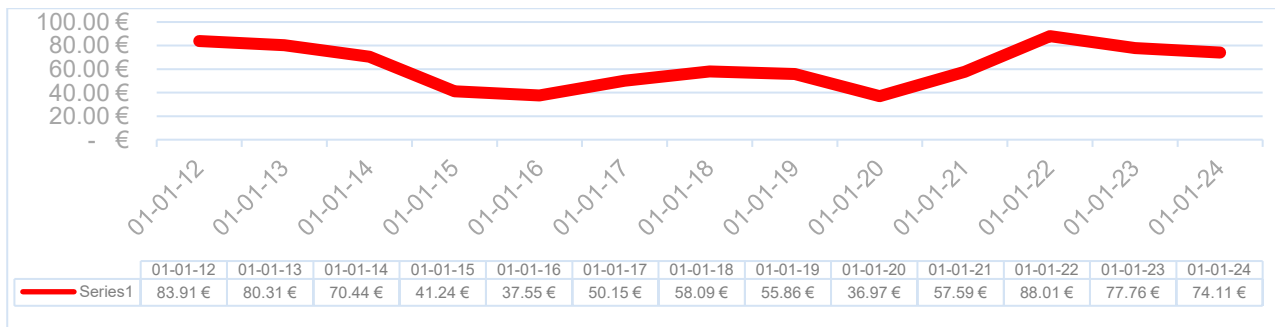
**Keywords:** *strategic three-dimensional matrix, brand value, financial result, sustainability index, car industry*

## 1. INTRODUCTION

*„American companies innovate, Chinese companies replicate, and the EU regulates.“*  
A meme on social networks.

Is it academically appropriate to recount memes (jokes) from social networks? We believe it is academically permissible if they reflect reality. Consider the topic of artificial intelligence, which was a key issue at the World Economic Forum in Davos in 2024. American companies were the first to release applications that shocked the world at the end of 2023 (chat GPT). The Chinese have shown that they are not far behind in this technology, but the EU was the first to call for deep regulation of this technology. Consequently, the EU has strictly regulated exhaust emissions and forced the automotive industry, before the economic crisis of 2008, to comply with strict legal solutions and to focus on sustainability. The German automotive industry accounts for about 5% of Germany's GDP, making it very significant for the entire EU. Even before the 2008 economic crisis, the EU had imposed very strict rules on exhaust emissions. Today these rules are even stricter.

On April 19, 2023, the European Commission adopted Regulation (EU) 2023/851 of the European Parliament and of the Council amending Regulation (EU) 2019/631. "The revised regulation on CO<sub>2</sub> emission standards will ensure that by 2035 all new cars and vans registered in Europe have a zero-emission rate. As an interim step towards a zero-emission rate, the average emissions of new cars must be reduced by 55% and new vans by 50% by 2030." At Germany's request, a concession was made to exempt e-fuel cars from the regulation. What about trucks and buses? On February 14, 2023, the EU Commission proposed a target of zero emissions for new city buses by 2030 and a reduction in emissions for new trucks by 90% by 2040. An agreement was reached on a target to reduce CO<sub>2</sub> for buses, 100% by 2035, with a target reduction of 85% for 2030. The European Commission (EC) proposed a reduction for truck manufacturers of 45% by 2030, followed by 65% in 2035 and 90% in 2040. Concerns from countries like Poland resulted in a decision to review in 2027. Undoubtedly, the European Commission is striving to achieve the EU's climate neutrality goal by 2050 through draconian measures and to reduce demand and dependence on imported fossil fuels, as Figure 1 shows how unpredictable fuel prices are. The EU has tried to achieve its goal by increasing energy production from renewable sources and now from nuclear sources as well. This implies that there should be as many electric cars, electric buses, electric trucks, and electric delivery vehicles as possible on European roads.

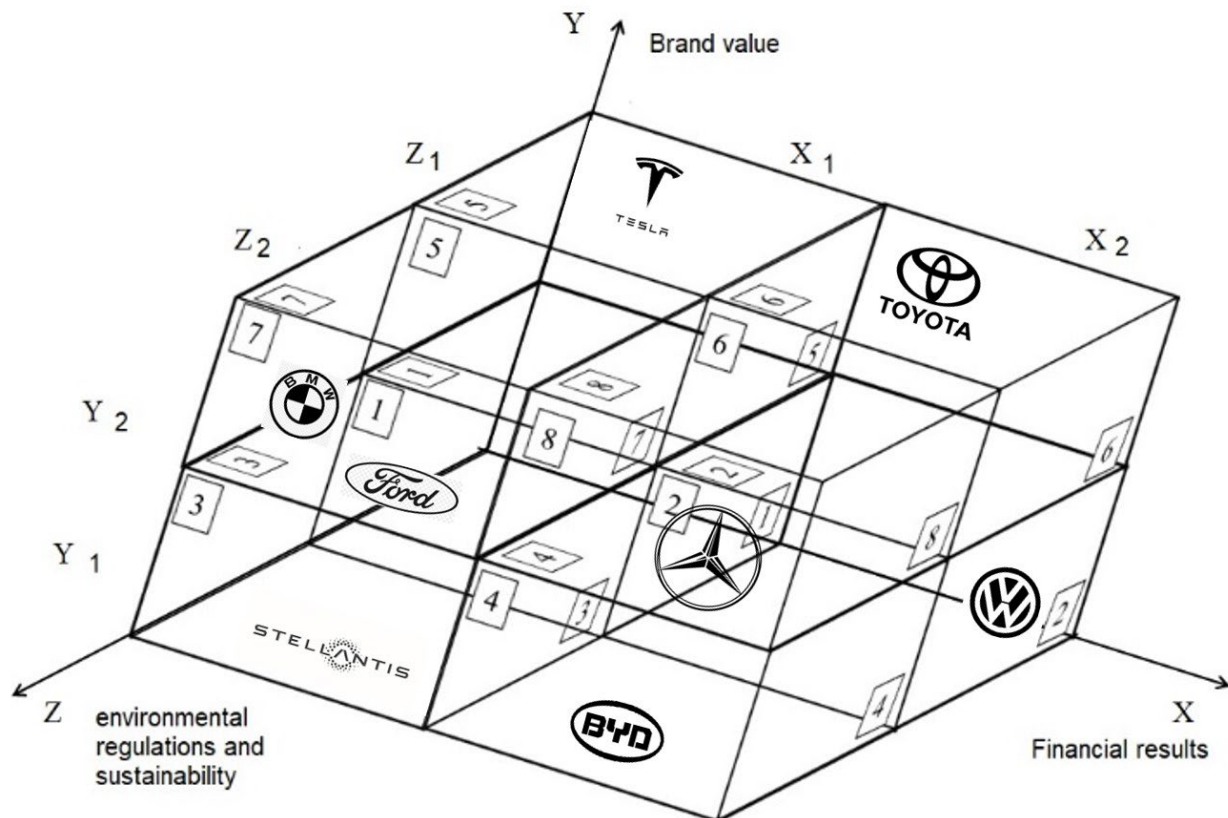


Source: Authors based on OPEC data

**Figure 1:** OPEC fuel price in EUR

## 2. REVIEW OF THE THREE-DIMENSIONAL (3D) MATRIX - BRAND VALUE, FINANCIAL RESULTS, ENVIRONMENTAL SUSTAINABILITY AND REGULATIONS

For the purposes of Symorg2010, a new strategic matrix has created as new approach, which is three-dimensional and "simultaneously measures the impact (contribution) of three (3) factors on the company, namely: 1) ecological sustainability strategy (Z-axis); 2) brand value (Y-axis); 3) financial-market results (X-axis)." (Bajramović 2010) The automotive industry has taken as an example at that time. The intention is to show what happened 14 years later in the auto industry also to determine whether this new strategic concept was scientifically justified at the time.



Source: Bajramović (2011)

**Figure 2:** Three-dimensional (3D) matrix: strategy of sustainability, brand value and financials results

Explanation of eight boxes in the strategic three-dimensional (3D) matrix:

- Box 1: low brand value (Y1), low financial results (X1) and low investment in IR and sustainability (Z1),
- Box 2: low brand value (Y1), good financial results (X2) and low investment in IR and sustainability (Z1),
- Box 3: low brand value (Y1), low financial results (X1) and high investment in IR and sustainability (Z2),
- Box 4: low brand value (Y1), good financial results (X2) and high investment in IR and sustainability (Z2),
- Box 5: high brand value (Y2), low financial results (X1) and low investment in IR and sustainability (Z1),
- Box 6: high brand value (Y2), good financial results (X2) and low investment in IR and sustainability (Z1),
- Box 7: high brand value (Y2), low financial results (X1) and high investment in IR and sustainability (Z2),
- Box 8: high brand value (Y2), good financial results (X2) and high investment in IR and sustainability (Z2).



## 2.1. Proof of concept: Three-dimensional (3D) matrix: strategy of sustainability, brand value and financials results

Three-dimensional matrix: strategy of sustainability, brand value and financials results created 2010 on basis of car industry. What happened in next 14 years in this sector that can proof or disproof this strategic concept? In the paper "Three-Dimensional (3D) Matrix of Contributions of Ecological Sustainability Strategy, Brand Value, and Financial-Market Results in the Automotive Industry" (Bajramović, 2010), where this matrix was proposed, it is written on page 68 about the company Volkswagen as follows: "...Volkswagen is an example of a manufacturer that did not want to invest significant amounts in R&D and the concept of ecological sustainability. In Figure 2, we can see that it dropped from 35th place in 2001 to 55th place in 2009. However, it should be mentioned that Volkswagen's brand Audi did make a shift from 81st place in 2004 to 65th place in 2009 without those major investments in R&D and ecological sustainability. However, it is certain that this is short-term, and such a trend will continue until 'stricter' laws come into effect. On the other hand, as we have already pointed out, it is certain that by then this brand, as a 'potentially ecologically sustainable competitor,' will simply adopt the technical solutions of its competitors and overcome complications."

In 2015, Volkswagen caught in a major ecological cheating on emissions tests from 2009 to 2015. The 3d matrix presented at Symorg2010 had anticipated that Volkswagen would merely copy the technology of others, which indeed occurred. Worse VW was found to have falsified compliance with standards, a deception uncovered by students and this misconduct cost Volkswagen approximately \$33.3 billion in the US alone. In 2024 the trial of former VW leader Martin Winterkorn had begun. (Bloomberg)

## 2.2. Brand value index of car brands in 2023

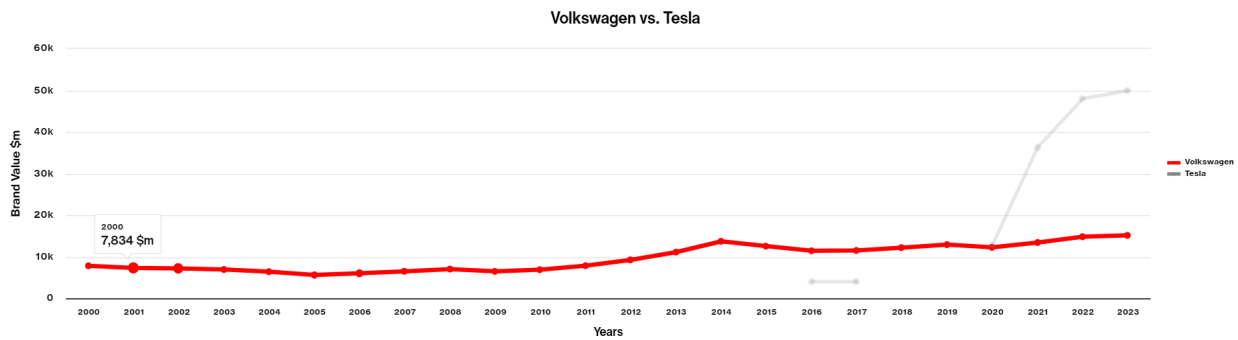
In Table 1, the 2023 rankings from the "Interbrand" website show the positions of car manufacturers among the top 100 most valuable brands across all sectors. Notably, the Chinese brand BYD is not yet among the top 100, indicating its potential is still unfolding. Xiaomi, which introduced its super EV car (a replica of Porsche's electric model) in 2024, is predicted to significantly increase in value. BMW improved from 15<sup>th</sup> place in 2009 to 10<sup>th</sup> in 2023. Daimler (Mercedes-Benz) moved from 12<sup>th</sup> place in 2009 to seventh in 2023. Additionally, Toyota advanced from 8<sup>th</sup> place in 2009 to 6<sup>th</sup> place in 2023.

**Table 1:** Brand value index of car brands in 2023 on total 100 most value brands of worlds

Rank number	Car producers	Rank situation	in million \$	Growth
6	Toyota	rank unchanged	64,504	8%
7	Mercedes-Benz	up 1 place	61,414	9%
10	BMW	up 3 places	51,157	10%
12	Tesla	rank unchanged	49,937	4%
27	Honda	down 1 place	24,412	7%
32	Hyundai	up 3 places	20,412	18%
45	Audi	up 1 place	16,352	9%
47	Porsche	up 6 places	16,215	20%
50	Volkswagen	down 2 places	15,140	2%
51	Ford	down 1 place	14,867	3%
63	Nissan	down 2 places	12,676	4%
70	Ferrari	up 5 places	10,830	16%
87	Xiaomi *	down 3 places	7,266	-1%

Source: Author with data of interbrand <https://interbrand.com/best-global-brands/nissan/> (Retrieved 9.4.2024.)

The company Tesla, which entered the automotive industry around 2013, ranked 12th among the top 100 most valuable brands in 2023, according to the same site. Tesla has successfully built a strong "cult" and loyal user base around its perspective on EV vehicles, as evidenced by a chart comparing the brand values of VW and Tesla. Tesla's strong commitment to eco-projects helped to establish, arguably, a cult following, significantly boosting its brand value to \$49.9 billion in 2023, while Volkswagen, shaken by ecological scandals, maintained a nearly unchanged position at 50th (up from 55th in 2009). VW managed to partially shield its Porsche and Audi brands from the ecological scandal fallout. According to Ljajić (2023) any company "should always try to turn crises, if possible, into an opportunity for improvement, redefining already existing and shaping new strategies, a new competitive challenge and solving delayed and accumulated problems."



Source: interbrand

**Figure 3:** Brand value in millions of \$ - Volkswagen vs Tesla

## 2.2. Sustainability index of car brands in 2023

Until 2019, the Dow Jones Sustainability World Index was used to measure progress in sustainable development and ecology. During the period up to 2009, some manufacturers, including Volkswagen, which led the index in 2002, abandoned the concept of ecological sustainability, ranking last in 2007, 2008, and 2009. In this paper, we will use ESG Risk Ratings (short for Environmental, Social, and Governance Risk Ratings). Sustainalytics' ESG Risk Ratings evaluate how much a company's overall business value is potentially affected by environmental, social, and governance (ESG) issues. The ESG Risk Ratings provide a score on a scale of 0-100, where a lower score indicates lower levels of unmanaged ESG risk.

**Table 2:** Total ESG Risk score of car industry

no.	Car / factory name	Total ESG Risk score				Environment Risk Score	Social Risk Score	Governance Risk Score
1	Mercedes-Benz	21	31	percentile	medium	6,0	7,4	7,5
2	Ford	22	37	percentile	medium	7,4	6,4	8,5
3	Renault	22	37	percentile	medium	6,1	9,1	7,2
4	BMW	25	48	percentile	medium	4,9	11,1	8,8
5	Tesla	25	50	percentile	medium	3,3	14,1	7,8
6	Volkswagen	26	53	percentile	medium	5,7	9,1	11,2
7	Nissan	32	75	percentile	medium	9,2	14,3	8,4
8	Stellantis	data not available						
9	Toyota	data not available						
10	Hyundai	data not available						
11	Honda	data not available						
12	BYD	data not available.						
13	Xiaomi	data not available						

Source: Author with data of <https://finance.yahoo.com/>

In recent years, there have been significant changes in the auto industry. Initially, American Chrysler merged with Italian Fiat and French Peugeot, affecting the company's name and operations in Serbia, including the production of the Fiat 500L and the new EV car model. Tesla entered the car-manufacturing sector around 2013 and began pushing boundaries in the field of electric vehicles (EV) by 2017. The "Diesel gate" scandal revealed that many manufacturers, besides VW, such as Renault, had also cheated on emissions tests. Nissan and Renault formed an alliance to develop platforms for joint models. Daimler (Mercedes-Benz) was installing Renault engines in its cheaper A and B series models. Nissan in 2018 got guilty judgment regarding the false statements and get penalty of 200 million yen. In 2021, Daimler changed its name to Mercedes-Benz. BYD from China has become a significant global player with most sold EV car in history (3 million pcs). In 2024, Xiaomi introduced a super-luxury model expected to capture a large market. In 2023/2024, Toyota displayed a revised plan to not heavily enter the electric car market but instead focus on Plugin Hybrid Electric Vehicles (PHEV), Hybrid Electric Vehicles (HEV), Carbon Neutral Fuels (CN Fuel), Hydrogen Engine vehicles (H2), and Fuel Cell Electric Vehicles (FCEV). However, questions about the finances remain unanswered.



### 3. FINANCIAL RESULTS OF EIGHT CAR PRODUCER AND EV PRODUCTION

In this section, we provide data on the car sales of eight distinctive automobile manufacturers over a 14-year period from 2010 to 2024. Additionally, we include financial data (ratios: IR ratio, ratio of sales, ratio of EV car) for these eight specific car producers: BMW, Mercedes-Benz, VW, Tesla, Toyota, Stellantis, BYD and Ford. As Rakićević et al. (2023) wrote in covid-19 crisis most of car producer had down of sale due to falling demand as we can see in table 3 but it also happened with financial results in 2020. However, in other years of this 14 years period we can clearly see that company who invest much in R&D, use way of sustainability development, and have high ratio of EV cars in production lane are made much better results than the one who are not willing to track way of sustainably development. As Damjanovic et al. (2018) wrote that the role of financial and marketing indicators, depending on the type of company, determines what is in focus, so for companies that sell consumer goods, monthly turnover carries 45% of importance, for pharmaceutical companies, order value 32% of importance. When it comes to the automotive industry, R&D will be the most important issue in the coming years, and that is why investment in R&D need to analyzed in this industry in particular.

**Table 3:** Sale of eight specific car producers in 1.000 cars

No.	Producer	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1	BMW	1461	1669	1845	1964	2118	2258	2352	2469	2483	2564	2256	2461	2382	2662
2	Mercedes-benz	1277	1381	1452	1566	1723	2001	2198	2374	2383	2385	1944	2041	2041	2044
3	VW	7278	8361	9345	9728	10217	10010	9635	10039	10601	10732	9145	8611	7957	8901
4	Tesla								101	245	112	500	936	1314	1809
5	Toyota	7237	7308	7352	8871	9116	8972	4482	4423	4655	4272	4895	5836	6003	6393
6	Stellantis							8681	8971	8964	8977	8958	7646	8230	8822
7	BYD														
8	FORD	5524	5695	5668	6330	6323	6635	6651	6607	5982	5386	4187	3942	4231	4413

Source: Author on annual reports of these eight specific car producers

**Table 4:** IR ratio, Ratio of sale, ratio of EV car, of eight specific car producer in 1.000 of car

Producer	Ratio	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
BMW	Ratio of IR in total revenue		4,4	4,6	0,6	5,5	5,2	4,6	5,0	7,1	6,2	0,6	5,7	4,6	4,8
Mercedes		5,0	5,3	4,9	4,7	4,4	4,4	4,9	5,3	5,4	5,6	7,5	6,4	6,1	4,1
VW		5,4	4,5	4,6	5,2	5,7	5,6	5,3	5,0	5,8	5,7	5,4	5,1	5,1	6,8
Tesla		79,7	102,3	66,3	11,5	14,5	17,7	11,9	11,7	6,8	5,5	4,7	4,8	3,8	4,1
Toyota		3,8	3,8	4,2	3,7	3,5	3,7	3,7	3,8	8,5	6,2	6,9	8,3	9,1	2,9
Stellantis											3,3	3,4	3,1	2,9	3,0
BYD		3,0	3,0	2,6	2,6	3,4	2,6	3,2	3,6	3,8	4,4	4,8	3,7	4,4	6,6
FORD			1,7	1,7	0,9	1,1	1,3	1,2	0,4	0,3	0,4	1,0	0,8	2,0	2,2
BMW	Ratio of EV in total sales					0,8	1,3	2,6	4,2	5,7	5,7	8,5	13,3	18,2	21,3
Mercedes												14,0	16,3	16,3	19,7
VW												4,5	8,6	9,9	11,0
Tesla									100	100	100	100	100	100	100
Toyota														0,2	0,4
Stellantis															5,5
BYD										45,5	67,1	73,1	54,0	49,1	52,3
FORD														1,5	1,6
BMW	Ratio of profit before taxes in revenues	4,1	4,1	4,2	3,6	3,5	4,1	4,0	4,0	3,9	4,1	4,4	4,5	6,0	5,8
Mercedes		6,8	7,9	7,1	8,6	7,8	8,5	8,2	8,5	6,3	2,5	5,4	21,7	13,6	12,8
VW		5,7	11,9	13,2	6,3	7,3	-0,6	3,4	6,0	6,6	7,3	5,2	8,0	7,9	7,2
Tesla		116	-115	-88	3,0	3,6	-5,3	5,3	0,8	7,8	8,5	13,7	11,8	21,4	14,0
Toyota		1,5	3,0	2,3	6,4	9,5	10,6	10,5	7,9	8,2	8,2	8,2	8,1	9,5	12,3
Stellantis								2,8	5,6	3,7	3,7	1,6	10,1	10,9	11,7
BYD		6,7	3,7	0,7	1,7	1,6	4,9	6,6	5,5	3,4	1,9	4,4	2,1	5,0	6,2
FORD			11,4	10,6	15,1	10,2	14,9	9,6	8,6	7,2	5,8	2,4	7,7	8,1	6,8

Source: Author on annual reports of eight specific car producer

## 4. DISCUSSION

Ford has shown limited interest in the EV segment, which is reflected in their annual reports where there is no clear data on their investment in R&D and the sales of EV cars. It is evident from Table 4 that their sales significantly dropped from 6.6 million cars during 2015-2017 to 4.4 million cars in 2023. The share of EV cars was merely 1.6% in 2023. The ratio of revenue (pre-tax profit) halved from 2013 to 2023 to 6.8%. Ford represents Box 1 with solid financial results, a brand value position of Y1, and a Z1 position regarding ecological standards, indicating that minimal investment in R&D has jeopardized its earlier standings. As seen from Tables 3 and 4, VW reached sales of over 10 million cars in 2014 and 2015. During 2014, the profit before tax and total revenue ratio was over 7%, but due to penalties, it dropped to -0.6% in 2015. According to annual reports, VW consistently invested about 5% to 5.8% in research and development, which increased to 6.8% in 2023. The share of EVs in total vehicle sales rose to 11%. With these EV market results, the ratio of revenue recovered to over 7.2%. VW represents Box 2 with good financial results (X2), an inadequate brand value (Y1), and a Z1 position regarding ecological standards, as proven by its ESG score.

Stellantis is a company formed by the merger of traditional auto manufacturers (Chrysler, Fiat, Peugeot), which were not significantly involved in the electric vehicle (EV) narrative before the merger; hence, there are no data prior to 2017. From 2021 to 2023, the sales ratio (profit before taxation/revenue) increased to over 10%. The share of purely electric vehicles rose to 5.5% in 2023. Among all manufacturers observed, Stellantis had almost the lowest investments in R&D, as indicated by the IR/revenue ratio. Stellantis represents Box 3 with solid financial results (X1), a low brand value (Y1), and a Z2 position in ecological standards, showing an increased offering of these vehicles and investments in R&D. American Tesla and Chinese BYD are manufacturers that have achieved significant market success due to their positioning in the electric vehicle niche. BYD employs a large number of workers: 201.000 (2017), 221.000 (2018), 229.000 (2019), 224.300 (2020), 288.200 (2021), 570.100 (2022), 703.500 (2023) which enabled it to sell 3 million cars in 2023. However, their sales ratio was 6.2% in 2023. It's unclear how much state subsidies contribute. BYD represents Box 4 with good financial results (X2), a brand value (Y1) not yet among the top 100 globally, and a Z1 position in ecological standards, offering a large number of electric vehicles but lacking data on ESG scores and true orientation towards ecological sustainability. Tesla, the American competitor in the Chinese market, only became profitable in 2018, with its revenue ratio (pre-tax) ranging from 8 to 21% from 2018 onward (a record). By the end of 2023, Tesla achieved this with 140,473 employees, significantly fewer than BYD. Tesla represents Box 5 with solid financial results (X1), as its stock price fell from \$250 to \$130-180\$ in 2024. Y2 brand value (supported by a large loyal customer base), and a Z1 ecological standards position as a one of leader in the EV industry, though it scored the worst in the Social Risk Score (14.1) and performed poorly in the Governance Risk Score, similar to other manufacturers.

Toyota, a traditional car manufacturer, initially focused on EVs (e.g., the Prius model) but shifted strategy in 2023. Its sales ratio increased from 6.4% in 2013 to 12.3% in 2023. The share of purely battery electric vehicles was just 0.4% in 2023. Toyota changed its strategy to lead in PHEV and HEV vehicles. In the 3D matrix, Toyota occupies Box 6 with excellent financial results (X2), Y2 brand value, and a Z1 position in ecological standards. BMW maintained strong performance with substantial investments in R&D, allocating 7.1% of its revenue in 2017 and just 0.6% during the COVID-19 years. The share of electric vehicles reached 21.3%, and sales consistently grew from 1.46 million in 2010 to 2.66 million in 2023. The ratio of revenue increased from 4.1% in 2010 to 5.8% in 2023. BMW occupies Box 7 in the 3D matrix, with solid financial results (X1), Y2 brand value, and a Z2 position in ecological standards, reflecting substantial investments in environmentally sustainable technology at the expense of financial gain. Mercedes has perhaps benefited the most from the EV narrative among traditional car manufacturers. Its sales ratio nearly doubled from 6.3% in 2018 to 12.8% in 2023, with an EV share of 19.7% in 2023 and R&D investments between 5% and 6%. In the 3D matrix, Mercedes occupies Box 8, displaying excellent financial results (X2), Y2 brand value, and a Z2 position in ecological standards.

Companies BMW and Mercedes-Benz are the only traditional manufacturers who have managed to achieve constant sales growth as well as financial results thanks to huge investments in R&D and following trends around the EV product niche. Ford and VW have experienced a significant decline in the number of vehicles sold precisely because other traditional manufacturers, as well as newcomers like Tesla and BYD, have taken a large part of the market share. Toyota and Stellantis have managed to maintain and slightly increase market share thanks to increased investments in R&D and environmental initiatives. The general conclusion that arises is that companies must balance ESG scores and focus on sustainable development through investments in R&D without compromising financial results and brand value, and vice versa. The study shows that the three-dimensional matrix can be an important strategic tool in positioning any company in relation to three factors, with the possibility of using this matrix to observe three other factors as well (Bajramović & Ahmatović).

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# SUSTAINABLE MANAGEMENT IN THE OIL AND GAS INDUSTRY: TOWARD AN INTEGRATED CCS MODEL

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**Abstract:** *This paper presents a comprehensive exploration of carbon capture and storage (CCS) through a systematic literature review, case studies, and management concepts. CCS has emerged as a key solution to bolster decarbonization efforts, garnering significant attention from both academia and industry practitioners. Given the complexity of CCS endeavors, efficient management is essential not only during project implementation but also throughout the lifecycle of facilities involved in capturing, transporting, storing, and utilizing recycled carbon dioxide. To address this need, we have conducted an analysis of relevant studies covering various aspects of CCS and proposed a management model that integrates sustainable, responsible, and economically viable practices into the CCS acumen.*

**Keywords:** *Carbon Capture and Storage, Sustainable Management, Oil and Gas, Decarbonization*

## 1. INTRODUCTION

Carbon capture and storage (CCS) has recently gained significant momentum due to the global rise in decarbonization efforts aiming to find effective solutions for reducing CO<sub>2</sub> emissions and assist businesses worldwide in achieving their sustainability goals. The oil and gas industry has been leading the way in implementing CCS, utilizing the technology to purify natural gas and enhance oil production, generate cleaner energy and reduce total emissions, and produce higher-quality products and distribute CO<sub>2</sub> to other industries. Hence, the primary motivations driving CCS adoption in this sector are perceived as technical, environmental, and economic, respectively, resulting in emissions reduction from both the extraction and refining processes, as well as from subsequent fossil fuel combustion (Turan, 2020; Deng et al., 2022).

Although CCS was developed decades ago, the complexity and resource requirements of such an endeavor have resulted in less widespread deployment of the technology across the globe with only major players in the oil and gas industry being able to participate in this arena. Consequently, we have identified a lack of comprehensive approaches for executing CCS projects and, in line with innovative management methods, we aim to propose one that is sufficient for future endeavors in this field. Naftna Industrija Srbije was the first in Europe to implement the novel technology for removing CO<sub>2</sub> from natural gas and injecting it into exploited oil fields; thus, this experience is crucial and serves as a driving force for creating an integrated CCS model that adheres to the principles of responsible and sustainable operations in the oil and gas industry (Okazaki et al., 2018; Turan, 2020; IEA, 2022). Building on this, the paper outlines the most important theoretical aspects of implementing CCS, summarizes lessons learned from the concrete project, and introduces a model for managing CCS projects.

## 2. CARBON CAPTURE AND STORAGE

### 2.1. Theoretical Background

Carbon capture and storage represents a modern, innovative, and sustainable technology used to remove carbon dioxide from the atmosphere and store it permanently, typically in underground geological formations, enabling the decarbonization of industrial processes and fossil fuel energy production processes (Praetorius & Schumacher, 2009; Leung et al., 2014; Steele et al., 2021). CCS is often considered one of the most adequate solutions for achieving sustainable development goals and, as such, it encompasses various strategies, processes, procedures, techniques, and tools that are incrementally developed and simultaneously used in oil refining, natural gas processing, and other activities in the oil and gas industry that significantly impact carbon dioxide emissions (Gibbins & Chalmers, 2008; D'Amore et al., 2020). For a more

comprehensive understanding, this technology can be viewed through the lens of two main sub-processes – carbon capture and carbon storage, as well as two additional processes – transportation that connects capturing and storing CO<sub>2</sub> and carbon utilization bolstering CCS benefits.

Carbon capture is the first and fundamental process of CCS involving the separation of carbon dioxide from the emission source and its preparation for transport and permanent storage, thereby preventing its release into the atmosphere (Belyakov, 2019; IEA, 2020). Following carbon capture, the next step is transportation, which, although not always emphasized as a separate process, is integral to CCS, thus connecting carbon capture and storage by facilitating the relocation and delivery of CO<sub>2</sub>, even to the most remote storage sites or utilization points (McCoy & Rubin, 2008; Praetorius & Schumacher, 2009; Leung et al., 2014; IEA, 2020). Furthermore, carbon storage is a process aimed at preventing the re-entry of carbon dioxide into the atmosphere by employing various storage methods that minimize risks and threats to society, the economy, and the environment (Rackley, 2010; Cook, 2012; Leung et al., 2014; Shirmohammadi et al., 2020). The most common form of storing collected CO<sub>2</sub> is storage in deep geological formations, considered the safest and most practical solution, but other options encompass storing captured CO<sub>2</sub> in oceans, the biosphere, artificial reservoirs, and, of course, using it in industry, i.e., “storage” in the form of raw materials and products intended for commercial use (Cook, 2012; Leung et al., 2014; IEA, 2020).

The most significant application of CCS in the oil and gas industry is enhanced oil recovery (EOR), which serves both as geological CO<sub>2</sub> storage and as a means to increase reservoir utilization and oil production (Riley, 2010; Leung et al., 2014). By injecting captured CO<sub>2</sub> into depleted and partially depleted oil and gas reservoirs, typically at the basin floor, oil and gas movement toward wells is stimulated, thereby allowing even the smallest amounts of oil or gas trapped in the pores and cavities of the reservoir to be brought to the surface and sent to refining and processing facilities (Riley, 2010; Hill et al., 2013; Leung et al., 2014). Given this context, EOR projects, accompanied by ongoing research into enhanced gas recovery, yield substantial economic and ecological benefits, thus representing the most promising CO<sub>2</sub> utilization and monetization opportunity.

## **2.2. Managing CCS Projects**

As CCS technology evolved, approaches to managing these endeavors also changed, transitioning from a mere engineering perspective to broader sustainability considerations. This shift has underscored the importance of addressing safety risks, achieving social acceptance, and protecting the environment as crucial facets of efficient CCS management, thereby creating substantial room for further streamlining CCS implementation (Larkin et al., 2019).

Many CCS endeavors, including the reference case explained later, adhere to strict procedures established by the technology provider or project owner, which is quite understandable from a technological standpoint. However, given the uncertainty surrounding CCS deployment, which could potentially jeopardize the realization of its benefits and impede decarbonization efforts, integrating risk management as an inseparable component of CCS management becomes imperative (Zhang et al., 2019). Safety concerns, especially those related to CO<sub>2</sub> leakage from geological storage, necessitate the adoption of adequate risk management practices that ensure the protection of both people and the environment while maintaining operational efficiency and cost-effectiveness (Kuckshinrichs & Vögele, 2015; Markewitz & Bongartz, 2015). As such, risk management should always be supported by the installation of monitoring and control systems that provide continuous insight into the status and movement of CO<sub>2</sub>, from its delivery and injection to long-term storage (Leung et al., 2014). Additionally, managing CCS projects requires the integration of and adherence to sustainability principles, which is essential not only for overcoming challenges within the local community but also for addressing global issues that endanger people, the environment, and the economy worldwide (Schumann, 2015; De Madeiros Costa & Arlota, 2021; Jain & Kaur, 2022). Therefore, managing CCS aligns with a broader scope that extends beyond the company undertaking the initiative to encompass society as a whole.

## **2.3. Industry Experience**

According to the Global CCS Institute (2022), there were 196 active CCS projects worldwide in 2022, with the United States, Canada, and developed European countries leading in the development and implementation of smart CCS systems and associated technologies. One CCS project has been implemented in the Republic of Serbia which, in terms of complexity, innovation, and scope, represents the most demanding and significant project of its kind in the region, and certainly one of the best examples of practical application of CCS. This project was initiated in 2013 by Naftna Industrija Srbije and involved the

implementation of a CO<sub>2</sub> EOR project at the “Rusanda” oil field and the construction of the first HiPACT (High-Pressure Acid-gas Capture Technology) plant in Europe (Okazaki et al., 2018; Karas & Nešić, 2019; Fomynikh, 2022). In simple terms, the system works by transporting natural gas with a high CO<sub>2</sub> content to the HiPACT plant from seven interconnected gas fields; then, at the HiPACT plant, CO<sub>2</sub> is separated by treating the natural gas and CO<sub>2</sub> mixture with amine gas; and the separated (captured) CO<sub>2</sub> is then injected into the “Rusanda” oil field to increase oil production and reservoir utilization while achieving permanent CO<sub>2</sub> storage in geological formations (Okazaki et al., 2018; Karas & Nešić, 2019; Karas, 2022). Hence, this is a unique project that combines carbon capture from industrial processes and its injection into a partially depleted oil field, serving as a reference example for numerous local and global researchers and practitioners.

### **3. RESEARCH METHODOLOGY**

The research methodology employs a systematic literature review, case analysis, and conceptualization to attain insights into the pertinent findings regarding CCS theory and practice, as well as to propose suitable approaches for managing CCS endeavors.

#### **3.1. Systematic Literature Review**

Through a systematic literature review, we analyzed over thirty papers relevant to various aspects of CCS implementation. The aim was to identify the foundational principles of both CCS theory and practice, thereby validating existing findings, discerning the latest developmental trends, and facilitating the creation of a model for managing CCS. Although the systematic literature review has primarily focused on recent studies, given the infrequent realization of CCS projects, we broadened our scope to include earlier studies, which form the backbone of CCS development. By reconciling these perspectives, particularly in light of the ever-evolving environmental, social, and governance concerns, this paper offers a comprehensive outlook on managing CCS projects and should serve as a guiding resource for future initiatives on CCS and other similarly intricate decarbonization endeavors.

#### **3.2. Case Analysis**

We select the implementation of a CO<sub>2</sub> EOR project at the “Rusanda” oil field and the construction of the HiPACT plant as the most relevant case for our research. The selection criteria included project impact, comprehensiveness, and data availability, which guided us toward but were not limited to this specific CCS endeavor. Additionally, we considered the CO<sub>2</sub> EOR project at the “Ivanić i Žutica” oil field in the Republic of Croatia (Novosel et al, 2020; Franki et al., 2021), the “EnCana Weyburn” CO<sub>2</sub> EOR project in Canada (Rackley, 2010), the “Sleipner” and “Snøhvit” projects in Norway (Rackley, 2010; Cook, 2012; Leung et al., 2014; IEA, 2020), and other cases. However, data availability was the factor that predominantly influenced the authors of the paper in selecting the HiPACT plant in the Republic of Serbia as the reference case, and others as supporting cases for the research.

#### **3.3. Conceptualization and Generalization**

Conceptualization and generalization build upon the foundational systematic literature review and case analysis, thus serving as methods to synthesize relevant findings and propose an integrated CCS model. These methods were also utilized to achieve a clearer understanding of possible approaches to managing various aspects of CCS endeavors and to comprehend all relevant factors influencing their successful implementation. Therefore, conceptualization and generalization can be seen as a means of structuring the CCS management model.

### **4. INTRODUCING A MODEL FOR MANAGING CCS PROJECTS**

From a project management perspective, the construction of the HiPACT plant was executed entirely in a traditional manner, following the standard project phases from initiation and planning, through execution, monitoring, and controlling, to closure and operational launch. After the operational launch, strict procedures were adopted and key metrics established, along with the implementation of smart monitoring systems, to ensure comprehensive oversight of CO<sub>2</sub> capture, movement, and storage. Given that these measures primarily focus on mitigating risks associated with these processes and addressing geotechnical challenges inherent to such projects, we identified the necessity for restructuring them to become more flexible and enhance sustainable and societal performance.

#### 4.1. Management Concepts Complementing CCS Implementation

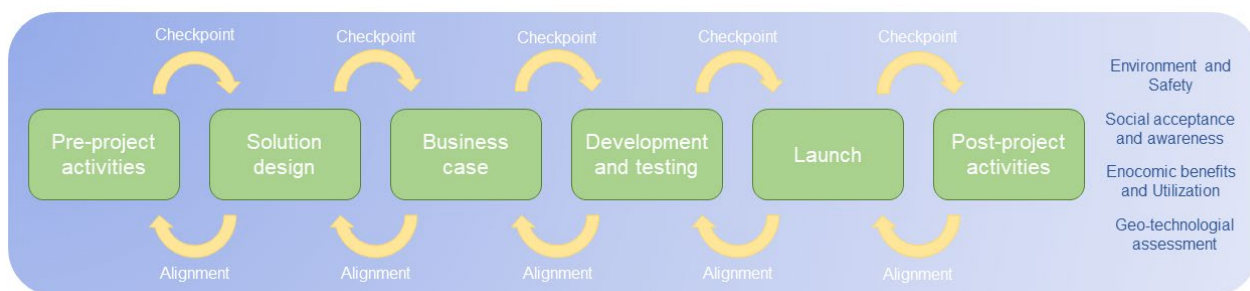
Drawing on the key features of CCS, the specifics of its management, and the experience gained from the reference project, we have outlined the Stage-Gate® Innovation Performance Framework and PRiSM™ (Projects integrating Sustainable Methods) as approaches that could complement the management of CCS endeavors. Additionally, we advocate for the adoption of agile practices whenever applicable.

The Stage-Gate® Innovation Performance Framework is a five-stage idea-to-launch system that provides a clear roadmap for developing new products and technologies; it structures projects into subsequent, interrelated, and incremental phases, while continuously assessing their alignment with pre-established criteria and goals ensuring project success and quality (Cooper, 2015; Stage-Gate International). As such, the Stage-Gate Framework guides the project through discovery, scoping, business case, development, testing and validation, and finally, the launch stages, and incorporates gates before the start of each phase to review deliverables, assess the project against the criteria, and facilitate decision-making regarding the next steps (Cooper, 2015; Stage-Gate International). Hence, the Stage-Gate Framework emerges as an approach complementary to managing CCS projects.

The PRiSM methodology complements the Stage-Gate Framework by sharing a significant alignment, especially in their phased approach to project management, and further extending this alignment by integrating six key sustainability principles and emphasizing the significance of post-project activities. The principles of commitment and accountability, ethics and decision-making, integrity and transparency, social and ecological equity, principal and value-based resource usage, and economic prosperity are inherent in the PRiSM methodology (Green Project Management), and serve as an essential addition to CCS technology, addressing aspects that may be missing in the undertaking and management of these endeavors.

#### 4.2. Integrated Phased Model for CCS Implementation (IPM-CCS)

The development of the Integrated Phased Model for CCS Implementation (IPM-CCS) is currently underway, representing a significant effort to advance CCS practice. The concept is to create a primarily phased model that allows for overlapping phases and integrates continuous health checks and subsequent alignment, thus fostering incremental development and welcoming changes throughout the project lifecycle (Figure 1). With criteria constantly evolving and project goals being reassessed, this model goes beyond technical aspects and delves into sustainability, societal, and economic considerations, aiming to enhance CCS implementation and support its wider deployment.



**Figure 1:** Integrated Phased Model for CCS Implementation (IPM-CCS)

The implementation of CCS should always commence with numerous pre-project activities, including technology assessment, vendor identification, procurement and contracting, establishment of initial criteria and working procedures, creation of project governance, alignment with the company's strategy and goals, and others. Although this phase may appear simple and less important compared to others, the reality is quite the opposite, as projects can potentially be abandoned due to factors such as inadequate technology or vendors, regulatory constraints, or lack of support from authorities. Nonetheless, the purpose of preliminary activities is to answer these questions and provide valuable inputs for the continuation of the project.

Upon selecting a technology provider or deciding on developing the solution internally, if possible, the IPM-CCS enters the solution design phase, comprehending geological, engineering, construction, mechanical, hydrostatical, electrical, health and safety, and all other studies that must be conducted before allocating significant resources to the CCS deployment. All these studies serve as inputs to the business case phase, which welcomes piloting and thoroughly examines the justification of the CCS endeavour, thus evaluating not only the adequacy of the technological solution but also the economic, financial, social, and environmental

benefits. As such, this phase is accompanied by a checkpoint aimed at preventing inefficient investment that could occur if a minimum of these benefits is not met, thereby leading to revising proposed solutions or even abandoning them entirely. Furthermore, it is important to note that the outputs of the solution design and business case phases should explicitly state whether the storage options proposed in technological solutions are sufficient and appropriate for storing captured CO<sub>2</sub>.

During the development and testing phase, the IPM-CCS model prioritizes technology deployment, building facilities and infrastructure, testing CO<sub>2</sub> capture and storage in a controlled environment, identifying potential leakage points, and establishing an effective monitoring system. While the emphasis is primarily on technical efforts, this phase should also encompass integrating sustainability practices, conducting social acceptance research and campaigns, providing comprehensive personnel training, continuously reassessing economic benefits, and all other activities necessary to launch a fully operational CCS plant. The checkpoint following the development and testing phase is also guided by a technical narrative and prevents the project from proceeding to the go-live stage if any of the aforementioned conditions are not met.

The launch phase, typically perceived as the operational moment for the CCS plant, is proposed to be extended to a 6 to 18-month period within the project scope, serving as the final confirmation of technology effectiveness, health and safety protection, and business justification. Thereafter, we enter post-project or post-launch activities that embody principles of environmental care and safety, social awareness and acceptance, economic benefits and carbon utilization, and continuous and responsible geo-technological assessment.

## 5. CONCLUSION

Carbon capture and storage represents as a promising opportunity for the decarbonization and achieving sustainable goals, necessitating further efforts to facilitate technology development, reduce implementation costs, and increase awareness of its potential. By employing the Integrated Phased Model for CCS Implementation (IPM-CCS), some of these expectations could be reached, at least at a single-project or single-company level, thereby enhancing CCS practices and offering insights into the novel approaches to managing these types of projects. The IPM-CCS, although in its initial development phase, aims to comprehensively understand all facets crucial for the successful deployment of CCS technology and, building on that, expand management practices beyond the merely technical arena, emphasizing the social, environmental, and economic dimensions of this all-permeating endeavour. Furthermore, the authors suggest collecting new data from the reference project and conducting empirical examinations, thereby creating room for the verification and practical application of the IPM-CCS.

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# INTEGRATION OF SUSTAINABILITY IN HIGHER EDUCATION INSTITUTIONS

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**Abstract:** *In recent years, sustainability and sustainable practices have gained prominence in both, scientific and practical communities. This paper focuses on the analysis of existing literature, with the aim of creating a theoretical framework, encompassing the integration of sustainability concepts and practices within higher education institutions. Additionally, based on the conducted research, four key domains within higher education institutions for integrating sustainability into, were identified: Study Programs and Curricula; Operations, Student Life, and Campus; Research, Science, Networks and Partnerships; and Projects. Exploring these domains resulted in enhancing the understanding of how higher education institutions can contribute to sustainable development and address global challenges, in synergy with stakeholders within their environment.*

**Keywords:** *sustainability, sustainable practices, integration, higher education institutions*

## 1. INTRODUCTION

Concern for sustainability is one of the challenges that captures attention in political, scientific and practical communities and is often the subject of debates due to its impact on all aspects of life. Sustainability implies the ability of current generations to meet their own needs without compromising the ability of future generations to meet their own needs. Extreme problems caused by a lack of consideration for sustainability are increasingly becoming almost common. To change that, it is necessary to build the responsibility of each individual to positively influence society, the environment and resources through decision-making and working methods (Staniškis & Katiliūtė, 2016). The awareness, mindset and working methods of all stakeholders - employers, industry and society - need to change. A transition to a more sustainable way of learning, living and doing business is needed, requiring collective action by all stakeholders and systematic change (Nurdiana et al., 2019).

One particularly important stakeholder in promoting sustainability and sustainable practices should for sure be the higher education sector. Traditionally, higher education is focused on the creation, development and transfer of knowledge and skills in response to the needs or demands of employers, industry and the market (Staniškis & Katiliūtė, 2016). Therefore, approaches to learning and teaching should be changed in accordance with new challenges in the world. Higher education institutions (HEIs) are an important driving force and wheel for training leaders and citizens who will contribute to the development of sustainable practices (Pantaleão & Cortese, 2018). Spreading the culture of sustainability, through cooperation between individuals, companies and government institutions, develops and builds, when there is an appropriate environment through learning for it (Pantaleão & Cortese, 2018).

In June 2022, the European Commission published the Recommendation on Learning for the Green Transition and Sustainable Development, where they recommend how to integrate sustainability into all aspects of education and training (European Commission, n.d.). Some of the recommendations relate to education, such as making learning for the green transition and sustainable development a priority in education policies and programs and providing all students with opportunities to learn about the climate crisis and sustainability in formal and non-formal education. However, it should be emphasized that the focus is not only on education, but research, networks, and processes also need to be changed (European Commission, n.d.).

Following the new recommendations of the European Commission and regarding the analysis of existing literature, the concept of sustainability and sustainable practices can be observed through four key areas of operations in HEIs namely:

- Study Programs and Curricula,
- Science, Research, Networks and Partnerships,

- Operations, Student Life and Campus, and
- Projects.

Therefore, the main aim of this paper is precisely to summarize the existing scientific literature gathered through conducted desk research in order to obtain answers to the following research questions (RQ):

RQ1: In the scientific literature, with which domains of higher education processes do scientists associate the concept of sustainability and sustainable practice?

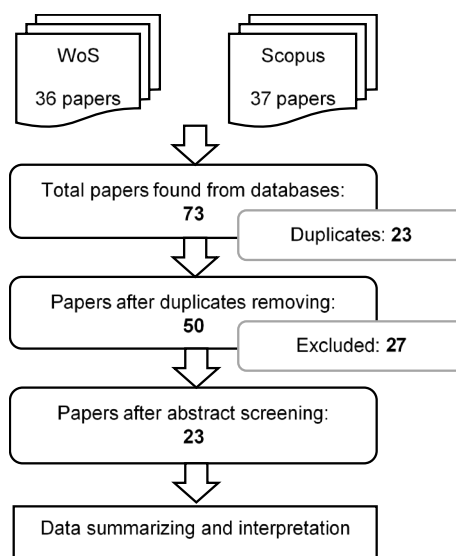
RQ2: What research and development initiatives related to sustainability and sustainable practices are recognized in the domains of higher education institutions?

The main aim of this paper is to emphasize the importance of incorporating the concept of sustainability and sustainable practices into the processes of HEIs and to identify research and development initiatives of sustainability and sustainable practices in the domains of HEIs.

This paper follows the structure as outlined below. In the next chapter, the research methodology used in this paper is explained. In the third chapter, an overview of existing research dealing with sustainable development and the role of HEIs in sustainable development is provided. The fourth chapter refers to an overview of research results, where development and research initiatives in certain domains of HEIs, are presented. And finally, the paper ends with concluding remarks, giving motivation for future research on the topic presented in the paper.

## 2. METHODOLOGY

To gain insight into the research area, secondary data was collected through conducted desk research. The Web of Science platform and the Scopus database were searched. The selection of papers included in the analysis, as well as their quality and transparency are based on the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Shamseer et al., 2015). The research query was as follows: (("high education" OR "high education institution") AND ("sustainability" OR "sustainable practices")).



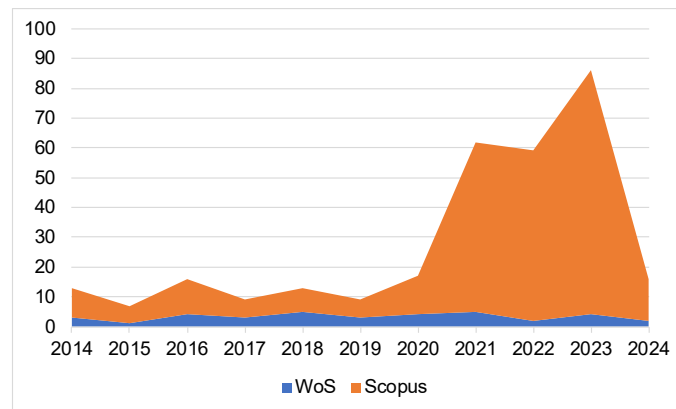
**Figure 1:** PRISMA protocol for research analysis (Source: authors)

No additional search restrictions were set when searching the Web of Science platform, and a total of 36 papers were retrieved for research analysis. To obtain a more comprehensive overview of the topic of sustainability in higher education, the Scopus database was searched using the same query, and a total of 274 papers were found. An additional limit was set in the Scopus database to limit the number of papers to be analyzed. It should be pointed out, that only papers with the abstract containing the conditions defined in the query were included in this research. Therefore, from the Scopus database, 37 papers were included in the analysis. Of the total of 73 papers, 23 duplicates were identified, so a total of 50 papers were available for further analysis. After reviewing the abstracts of the papers, only papers dealing with topics related to the research questions were taken into account. Ultimately, 27 papers were omitted from further analysis, while 23 papers relevant to the research were identified.

### 3. RESEARCH BACKGROUND

In the last few years, sustainability and sustainable practices have been trying to be incorporated into HEI operations, which is desirable because the academy should be a leader in introducing changes in the industry (Paulauskaite-Taraseviciene et al., 2022) (Crespo et al., 2017).

Figure 1 shows the increase in published papers on the research topic of sustainability and sustainable practices in HEIs. Papers on the researched topic have been mostly published since 2014. Before 2014, only 4 papers were published on this topic. Despite this, it can be concluded that more attention to research in this area has been given since 2020 when the number of published papers increased each year.



**Figure 2:** The trend of publication of papers in WoS and Scopus related to sustainability in higher education institutions (Source: authors)

In 2015, the United Nations Member States adopted a very important document, the 2030 Agenda for Sustainable Development, which should be a guide for the peace and prosperity of society today and in the future (United Nations, n.d.-b). As part of this document, 17 Sustainable development goals (SDG) are described, presenting guidelines for sustainable development. All 17 goals refer to a certain aspect of improving the quality of life in society, protecting resources and being responsible towards everyone and everything. These goals should be integrated into the activities of individuals, companies, public institutions and the government, and everyone is expected to act together (United Nations, n.d.-b).

Higher education institutions play a crucial role in driving transformation within the existing operational and educational frameworks. Their focus should center on four critical domains where they can implement sustainable practices and contribute to overall sustainability, namely: Study Programs and Curricula; Science, Research, Networks and Partnerships; Operations, Student Life and Campus; and Projects. Education for Sustainable Development (ESD) equips students with the knowledge, skills, values, and agency to tackle interconnected global challenges. These challenges include climate change, biodiversity loss, unsustainable resource utilization, inequality, and other pressing issues (Unesco, n.d.).

Universities play a pivotal role in advancing sustainability because they engage with all 17 United Nations' Sustainable Development Goals (SDGs). Through their teaching and research across various disciplines - such as arts and humanities, natural sciences, social sciences, and medicine - universities uniquely scrutinize sustainability objectives and concepts. Their ability to swiftly integrate sustainable literacy into curricula empowers students. Teaching staff can innovate existing courses by infusing them with sustainable development themes. Additionally, research conducted within higher education institutions serves as vital sustainability laboratories (Cornish, 2023). Although researches are long-term projects and require certain resources, they play a key role in working towards a sustainable future.

### 4. FINDINGS

The results of the literature analysis based on the criteria defined in the PRISMA protocol are presented below. The results presented in Table 1 show the domains of processes of HEIs in which researchers investigate sustainability and sustainable practices. It is evident that the concept of sustainability and sustainable practices is important to observe through all domains of HEI activity and that the future development of sustainability in HEIs requires inclusion in all processes.

**Table 1:** HEI Domains investigated in sustainability context in referenced papers

HEI Domains	References
Study Program and Curricula	(Pantaleão & Cortese, 2018), (Staniškis & Katiliūtė, 2016), (Nurdiana et al., 2019), (Wood et al., 2016), (Paulauskaite-Taraseviciene et al., 2022), (Shields et al., 2014), (Montenegro de Lima et al., 2020), (Dino et al., 2022), (Paletta & Bonoli, 2019), (Miotto et al., 2020), (Aguar et al., 2023), (Usak et al., 2021), (Burcea & Marinescu, 2011), (Leal Filho et al., 2024), (Uhan et al., 2024), (Pérez Machin, 2023), (Prazian & Prykhodko, 2023), (Budeanu, 2002), (Escrig-Olmedo et al., 2017)
Operations, Student Life and Campus	(Pantaleão & Cortese, 2018), (Merger et al., 2018), (Nurdiana et al., 2019), (Montenegro de Lima et al., 2020), (Paletta & Bonoli, 2019), (Miotto et al., 2020), (Yin et al., 2021), (Aguar et al., 2023), (Rodrigues & Morais, 2021), (Usak et al., 2021), (Crespo et al., 2017), (Leal Filho et al., 2024)
Research, Science, Networks and Partnerships	(Nurdiana et al., 2019), (Montenegro de Lima et al., 2020), (Paletta & Bonoli, 2019), (Miotto et al., 2020), (Aguar et al., 2023), (Usak et al., 2021), (Leal Filho et al., 2024), (Uhan et al., 2024)
Projects	(Nurdiana et al., 2019), (Montenegro de Lima et al., 2020), (Dino et al., 2022), (Paletta & Bonoli, 2019), (Aguar et al., 2023), (Usak et al., 2021), (Crespo et al., 2017), (Leal Filho et al., 2024)

Source: authors

Sustainability and sustainable practices in the field of Study programs and Curricula are mentioned in 19 analyzed papers. The domain Operations, Student Life and Campus are covered in the context of sustainability and sustainable practices in 12 papers. Science, Research, Networks and Partnerships domain is the subject of discussion in 8 papers. And at the end, how sustainability should be dealt with through project activities and the Projects domain is stated in 8 papers.

Table 2 shows the HEI domains and associated development research initiatives related to sustainability and sustainable practices.

**Table 2:** HEI Domains and recognized sustainability-motivated research and development initiatives

HEI Domains	Research and development initiatives
Study Program and Curricula	<ul style="list-style-type: none"> <li>Integrating sustainability and sustainable practices into the curriculum in formal and informal education programmes (Pantaleão &amp; Cortese, 2018), (Shields et al., 2014), (Nurdiana et al., 2019)</li> <li>Integrating sustainability issues into regular disciplinary course topics and student projects (Wood et al., 2016), (Shields et al., 2014), (Escrig-Olmedo et al., 2017)</li> <li>Building skills for the creation of co-design and co-production in the context of sustainability for industry and society (Montenegro de Lima et al., 2020)</li> <li>Raising awareness of students for environmentally sustainable development in the context of the study program field (Montenegro de Lima et al., 2020)</li> <li>Promoting ideas and critical thinking about incorporating sustainability goals into practical problems and developing solutions (Staniškis &amp; Katiliūtė, 2016)</li> <li>Developing sustainability agent/ambassador through education (Nurdiana et al., 2019), (Wood et al., 2016)</li> <li>Providing transdisciplinary competences (Nurdiana et al., 2019), (Paulauskaite-Taraseviciene et al., 2022)</li> <li>Implementing a Service-learning approach into education (Hernández-Barco et al., 2020)</li> </ul>
Operations, Student Life and Campus	<ul style="list-style-type: none"> <li>Sustainability of the configuration and infrastructure (Pantaleão &amp; Cortese, 2018)</li> <li>Energy efficiency and conservation of resources (Pantaleão &amp; Cortese, 2018), (Merger et al., 2018), (Staniškis &amp; Katiliūtė, 2016)</li> <li>Rational use of resources (Merger et al., 2018), (Staniškis &amp; Katiliūtė, 2016)</li> <li>Management of waste disposal (Pantaleão &amp; Cortese, 2018)</li> </ul>

	<ul style="list-style-type: none"> <li>• Ensuring health and fresh food as well as encouraging healthy habits (Pantaleão &amp; Cortese, 2018)</li> <li>• Establishing a green environment (Montenegro de Lima et al., 2020)</li> </ul>
Research, Science, Networks and Partnerships	<ul style="list-style-type: none"> <li>• Strategizing sustainability research (Nurdiana et al., 2019)</li> <li>• Understanding the interdependence of environmental, technical, economic and social sciences</li> <li>• Performing interdisciplinary research and development (Staniškis &amp; Katiliūtė, 2016)</li> <li>• Giving to foster transdisciplinary research and cross-boundary thinking (Paulauskaite-Taraseviciene et al., 2022), (Aguiar et al., 2023)</li> <li>• Sustainable development events open to the community (e.g. conferences seminars, workshops) (Paletta &amp; Bonoli, 2019)</li> <li>• Strengthening partnerships that emerge from working on specific projects in collaboration or consulting (Aguiar et al., 2023)</li> <li>• Joint degrees with other universities, joint research and SD partnerships (e.g. enterprises, non-governmental organizations and governments) (Paletta &amp; Bonoli, 2019)</li> </ul>
Projects	<ul style="list-style-type: none"> <li>• Leading and sustaining the process of change in the industry, academy and other organizations through projects (Staniškis &amp; Katiliūtė, 2016)</li> <li>• Implementing life cycle analysis to projects, activities, etc. (Crespo et al., 2017)</li> <li>• Selecting and applying improvement sustainable solutions in projects, systems, etc. (Crespo et al., 2017)</li> <li>• Integrating preventive managerial and technological tools in projects to achieve more sustainable development of industry and society (Staniškis &amp; Katiliūtė, 2016)</li> </ul>

Source: authors

In the education system, it is necessary to prioritize and integrate the implementation of sustainability into curricula (Pérez Machin, 2023). In addition, the selection and application of effective pedagogical approaches and concepts in different curricula is essential (Paulauskaite-Taraseviciene et al., 2022). The new generations of academics should promote sustainable practices and be drivers of sustainable changes. The promoters of sustainable practices can be divided into three categories: Sustainability Saviors (who are concerned with solving sustainability problems), Sustainability Nurturers (who are concerned with promoting the understanding of sustainability), and Sustainability Strugglers (who struggle for sustainability using constructivist and transformative approaches) (Wood et al., 2016). In addition, in education, it should be possible to improve transdisciplinary skills and implement Service-learning as a teaching approach where students create and develop solutions that solve sustainability problems and contribute to economic, ecological and social sustainability.

Operations, Student Life and Campus include initiatives to improve sustainable conditions in the study environment. Configuration and infrastructure sustainability refers to compliance with green environmental policies and the relationship between university policies and green environmental policies (Crespo et al., 2017), (Merger et al., 2018). In addition, this area includes ensuring a better-quality environment for all students with access to and provision of healthy food, green oases, a place to exercise and other amenities.

In addition to changes in their operations, universities should use research and scientific work to identify solutions and new paths for sustainability in the economy and industry. Sustainability science and research require transdisciplinary, therefore active collaboration with different societal actors, especially those outside the academic community, is needed throughout the process (Plummer et al., 2022). Scientists and societal actors should jointly develop different scenarios for sustainability challenges and be agile to prevent any serious consequences in time.

Projects carried out by HEIs always strive to achieve scientific and social contributions, but these contributions should be linked to some of the goals related to the mentioned concepts of sustainability (SDGs, ESG, Triple Bottom Line etc.). Project implementation based on the life cycle framework, circular economy or other related approaches provides additional value in their implementation and contributes to agility and sustainability.

## 4. CONCLUSION

In the context of higher education, sustainability and sustainable practices are of critical importance, since it is these institutions that shape the minds and habits of future leaders, workers and society in general. However, it is evident that many institutional leaders still lack awareness of sustainable principles within the educational context. In order to solve this gap, it is necessary to recognize that sustainability goes beyond projects and other one-time initiatives, and that it should be an inherent obligation of both, institutions and individuals to foster it.

According to existing literature, sustainability within higher education manifests across four key domains, elaborated within this paper. These domains encompass various aspects related to sustainable practices. However, it is essential to recognize that meaningful progress requires diligent attention and concerted efforts in all four domains. By fostering awareness and active engagement among stakeholders within the institutions - ranging from management and teachers to scientists and professional services - it is possible to drive transformative change throughout the entire educational system.

Moreover, science of sustainability thrives on transdisciplinary, so collaborative efforts must extend beyond academia, engaging diverse social stakeholders. By fostering active partnerships with those outside the academic community, it is possible to collectively advance sustainable practices and ensure a harmonious future for HEIs and society around it.

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# CSR EFFECT ON EMPLOYER BRANDING

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**Abstract:** *There is plenty of evidence on the positive impact of social responsibility in companies and what it encompasses, as well as numerous literature that cites obstacles in maintaining a good reputation and thus a good employer brand. This paper seeks to further clarify the relationship between social responsibility and employer branding, because the connection evidently exists, but a more detailed analysis of the viewpoints of both concepts is necessary. Through numerous scientific works from the past few years, as well as case studies of some of the leading multinational companies, some additional conclusions will be presented about the interdependence of corporate social responsibility and employer branding, two very fluid elements of business since their basic postulates are constantly changing and that different cultures see their essence differently.*

**Keywords:** CSR, Employer branding, Corporate reputation.

## 1. INTRODUCTION

The overall business and behavior of companies affects the perception of all stakeholders, so nowadays, more than ever, companies must be consistent, fair and transparent, although this is not easy, since a complete market analysis should be performed before carrying out any socially responsible activity, because it can be interpreted differently, seen as unnecessary or "too" philanthropic.

Numerous literature touches upon the links between social responsibility on one side, and the image and reputation of companies on the other side, and that the employer brand derives from the reputation of the whole company. Consequently, it seems that reputation is what connects these two concepts and permeates them equally and together with earnings forms a closed circle - social responsibility > reputation > employer brand > profit. The aim of this work is to present all these concepts individually, as well as to establish their interdependence and their causal-possession relationship in the business environment.

## 2. LITERATURE REVIEW

Corporate social responsibility (CSR) is not a new concept, but over decades it has developed together with social norms, morals and awareness of man's impact on nature. In 2001, the Commission of the European Communities defined CSR as "a concept in which companies integrate social and environmental concerns into their operations and interactions with their stakeholders on a voluntary basis." Analyzing the definitions over the years, numerous inconsistencies are observed, but also certain overlaps in terms of the dimensions that CSR encompasses, namely: 1) social, 2) economic, 3) philanthropic, 4) stakeholder dimension and 5) natural environment dimension (Vlastelica, 2016). From a financial point of view, CSR imposes additional costs on the company that could be spent on other strategies to improve the company's competitive position (Carlini et al. 2019). CSR also acts as a strategic tool for differentiation and positioning of companies in the global market. It plays a significant role in reputation management and provides a clear picture of why a particular company is a better place to work (Bharadwaj & Yameen, 2021).

Research indicates that a socially responsible image of a company has a positive effect on stakeholder engagement, and this has unfortunately led to some companies behaving socially responsibly in a superficial way. Such behavior brings the risk of the company being perceived as insincere (Carlini et al. 2019). With the invasion of the era of smartphones and social media, it has become extremely easy to track the mistakes of individuals and corporations. Therefore, companies today operationalize CSR in their core business functions and invest in it to present themselves as an ideal place to work (Bharadwaj & Yameen, 2021). The development of CSR projects helps the company to build a better reputation among internal and external stakeholders, and through attracting talent, recruiting, motivating and retaining employees, CSR helps in building employer brands (Verčič & Čorić, 2018).

Employer branding, as a relatively new concept, can be described as a set of specific attributes that a particular company possesses that demonstrate that company's ability to attract and retain a quality workforce (Budhiraja & Yadav, 2020). The concept of employer branding is associated with corporate reputation, and some authors call it a protector of reputation (Verčič & Čorić, 2018). Good employer brands provide a distinctive identity that

current employees can identify with and potential employees want to join (Morokane, Chiba, & Klein, 2016). The employer brand frames the employee value proposition that integrates and unites the efforts of the company, marketing and human resources and provides it with additional sources of competitive advantage (Carlini et al. 2019). It is divided into internal and external branding. Internally, it focuses on activities that enable employees to develop within the institution. External branding aims to raise brand awareness, as well as fulfilling the goals of socially responsible business (Özcan & Elçi, 2020).

A key and often overlooked part of the CSR branding process is the employees. They are an important internal group of stakeholders who contribute to and represent the corporate brand. Additionally, employees' insider status gives them greater awareness of the company's degree of sincerity in CSR strategies, whereby they enable employees to deliver on their brand promises and successfully implement CSR strategies (Carlini et al. 2019). This sincere "inside out" approach to CSR brand management obliges companies to incorporate the brand's ethical stance into policies and practices involving both current and potential employees (Carlini et al. 2019).

Sustainability, as an all-pervasive concept, is increasingly being studied as one of the key aspects of companies' long-term and short-term goals. On the other hand, human resources are no longer something that can be "used" but have become a much more complex concept that includes various factors on which it depends and significantly affects the entire business, which is why it is necessary that the strategic management of human resources is integrated with business strategies and goals, including those related to sustainability and social responsibility. Thus, the notion of human resource sustainability appears, which represents a "long-term orientation towards achieving socially responsible and economically appropriate practices" in human resources and is one of the key aspects of corporate governance (Budhiraja & Yadav, 2020).

The combination of human resource management and sustainability is based on the assumption that the key role of the employees and management of the organization is to promote the sustainability of the organization. Thus, at the strategic level, by coordinating human resources and corporate social responsibility, employer branding and emotional bonding of employees can be achieved. On the other hand, at the operational level, in order to achieve sustainability, corporate social responsibility activities can be used to implement and develop the employer brand. Sustainable human resource management includes:

- Engagement of employees in order to achieve the sustainability of the entire business of the organization;
- Engaging employees to achieve sustainability in relation to the environment and environmental protection;
- Ensuring the sustainability of human resources within the company itself (Budhiraja & Yadav, 2020).

Signaling theory is one of the theories that deal with the study of how CSR and employer branding are connected. According to this theory, information about the values, beliefs and strategies of existing and future employees is very limited, so the only way to assess the impact is to interpret the signals that the company sends to the market. At the same time, CSR is viewed as one of the signals that a potential candidate receives about the company, which help him when deciding whether to hire and stay in that company (Kumar, Rose, Jain, Pole & Bhatt, 2021).

On the other hand, the theory of social identity is applied in the study of the reasons for which potential employees are attracted to companies that significantly deal with CSR. In addition, there is a theory about the adaptation of the organization of people, which is based on the theory of signals and the theory of social identity. This theory is based on the assumption that people strive to achieve correct personal and organizational values and norms, which is significantly helped by socially responsible practices in the company (Kumar et al., 2021).

### **3. CASE STUDIES REVIEW**

In this part of the paper, research on the connection between CSR and employer branding will be presented using the examples of Coca-Cola Kwanza and Coca-Cola HBC Srbija. Also, this part of the paper includes a comparative analysis of the presented case studies.

#### **3.1. Coca-Cola Kwanza**

The Coca-Cola Company, as the largest company in the world in the beverage industry, was the subject of research conducted by Judith George in 2017. This research, carried out in the Coca-Cola Kwanza company in Tanzania by examining the attitudes of employees, showed that employees consider that the company's key CSR activities are related to supporting sports activities, while supporting education, people in need and

the welfare of employees are secondary, as well as that employees are not satisfied with this prioritization. The Coca-Cola Kwanza company considers itself an extremely socially responsible company that provides support to both its external and internal stakeholders. This company is aware of the impact that its business operations have on the environment, which is why it has established various initiatives in the field of social responsibility. However, for CSR, it is necessary that all employees are involved in the implementation of these activities and believe in them, and if they feel neglected, they will be bad brand ambassadors of the company, which can have a bad effect on the employer's brand (George, 2017).

Also, Coca-Cola Kwanza is very committed to environmental protection. It is interesting that this research has shown that it does not significantly motivate employees to perform their work and work in the company, so therefore it does not have a significant impact on the employer's brand, although most authors in this field think otherwise. Namely, only 55% of the employees who participated in this research answered that they consider the CSR activities of the company in the field of environmental protection to be significant, as many as 37% are indifferent, while 8% do not agree with it at all. Also, the Coca-Cola Company is globally committed to improving the working and living environment and overall health, which is why Coca-Cola Kwanza won an award from the Tanzanian government for occupational health in 2012. For example, in response to increasing public concern about obesity, the company expanded its portfolio to include sugar-free products. The results of this research show that as many as 97% of employees agree with the importance of this topic within CSR and that, therefore, the company's actions in this area have a positive impact on their job satisfaction and the perception of the company as a desirable employer.

The overall results of this research show that the majority of employees do not see CSR activities as the cause of their satisfaction, but only affect external stakeholders. Therefore, it is crucial for building the Coca-Cola Kwanza employer brand that CSR activities are communicated in such a way as to motivate employees as well, so that they would want to invest their time and energy in the company's CSR initiatives and in general be more motivated to work in the company (George, 2017).

### **3.2. Coca-Cola HBC Srbija**

The Coca-Cola HBC company was ranked in December 2023 for the seventh time as the world's most sustainable beverage company by the Dow Jones Sustainability Indicator (DJSI) for 2023, which places it in the first 1% of 9,400 companies in 62 industries in terms of sustainability. These Coca-Cola HBC rankings reflect one of its four core values, which is simply: "We work sustainably." Also, this company has a double "A" rating from CDP, a global non-profit organization for environmental protection, which recognizes the company's leadership in corporate transparency and performance.

Coca-Cola HBC Group's Sustainability Mission 2025 presents science-based sustainability goals in six areas that the company has implemented in its operations, making it one of the first companies to fully align its sustainable operations with the United Nations' Sustainability Goals. The six areas through which the I value chain of the company is presented are:

- Reduction of emissions;
- Water consumption and management;
- Responsible supplying;
- Packaging, i.e. a world without waste;
- Nutrition and
- People and community.

In accordance with this Mission, the Coca-Cola HBC Company strives to support the people and communities in which it operates as well as the planet and thereby develop its business on a sustainable basis, continuously measuring progress. Also, the company transparently reports to the public and interested parties about its practices in the field of sustainable business through its annual reports on sustainable business.

One of the sustainability strategies that this company introduced in 2021 is "Net Zero by 40", with which it committed to reduce direct carbon dioxide emissions during its operations to a minimum by 2040. This is an extremely demanding undertaking, which requires major changes in daily operations, and in order to be successful, the commitment of employees at all organizational levels is necessary.

The Coca-Cola HBC Serbia company, as part of the Coca-Cola HBC Group operating in the Serbian market, is extremely proud of the sustainability and corporate social responsibility practices that it implements both as part of the Group and individually in the local market. The company also has a special sector that deals with corporate communication and sustainable business, which implements a large number of donations and sponsorships of socially responsible initiatives in the areas of:

- The welfare of the local community and the promotion of a healthy life;
- Environment protection;
- Development and education of young people.

Some of the initiatives that Coca-Cola HBC Serbia regularly supports are the Special Olympics of Serbia, Youth Sports Games, Campaigns with a Purpose, Nurdor, Belgrade Open School and the Red Cross. In addition, water and juices are donated to the children's oncology department of the Mother and Child Institute and to organizations that work with the blind or people with autism. This company is also one of the founders of the Sekopak organization, which deals with the collection and disposal of packaging waste, and in the company itself, special recycling bins are placed in every office and in the corridors.

All this would not be possible without the dedication and commitment of all employees. Volunteer actions for cleaning the environment, greening the area and socializing with people with developmental disabilities are often organized, for which at least 20 employees always sign up, and usually much more, which indicates a great commitment of employees in achieving the company's socially responsible goals. Thus, in March 2024, a volunteer action for "Green New Belgrade" was carried out, during which employees participated in planting trees on the Novi Beograd quay. Through this action, it is planned to raise new rows of trees and restore the existing ones, in order to create a healthier and more sustainable living and working environment and financial resources were donated for the purchase and maintenance of 36 new tree seedlings.

Also, at the end of each year, the company organizes a Humanitarian New Year's Bazaar, where employees from the entire company sell New Year's snacks, decorations, greetings, glasses, food, books and the like to each other, and all proceeds from sales are donated to charity. In the past year 2023, as much as RSD 365,370.00 was collected during the Humanitarian New Year's Bazaar, which was donated to the Safe House in Belgrade. Through participation in Bazaar 2023, more than 100 employees invested over 350 working hours in the community, supporting this socially responsible initiative. Employees are informed about all the company's socially responsible initiatives via the intranet, weekly e-mail newsletter and internal magazine, and the company is also active on all social networks.

One of the ways in which employees are additionally motivated to participate in socially responsible initiatives is the "Golden Coke" award, which is awarded to employees several times a year for engaging in the application of the company's values. The award is given by employees nominating their colleagues whom they believe have significantly contributed to the company's values with their persistence and positive energy, and 5 winners are determined for each of the 4 values. In December 2023, as many as 532 employees were nominated, of which 57 for working and thinking sustainably. Some of the prizes that the winners won for their socially responsible work are, in addition to the cash prize, an additional day off, a special cup and a personalized bottle of drink.

### **3.3. Comparative analysis of the connection between CSR and employer branding in different markets**

This paper presents research on the connection between Coca-Cola HBC Srbija and Coca-Cola Kwanza, two seemingly completely different companies in terms of their relationship to social responsibility. Also, Serbian and African markets were compared and different perceptions of employer branding and corporate social responsibility by employees on these two continents were observed. Even though both companies are parts of the same franchise, in the case of the African company, there are noticeable problems with attracting, retaining and motivating quality personnel, regardless of the awards and recognitions this company received in the field of corporate social responsibility. On the other hand, it is interesting although the Serbian market is specific in many ways and different from most of the European markets in the matter of acceptance of new practices by consumers, employees and public in general, it seems that in Coca-Cola HBC Srbija the sustainability initiatives are well accepted and are a huge motivating factor.

Although most authors in the fields of corporate social responsibility and employer branding agree that there is a clear reciprocal relationship between these two concepts, the research presented shows a much different picture in the market of Africa, which alludes to the difference in perception and understanding in this market compared to American and European markets. Also, the research shows that Serbian market is, besides its differences from other European markets, slowly but successfully thriving in sustainable practices. In the case of Coca-Cola Kwanza, the cause of the perceived difference is the lack or absence of adequate communication with internal stakeholders about the importance of socially responsible practices in business, while the focus of communication is directed towards external stakeholders. This can lead to the wrong perception of employees that getting involved in the company's CSR initiatives is a waste of time and resources that could

be diverted elsewhere, which significantly reduces employee motivation, their commitment and identification with the company's socially responsible goals, and thus their job satisfaction. Employees represent important brand ambassadors, especially when it comes to employer branding, which is why their indifferent or negative attitude towards business can have a bad effect on the employer's brand of that company, and thus the ability to attract and retain quality personnel.

For this reason, the author's recommendation is that companies devote themselves primarily to communicating the goals of social responsibility and their importance at the internal level, in order to have positive outcomes from these initiatives. This can be helped by the involvement of employees in deciding on the CSR activities to be implemented, the commitment of management and the incorporation of socially responsible issues into corporate values and culture.

#### 4. CONCLUSION

By analyzing the given theoretical framework, in combination with the results of the presented case studies, it can be concluded that the CSR activities of companies definitely affect both the reputation and the formation of the employer's brand, through presence in the media, in the minds of potential and actual consumers and through examples of good practice. The fact is that real and sustainable CSR cannot exist without a profit component. The problem is finding the line to draw and where profit turns into arrogance and greed. Another problem is harmonizing the needs and opinions of all internal stakeholders, i.e. employees, from top managers to operatives in the field, because every employee participates in building the brand of his employer and it is very important whether he truly believes in what the employer or the company proclaims.

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# DATA AND BUSINESS ANALYTICS

# CLUSTERING CONSUMER PROFILES IN PEER-TO-PEER TRAVEL ACCOMMODATION

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**Abstract:** *The sharing economy has significantly transformed the tourism landscape, introducing peer-to-peer accommodation platforms that have reshaped market dynamics and consumer behaviors. This study analyzes the socio-economic impact of these platforms on tourism. Employing a dataset from a survey of 344 respondents, we conducted a cluster analysis to identify distinct user profiles and their preferences. The analysis reveals two primary user clusters: 'Experienced Sharers' and 'Guided Novices', differentiated by their familiarity with and usage of sharing platforms. Key factors influencing user choices include personal experience, knowledge of shared accommodations, and socio-economic indicators such as city size and monthly income. Our findings underscore the dual impact of peer-to-peer accommodation: while it offers economic opportunities and diverse choices for consumers, it also presents challenges in terms of privacy concerns and the quality of service.*

**Keywords:** *sharing economy, peer-to-peer accommodation, cluster analysis*

## 1. INTRODUCTION

The sharing economy, driven by advanced technology, allows individuals to make use of otherwise wasted physical assets through peer-to-peer platforms, which have become vital for sharing information and trading goods and services (Lee, 2020).

The rise of sharing economy platforms has reshaped tourism and hospitality, presenting challenges and opportunities. The sharing economy provides many benefits to both sides, from service providers engaging in entrepreneurship and earning additional income to users of these services getting the chance to use something much lower price. Although the sharing economy impacts various industries, its most significant and most noticeable effect is on tourism (Alrawadieh & Alrawadieh, 2018). Particularly in the tourism and hospitality industry, accommodation-sharing platforms have significantly altered the market landscape (Song et al., 2020).

Sharing accommodation (SA), also known as peer-to-peer accommodation, home sharing, or short-term rentals, has emerged as a significant component of the sharing economy. These platforms enable individuals to derive economic and social value from underutilized properties (La et al., 2021). On the demand side, accommodation sharing has streamlined communication between users and service providers, with mobile platforms offering diverse content and information channels tailored to tourists' needs (Song et al., 2020).

The rise of platforms like Airbnb, Uber, and Lyft has significantly transformed the landscape of the tourism industry, achieving substantial market share (Zervas et al., 2017; Zhang et al., 2022). Scholars have noted that expanding these tourism platforms reshapes the industry and influences tourist decision-making processes. Factors such as destination choices, travel frequency, duration of stays, and the range of tourism activities are being impacted. Airbnb emerged as a prominent sharing accommodation platform within the tourism sector (Jung et al., 2021).

In Serbia, the utilization of accommodation-sharing platforms such as Airbnb is on the rise, providing travelers with lodging options and hosts the opportunity to rent out their spaces. Comprehending user experiences is essential to fully grasp the advantages, disadvantages, and potential opportunities associated with such platforms and identify the critical factors contributing to their success. By exploring factors such as users' education levels, the status of their properties, and the nature of their travel, we can gain valuable insights into their preferences and concerns when selecting accommodation. Additionally, examining aspects like safety, pricing, amenities, and users' intentions for future usage is imperative for effectively tailoring services and enhancing overall user satisfaction (Au-Yong et al., 2019; Kurisu et al., 2021).

In this paper, clustering analysis is conducted on a dataset gathered through a survey involving over 400 participants. To ensure a comprehensive examination of opinions, specific questions were excluded from further analysis, allowing us to capture insights from all respondents, regardless of their prior usage of sharing accommodation platforms. While a small percentage of participants were excluded due to being outliers, the overall impact on the dataset was minimal. The primary objective of this research is to uncover distinct clusters within the dataset and identify attributes that exhibit the most significant variations among them. These insights are intended to inform further analyses, particularly in marketing and promotion strategies. By understanding the factors of greatest concern, desire, and importance to users, accommodation owners can better tailor their offerings and services to meet the needs of their target audience effectively.

The paper is organized as follows: After an introduction to peer-to-peer accommodation and the broader concept of the sharing economy, section 2 presents the methodology used to examine survey data. Section 3 provides the results of the cluster analysis. Finally, section 4 presents conclusions and visions for future research.

## 2. METHODOLOGY

The data analyzed in this paper was gathered using a survey conducted among students born between 1993 and 2003. At the outset, the dataset comprised 419 respondents. The survey was completed by 32% of males and 68% of females.

The computed Cronbach's alpha coefficient of 0.753 suggests a reasonably high level of internal consistency among the items within survey. This indicates that the items are sufficiently correlated, demonstrating reliability in measuring the underlying construct or constructs of interest.

After removing errors and outliers, the final count was 344 participants. Outliers were removed by first calculating the Z-scores for all data points. Rows with values exceeding three standard deviations from the mean were identified as outliers, and subsequently, these rows were excluded. Initially, there were 83 questions divided into distinct categories: Demographic Information; SA familiar; Respondents' concerns; Positive effects from SA; Recommendations; and Importance of reviews. However, this number was then reduced to 61 to accommodate users and non-users of sharing accommodation services. All the used attributes are presented in Table 1.

**Table 1:** Definition of the attributes used in the analysis

<b>Attributes</b>	<b>Definition</b>
Demographic	Gender
	Male or female.
	Year of Birth
	Year when the respondent was born.
	City Size
	The size of the city the respondent is coming from.
	Region
	The region of Serbia the respondent is coming from.
SA familiar	Monthly Income
	The income that the respondent is generating every month.
	Household Type
	Type of the household where the respondent is living.
Respondents' concerns	Residential Type
	Residential type where the respondent is living.
	Prior Awareness
	Respondent knowledge about sharing accommodation before the survey.
	Personal Experience
	Does the respondent know anyone who bought shared accommodation?
	Personal Knowledge
	Does the respondent know anyone who offered shared accommodation?
	Personal Usage
	Has the respondent ever used shared accommodation services?
	Location Concern
	Do location and surroundings of shared accommodation pose a threat?
	Provider Concern
	Does the service provider of shared accommodation pose a threat?
	Co-tenant Concern
	Other users with whom I share accommodation may pose a threat.
	Privacy Breach
	Sharing accommodation platform may use my personal information.
	Provider Use
	Service providers of shared accommodation could violate my privacy.
	Hidden Cameras
	Privacy in shared accommodation can be compromised (e.g., cameras)
	Hidden Costs
	Are respondents worried about hidden costs in shared accommodation?
	Higher Expense
	Do respondents view shared accommodation as pricier than hotel stays?
	No Savings
	Respondents believe shared accommodation will not offer savings.
	Quality - Price
	Respondents expect a lower quality for the price of accommodation.
	Promised Quality
	Respondents expect a lower than promised quality of accommodation.
	Communication Issues
	Respondents believe that communication with the provider is complicated.
	Doubtful
	Respondents believe that their complaints will not be respected.
	Responsiveness



Positive Effects from SA	Potential Earnings	Respondents believe they could earn money in shared accommodation.
	Financial Status	Respondents believe shared accommodation could boost financial status.
	Social Image	Respondents believe shared accommodation could improve social image.
	Community Recognition	Respondents see shared accommodation as earning social praise for supporting the local economy.
	Respect Gain	Respondents believe shared accommodation would earn them respect.
	Enhanced Reputation	Respondents believe sharing accommodation boosts reputation.
	Environmental Conservation	Respondents believe sharing accommodation saves natural resources.
	Sustainable Consumption	Respondents believe sharing accommodation is sustainable.
	Ecologically Friendly Behavior	Respondents believe sharing accommodation represents environmentally friendly behavior.
	Resource Inefficiency	Respondents believe sharing accommodation does not save resources.
	Enjoyable Experience	Respondents find participating in shared accommodation fun.
	Boring Experience	Respondents find participating in shared accommodation boring.
	New Experiences	Respondents see shared accommodation as providing new experiences.
	Trendy Experience	Respondents find participating in shared accommodation trendy.
	Complex Process	Respondents find participating in shared accommodation complicated.
	Senseless Endeavor	Respondents find participating in shared accommodation pointless.
Recommendations	Faculty Endorsement	Respondents would use shared accommodation if endorsed by faculty.
	Peer Influence	Respondents would use shared accommodation if other students used it.
	Friend Recommendation	Respondents will use shared accommodation if friends recommend it.
	Indirect Recommendation	Respondents will use shared accommodation if strangers recommend it.
	Family Recommendation	Respondents will use shared accommodation if their family recommends it.
	YouTube Recommendation	Respondents will use shared accommodation based on YouTube reviews.
	Social Media Recommendation	Respondents will use shared accommodation based on reviews on social media platforms.
Importance of reviews	Reviews	Before deciding on accommodation, the respondent checks reviews.
	Reviews Fraud	Online reviews assure the respondent that accommodation is legitimate.
	Review Anxiety	The respondent worries when they skip online reviews.
	Detailed Reviews	Detailed online reviews are crucial to the respondent.
	Photo Evidence	Attached images in online reviews are crucial to the respondent.
	Familiar Reviewers	Respondents prioritize online reviews from people they know.
	Unknown Reviewers	Respondents do not prioritize online reviews from people they know.
	Trusted Figures	Respondents do prioritize online reviews from well-known individuals.
	Abundant Reviews	Respondents prioritize accommodation with a high volume of reviews.
	High Ratings	Respondents prioritize accommodation that has a high rating.
	Provider Rating	Respondents prioritize accommodation with a provider with a high rating.
	Reviewer Profiles	Respondents prioritize checking profiles of people who left reviews.
	Live Experiences	Respondents prioritize reviews they hear in person rather than online.

Data is analyzed using python packages pandas, collections, matplotlib and sklearn and aggregated results are presented.

### 3. RESULTS

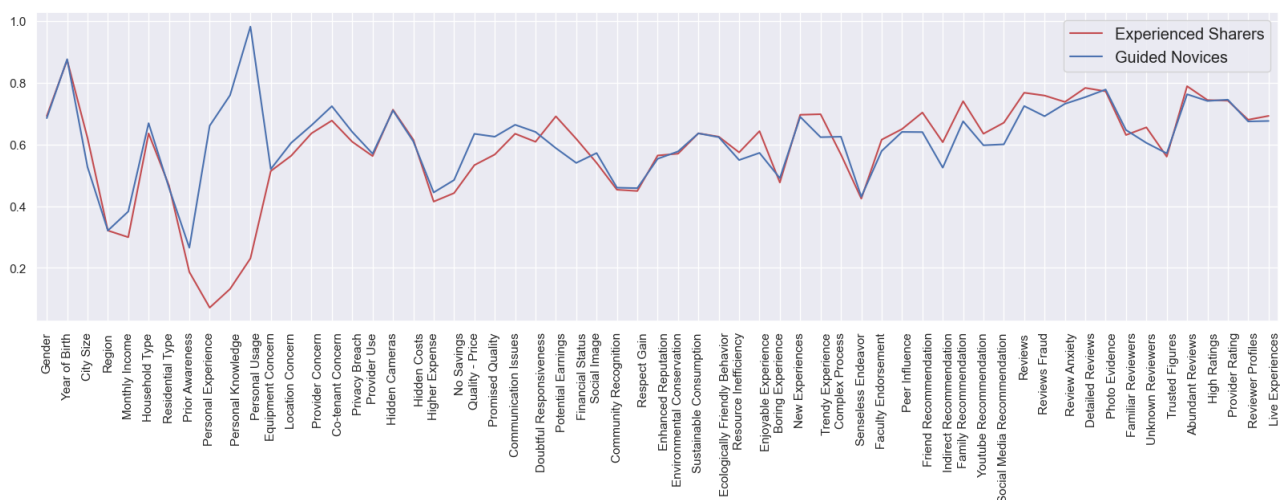
Clustering was conducted using the k-means method. The first step in cluster analysis involves creating an elbow method graph and comparing it with the silhouette score. In our analysis, the elbow method clearly identifies a significant decrease in the silhouette score at 2 clusters, suggesting that this is the optimal number of clusters for our data. This point represents where the gain in homogeneity within the clusters no longer justifies the increase in the number of clusters (Shi et al., 2021). In the next step, we examined the silhouette score for various numbers of clusters. We have discovered once again that 2 clusters have the highest silhouette score.

Figure 1 contains a silhouette plot displaying the silhouette score of each instance within a cluster. The silhouette score ranges from -1 to 1, where 1 represents an instance entirely belonging to its cluster, 0 indicates that the instance lies between two clusters, and -1 signifies that the instance belongs to a neighboring cluster (Rousseeuw, 1987). It is evident from the plot that there were no negative silhouette scores.



**Figure 1: Silhouette Analysis**

Cluster 0 contains 160 instances, while cluster 1 has 184 instances. In further analysis, cluster 0 is named *Experienced Sharers*, while cluster 1 is named *Guided Novices*. Besides determining the number of clusters, the correlation between attributes was assessed using Spearman because the data is not normally distributed. However, no significant correlation was observed, as the correlation coefficient does not exceed 0.2.



**Figure 22: Line Graph – Clusters**

It remains to analyze the line graph of clusters and normalized values for centroids (Figure 2). The most significant differences between these two clusters lie in the attributes *Personal Experience* and *Personal Knowledge*, which represent respondents' familiarity with knowing someone who offers or uses shared accommodation, and *Personal Usage*, which indicates whether respondents have previously used shared accommodation (Table 2).

These differences indicate that *Experienced Sharers* are much more familiar with sharing accommodation and have used it extensively. At the same time, are unfamiliar with and have not used it so far.

Furthermore, differences between clusters emerge, which are not as pronounced as the three previously mentioned. Noticeable distinctions lie in attributes such as *City Size*, *Monthly Income*, *Potential Earnings*, *Enjoyable Experience*, *Trendy Experience*, *Complex Process*, *Friend Recommendation*, *Indirect Recommendation*, *Family Recommendation*, *YouTube Recommendation*, and *Social Media Recommendation*.

Members of *Experienced Sharers* are from smaller cities, with higher monthly income, and they believe they can earn more by sharing accommodation than the members of *Guided Novices*.

**Table 2:** Most noticeable value differences

<b>Variables</b>	<b><i>Experienced Sharers</i></b>	<b><i>Guided Novices</i></b>
Personal Experience	0.668750	0.070652
Personal Knowledge	0.768750	0.130435
Personal Usage	0.981250	0.239130
City Size	0.612319	0.535417
Monthly Income	0.300272	0.382812
Potential Earnings	0.686141	0.592188
Enjoyable Experience	0.575000	0.639946
Trendy Experience	0.631250	0.690217
Complex Process	0.625000	0.567935
Friend Recommendation	0.647917	0.695652
Indirect Recommendation	0.528125	0.603261
Family Recommendation	0.681250	0.733696
YouTube Recommendation	0.598437	0.633152
Social Media Recommendation	0.598438	0.671196

It can also be noticed that members of *Guided Novices* have a better opinion on the process of sharing accommodation in general, where they believe that the process is more enjoyable and less complex than members of *Experienced Sharers*. One can guess that *Guided Novices* have great expectations from shared accommodation, as most of them haven't used it yet. Another evidence for this claim can be found in fact that they are more sensitive to recommendations, are more likely to consider using shared accommodation than members of *Experienced Sharers* cluster.

#### 4. CONCLUSION

Our research employed a cluster analysis of data collected using a survey, revealing two distinct user groups: *Experienced Sharers* and *Guided Novices*. These findings highlight significant differences in usage patterns, familiarity, and socio-economic factors that influence user preferences and decision-making processes in the context of shared accommodation.

The rise of platforms like Airbnb has undoubtedly provided substantial benefits, such as increased income opportunities for hosts and more diverse lodging options for travelers. However, the analysis also exposes underlying challenges, including privacy concerns and potential disparities in service quality. Such issues necessitate targeted strategies to enhance user satisfaction and trust, which are crucial for the sustainable growth of sharing platforms.

Moreover, the distinctions between the two identified clusters suggest that tailored marketing strategies could be more effective than a one-size-fits-all approach. Marketing efforts should be designed to address each user group's specific needs and concerns, thereby improving engagement and optimizing the overall experience.

As peer-to-peer accommodation continues to evolve, ongoing research will be essential to track its impact on traditional hospitality sectors and regional economic development. Future studies could expand upon this work by exploring the long-term effects of the sharing economy on tourism, particularly in terms of economic sustainability and community relations.

#### ACKNOWLEDGMENT

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# ASSESSING CORPORATE ENTREPRENEURSHIP: INSIGHTS FROM A CLUSTERING ANALYSIS

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**Abstract:** *Corporate Entrepreneurship (CE) is seen as a strong proponent of organizational innovation and performance. This paper demonstrates the application of cluster analysis based on the internal entrepreneurial environment measured with the Corporate Entrepreneurship Assessment Instrument and different categorical variables pertaining to organizations and the respondents themselves. To do this, a cluster analysis (CA) in the form of the k-prototype clustering algorithm, able to handle both categorical and numerical data, is applied on data gathered from 682 respondents from various organizations in the Republic of Serbia. The analysis reveals three distinct clusters regarding varying levels of environmental fitness for entrepreneurial activities within organizations. Firstly, we have entrepreneurial pioneers who combine their experience and youth in an innovative way and receive the most support for entrepreneurial activities, especially within private corporations and private SMEs. Secondly, there are limited traditionalists, older workers getting the least amount of entrepreneurial support. Finally, the dynamic balancers are the youngest employees with limited work experience but in an environment that still encourages some entrepreneurial activities. The findings contribute to understanding the current state of the entrepreneurial environment of organizations in the Republic of Serbia and which organizations might foster best practices, paving the way for organizational cooperation and the possible transfer of best practices to other organizations, thereby elevating the state of corporate entrepreneurship support for the employees.*

**Keywords:** *Corporate entrepreneurship, Cluster Analysis, K-prototypes, Corporate Entrepreneurship Assessment Instrument*

## 1. INTRODUCTION

In the contemporary global economy, knowledge is of great value and serves as a catalyst for exploration, research, innovation, and development. Entrepreneurship, seen as a field promoting these activities, has received considerable attention from researchers, examining how it affects the global economy, with a consensus being that entrepreneurship considerably positively influences economic development and growth. With their entrepreneurial behavior, entrepreneurs create value, be it for themselves or others either through the creation of employment opportunities or through solving the problems that exist in the market (Ziyae & Sadeghi, 2020). One characteristic that is a given with entrepreneurs is creativity, since it is needed for business opportunity identification and exploitation, and because of this, it is often associated with the entrepreneurial mindset (Anjum et al., 2020).

Authors Ziyae and Sadeghi (2020) emphasize how entrepreneurship as a practice is very important and commonly employed in successful firms of all sizes. The adoption of entrepreneurial practices promotes innovativeness and risk-taking, essentially molding firms to be more aggressive in their approach to business to better compete with new businesses and startups that function within those rules from day one. Therefore, organizations that were not previously entrepreneurially oriented have shifted their attention in this direction, recognizing the benefits of entrepreneurship and adopting entrepreneurial practices, hoping to increase competitiveness and financial gains in the global economy (Phan et al., 2009). Even thirty years ago, research strongly emphasized that entrepreneurial activities could help struggling organizations in challenging environments achieve industry leadership (Stopford & Baden-Fuller, 1994).

Corporate Entrepreneurship (CE), as an entrepreneurial practice established within existing organizations, play a significant role in fostering innovation within organizations as well as improving productivity and performance by supporting the acquisition of new knowledge (Zahra, 2015) and the identification and exploitation of opportunities.

Research has shown that CE has a significant positive impact on organizational performance and employee engagement (Ahmed et al., 2020). Adoption of entrepreneurial behaviour within corporations, as a core

element of corporate entrepreneurship, improves the performance of those businesses and can even lead to the creation of new startups, spinoffs, or spinouts (Nikolowa, 2014; Ziyae & Sadeghi, 2020). This approach of fostering the atmosphere within organizations that promotes innovativeness and its use for opportunity identification and exploitation can greatly contribute to competitive advantage in unstable and unpredictable markets (Shirokova et al., 2013).

Although there is sufficient evidence to support the claim that CE activities add value to organizations, further research on the topic is needed. Authors Anjum et al. (2020) hypothesize in their work that entrepreneurial intention and characteristics of individuals, such as aforementioned creativity, can be influenced by external environmental factors. From a CE standpoint, this makes sense, and it is precisely why metrics and evaluation methods of CE have been a focal point ever since the beginning of the century (Kuratko et al., 2015).

To examine the environmental factors in organizations that promote CE practices, Hornsby, Kuratko and Zahra proposed the Corporate Entrepreneurship Assessment Instrument (CEAI), which is used to evaluate the internal environment in relation to the support of CE activities in an organization. This instrument focuses on five factors related to said internal environment: Management support (measures the desire of managers to support entrepreneurial activities of their employees), work discretion (measures organizational support for independence, freedom, creativity etc.), organizational boundaries (measures adherence and insistence on procedures, rules and standards), rewards/reinforcements (measures the reward and support systems), and time availability (measures the time load, i.e. is there time available for entrepreneurial activities or is the work load too heavy) (Hornsby et al., 2002). This instrument, coupled with cluster analysis, is used in this paper to assess the support of organizations in the Republic of Serbia toward their employees.

The rest of the paper is structured as follows: Section 2 presents the research methodology; the results of the analysis are shown in Section 3; Section 4 examined the results of the research, and in Section 5 implications of this research is discussed.

## **2. METHODOLOGY**

The CEAI instrument, together with additional categorical questions of interest pertaining to age, gender, education level, years of employment and type of organization, was used to assess the internal entrepreneurial environment of organizations in the Republic of Serbia.

The main objectives were to examine the current state of the entrepreneurial environment of organizations in the Republic of Serbia and to gain deeper insights into the influence of certain variables on the entrepreneurial environment using cluster analysis, with the aim of identifying directions for its further improvement. There are many examples of CA being used in entrepreneurship research, e.g. to categorize countries into different entrepreneurial profiles (Marcotte, 2013), to assess entrepreneurial potential within country regions (Becker et al., 2011), to categorize SMEs (Hagen et al., 2012; Setyaningsih, 2012) and to determine the characteristics of successful SMEs (Sharma & Wadhawan, 2009). The review paper on the use of CA in entrepreneurship (Crum et al., 2022), shows how clustering has been used since the 1990s for various reasons, e.g. to categorize a firm as a small or medium-sized enterprise or to distinguish types of entrepreneurial founders and decision makers, and state that CA is a valuable tool in entrepreneurship research, at least for creating taxonomies.

To achieve the aforementioned objectives, a sample size of 682 respondents from the Republic of Serbia was gathered and further analyzed. IBM SPSS software was used for descriptive statistics. A clustering algorithm that can work with both categorical and numerical data and is based on Huang's k-prototypes algorithm (Huang, 1998) was implemented using the R programming language and environment (Szepannek, 2018).

## **3. RESULTS**

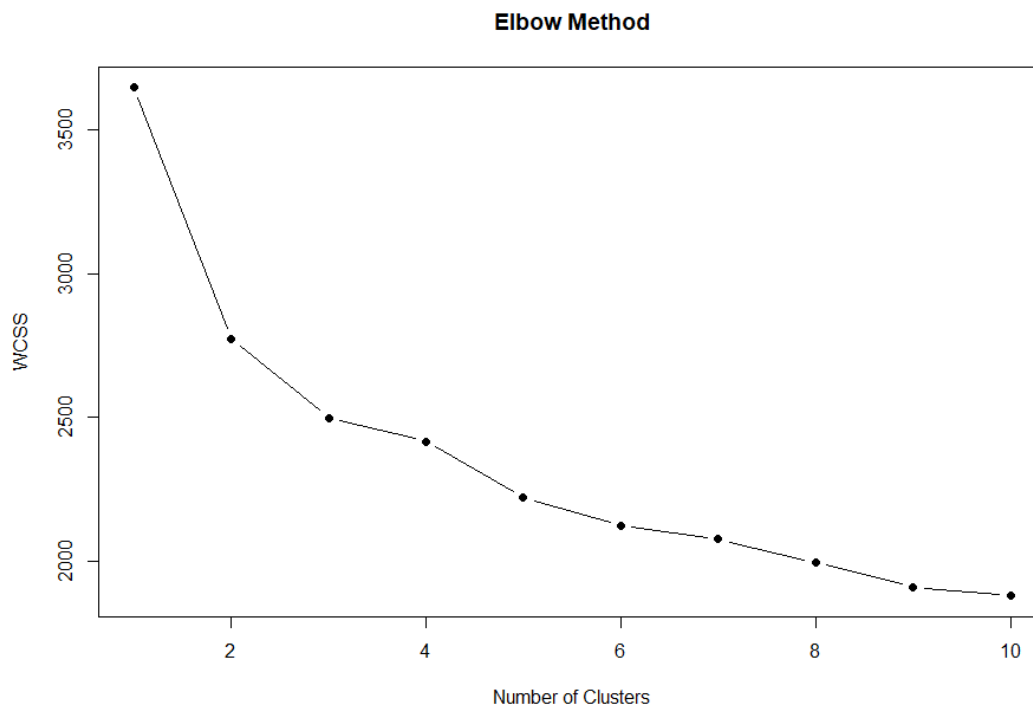
The data analyzed in this instance was gathered from a sample of 682 respondents. The frequency distribution pertaining to the categorical questions of interest is displayed in Table 1.

**Table 1:** Frequency distribution for respondents

<b>Gender</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative</b>
Male	296	43.4	43.4
Female	386	56.6	100.0
<b>Age</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative</b>
18 to 30	354	51.9	51.9
31 to 45	173	25.4	77.3
46 to 55	113	16.6	93.8
55+	42	6.2	100.0
<b>Organization type</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative</b>
Public administration	73	10.7	10.7
Public institution	122	17.9	28.6
Public corporation	86	12.6	41.2
Private SME	197	28.9	70.1
Private corporation	204	29.9	100.0
<b>Education level</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative</b>
Elementary	2	0.3	0.3
Highschool	132	19.4	19.6
Associate degree	77	11.3	30.9
Bachelor's degree	286	41.9	72.9
Masters/Doctoral degree	185	27.1	100.0
<b>Years of employment</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative</b>
up to 5 years	333	48.8	48.8
6-10 years	103	15.1	63.9
10 to 20 years	106	15.5	79.5
20+ years	140	20.5	100.0

By examining the frequency distribution table, it can be seen that 296 respondents are male and 386 female. More than half of the respondents are younger than 30 (51.9%). About 10.7% of respondents work in public administration, 17.8% in public institutions, 12.6% in public enterprises, 28.9% in private SMEs and 29.9% in private corporations. Almost half of the respondents (~49%) have been employed for less than 5 years, and the majority of respondents have a high level of education, i.e. a bachelor's degree or higher.

To determine the number of clusters, the Elbow method is used, calculating the within-cluster sum of squares (WCSS) for multiple possible number of clusters to strike the balance between capturing meaningful patterns and overfitting. The elbow method graph is shown in Figure 1.

**Figure 1:** Elbow method graph for cluster number identification

Based on this graph, the decision is made that there should be 3 clusters, as this is the first point at which the cumulative decrease in WCSS is higher than the decrease that would be achieved by the introduction of up to 10 clusters. These clusters are identified using the k-prototypes algorithm. Descriptive statistics for each of the 3 identified clusters for the categorical questions are displayed in Table 2.

**Table 2:** Descriptive statistics for 3 identified clusters

<b>Organization type</b>	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>
Public administration	21.8%	3.4%	5.2%
public institution	25.5%	19.0%	11.9%
Public corporation	26.8%	2.6%	5.8%
Private SME	14.6%	24.1%	41.0%
Private corporation	11.3%	50.9%	36.1%
<b>Gender</b>	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>
Male	39.3%	44.0%	46.2%
Female	60.7%	56.0%	53.8%
<b>Age</b>	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>
18 to 30	20.9%	31.9%	81.7%
31 to 45	39.3%	51.7%	5.8%
45 to 55	28.9%	12.9%	8.9%
55+	10.9%	3.4%	3.7%
<b>Years of employment</b>	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>
up to 5 years	18.8%	23.3%	79.8%
6-10 years	15.9%	42.2%	4.9%
10 to 20 years	30.1%	18.1%	4.0%
20+ years	35.1%	16.4%	11.3%
<b>Education level</b>	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>
Elementary	0.8%	0.0%	0.0%
Highschool	24.3%	9.5%	19.3%
Associate degree	13.4%	12.1%	9.5%
Bachelor's degree	40.2%	23.3%	49.8%
Masters/Doctoral degree	21.3%	55.2%	21.4%

Descriptive statistics for the 3 identified clusters, considering the 5 CEAI dimensions, are displayed in Table 3.

**Table 3:** Descriptive statistics for 3 identified clusters for CEAI dimensions

<b>Management support</b>						
Cluster	Mean	Min.	1st Qu.	Median	3rd Qu.	Max
1	2.22	1.00	1.84	2.21	2.58	4.26
2	3.84	1.84	3.42	3.79	4.26	5.00
3	3.40	1.58	3.05	3.37	3.79	5.00
<b>Work discretion</b>						
Cluster	Mean	Min.	1st Qu.	Median	3rd Qu.	Max
1	2.66	1.00	2.10	2.70	3.20	4.50
2	4.20	2.20	3.90	4.30	4.60	5.00
3	3.61	1.50	3.20	3.60	4.05	5.00
<b>Rewards/Reinforcements</b>						
Cluster	Mean	Min.	1st Qu.	Median	3rd Qu.	Max
1	2.57	1.00	2.00	2.67	3.00	4.17
2	4.26	2.83	3.83	4.33	4.67	5.00
3	3.85	2.17	3.33	3.83	4.33	5.00
<b>Time availability</b>						
Cluster	Mean	Min.	1st Qu.	Median	3rd Qu.	Max
1	2.80	1.57	2.43	2.86	3.14	4.43
2	3.15	1.71	2.71	3.14	3.57	4.14
3	2.99	1.57	2.71	3.00	3.29	4.43
<b>Organizational boundaries</b>						
Cluster	Mean	Min.	1st Qu.	Median	3rd Qu.	Max
1	2.66	1.14	2.29	2.71	3.00	4.43
2	2.38	1.43	2.11	2.36	2.71	3.86
3	2.62	1.00	2.29	2.57	3.00	4.29



## 4. DISCUSSION

The results show 3 distinct clusters with varying levels of quality of internal entrepreneurial environment. In cluster 1, the gender distribution is skewed in favor of women, who account for more than 60% of the cluster structure. In terms of type of organization, this cluster is dominated by public organizations, which account for about 74% of employers in this cluster. This cluster is dominated by the 31-45 age group, with 39.3% of people belonging to this age group, while the 45-55 age group is the second largest with 28.9% of respondents. As for work experience, more than 65% of respondents have at least 10 years of professional experience. About 61% of respondents have a bachelor's degree or higher, but on the other hand, about 24% of respondents have only completed high school. This group is characterized by having the worst managerial support score for entrepreneurial activities with a mean of 2.22 (out of 5), the worst work autonomy with a mean of 2.66, the worst score for rewards/reinforcements with a mean of 2.57, the worst score for time availability with a mean of 2.8, but the highest score for organizational boundaries with a mean of 2.66. These respondents could be categorized as *limited traditionalists*.

In cluster 2, the gender distribution is slightly skewed in favor of women, who make up 56% of all respondents in this cluster. In terms of type of organization, 75% of respondents work in the private sector, with 24.1% working for SMEs and 50.9% for large private corporations. The most represented age group is 31 to 45 years old, accounting for more than 50% of respondents. The second most represented age group is the 18 to 30 age group, which accounts for around 32% of respondents. In terms of work experience, 65% of respondents in this cluster have less than 11 years of work experience. More than half of the respondents in this cluster have a master's or doctoral degree (55.2%). This cluster is characterized by the fact that it receives by far the best support from management, with a mean score of 3.84. The same is true for work autonomy, rewards/reinforcements, and time availability, with mean scores of 4.2, 4.26 and 3.15, respectively. On the other hand, the mean score for organizational boundaries is the lowest, at 2.38. These respondents could be categorized as *entrepreneurial pioneers*.

In cluster 3, the gender distribution is also slightly skewed in favor of women, who make up 53.8% of all respondents in this cluster. The majority of respondents in this cluster stated that they work in private corporations (36.1%) or private SMEs (41%). In terms of age, more than 80% of respondents are under the age of 30, making this group the youngest of the 3 groups. In terms of work experience, as expected based on age, around 80% of respondents have no more than 5 years of work experience. In terms of education level, more than 70% of respondents have a bachelor's degree or higher, but about 20% of respondents have only finished high school. This cluster is characterized by the fact that the mean scores of all assessed characteristics are between the 1<sup>st</sup> and 2<sup>nd</sup> clusters, with mean scores of 3.4, 3.61, 3.81, 2.99 and 2.62 for managerial support, work autonomy, rewards/reinforcements, time availability and organizational boundaries, respectively. These respondents could be classified as *dynamic balancers*.

## 5. CONCLUSION

By analyzing the structure of the clusters obtained, it is possible to identify categories that influence the entrepreneurial environment and consequently, recommendations can be made to improve the quality of this entrepreneurial environment. A look at the results of the cluster analysis shows that the environment for CE in privately owned companies is significantly better than in public ones, both through better reward systems and through encouragement of employee independence. A recommendation for the top management of public administrations, institutions and corporations could be to try to adopt some of the best practices of privately owned ones in these areas and thus improve the environment for corporate entrepreneurship, a topic that has already received some attention in the literature (Omerbegović-Bijelović et al., 2016; Rakićević et al., 2020). One recommendation for both public and private organizations could be to be more open to allowing their employees more time for entrepreneurial activities and to be more flexible with their structures, rules, resources and tolerance for the risk of failure. Future research on this topic could focus on further exploration of the data using techniques such as biclustering, used for segmentation in many fields, such as marketing and healthcare (Nikolic et al., 2022; Vandromme et al., 2020; Wang et al., 2016), or structural equation modelling (Komazec et al., 2023; Nasution et al., 2020; Rakicevic et al., 2023) to gain a deeper understanding of the factors influencing CE. On the other hand, a cross-country analysis of countries in the region could be useful to determine the general state of the CE environment.

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# TIME SERIES ANALYSIS OF SHARED MOBILITY SERVICES USAGE

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**Abstract:** *The sharing economy refers to an economic system where individuals or entities share resources, assets, or services directly with others, facilitated by an online platform. The asset which is “shared” in the sharing economy and which attracts the attention of various stakeholders is mobility. Shared mobility services, encompassing various modes such as ride-sharing, bike-sharing, scooter-sharing, and carpooling, have emerged as pivotal components of urban transportation systems worldwide. As the shared mobility market is expanding in both developed and developing countries, it is of interest to analyse and predict the usage of shared mobility vehicles. As a case study, we will use ARIMA time series modelling to model the shared scooter usage in Bern, Switzerland. Our study provides insights into the temporal dynamics of shared mobility services, offering valuable implications for urban transportation policy, planning, and management.*

**Keywords:** *Sharing economy, shared mobility, time series modelling, predictions, ARIMA*

## 1. INTRODUCTION

With the emergence of the Internet, new business models have developed, including e-commerce, e-learning, social media platforms, sharing economy models, and others. The ones which attract attention are sharing economy models such as shared accommodation, carpooling, carsharing, ride-hailing, and crowdfunding. All these models, even though they are different, have common elements: the customer, the provider, the Internet, the platform, and the regulating environment (Ritter & Schanz, 2019). The form of sharing economy we focus on in this study is shared mobility.

Shared mobility services encompass various modes such as ride-sharing, bike-sharing, scooter-sharing, and carpooling. The value of the shared mobility market is, according to Allied Market Research (2022) 104.95 billion US dollars, with projections indicating up to 1 trillion US dollars in consumer spending by 2030 (McKinsey, 2023). The shared mobility market is closely connected to open innovation as both concepts reinforce collaborative ecosystems. Therefore, it is expected that open innovation will enhance the adaptability and sustainability of shared mobility services in the future, contributing to more efficient urban transportation systems leading to an even greater market growth (Turoń, 2022).

Just some of the benefits of shared mobility are reduced environmental impact, cost savings, traffic decongestion, optimised resource utilisation, social connectivity, and accessibility and flexibility (Li, Liu, & Zhang, 2018). Shared mobility is important for ecology, smart city development, and urban mobility because it promotes environmental sustainability, optimises resource utilisation, complements public transportation, encourages active transportation modes, facilitates data-driven decision-making, and enhances accessibility for all members of society (Ma et al., 2018). At the same time, some drawbacks of the shared mobility concept should be considered. Kireeva et al. (2021) identify the following: complicated rental processes, lack of trust in personal data collection and usage, low sense of privacy, security, lack of trust in the vehicle, and lower comfort compared to passenger cars.

European Union issued a Commission Notice regarding well-functioning and sustainable local passenger transport-on-demand, which advises for regularising ride-sharing practices (EUR lex, 2022). Acknowledgement of the importance of ride-sharing practices regularisation is at the same time a signal that significant numbers of EU citizens are participating in such a way of transport and that ride-sharing is not just a local phenomenon. As the shared mobility market is rising, the interest of the general public in participating in the shared concept as well, this study has the goal to implement predictive analytics and forecast the usage of shared mobility vehicles. The predictive model chosen is the Time Series analysis and the ARIMA model. The data used in this study is the data for the city of Bern, Switzerland related to the weekly number of shared e-scooters used. Bern was selected as a case study keeping in mind that the city has a diverse shared mobility ecosystem offering shared bikes, e-scooters, and cars, with four companies

operating. The mobility data is available from Fluctuo, a company specialised in gathering data on micromobility, public transport companies, and Mobility as a Service (MaaS) providers (Fluctuo, 2024).

The paper is structured in the following manner. In the next section, we provide a literature review on the participation in shared mobility services in Switzerland as well as a review of the studies that aimed to predict shared mobility usage. In the following section, we outline the company Fluctuo and the data on shared mobility they offer and the case study setting. After that, the results of the time series modelling are presented. We finish the paper with the discussion and conclusion.

## **2. LITERATURE REVIEW**

### **2.1. Participation in shared mobility services in Switzerland**

According to the available Eurostat data on participation in shared transport, the level of participation in shared transport in Switzerland is high (Eurostat, 2024). The data showed that in 2021, the percentage of individuals in Switzerland who participated in shared transport (in the last three months) was 0.79%, while in 2023, the last year for which the data is available, it was 1.55%. The same analysis pointed out that between 2021 and 2023, the highest rise in participation in shared transport was among those between 16 and 24 years old (rise from 1.89% to a staggering 4.41%). Interestingly, those living in towns and suburbs and those with medium and no formal education used shared transport more than the EU-27 average. The student population embraced the use of shared transport, as the participation rate was 2.24% in 2023. The presented results indicate that according to official statistics, the usage of shared transport among students is increasing. However, that percentage could be higher.

The Eurostat data indicates that the concept of shared mobility in Switzerland is more accepted by the younger individuals, students and those with medium and lower education. The micro-mobility sector in Switzerland is quite developed, with companies such as Bird, Bolt, Lime, Tier, Voi, Ubeeqo being present. The company which we focus on is Tier. This company currently operates in 33 Swiss cities, including Zurich, St. Gallen, Basel, Bern, and others and is one of the largest micro-mobility platforms in Switzerland.

### **2.2. Predicting shared mobility using time series**

Predicting shared mobility participation is of high interest for numerous stakeholders. So far different approaches to predicting participation or usage of shared mobility services have been taken. In this literature review we focus on studies which employed time series analysis.

The first chosen study by Camilleri and Debattista (2020) focused on optimising shared mobility in Malta, specifically ride-sharing services. Historical data are analysed to predict the total number of ride requests per hour. Various time series forecasting models, including Holt-Winter, ARIMA, and Facebook Prophet, are compared to determine their effectiveness in predicting demand patterns and algorithms. The Holt-Winter model outperformed other models based on Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE). Exogenous variables like temperature and public holidays were found to have no significant impact on the predictive model.

The second study, authored by Saum and associates (2020), observed the data collected at Thammasat University, Thailand. The type of mobility studied is shared micro-mobility, specifically e-scooters. The data used includes hourly e-scooter demand from January 23 to April 30, 2019. The study employed Box-Cox transformation, Seasonal ARIMA (SARIMA), and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models to predict the hourly demand and volatility of e-scooters. The model predicts the demand pattern and volatility of e-scooters, which is crucial for operational planning. The results show that the combination of these models provides valuable insights into demand patterns and helps in operational planning for shared e-scooter services.

The study by Boonjubut and Hasegawa (2022), aimed at optimizing the operations of bike-sharing systems, specifically in rebalancing bike availability across stations. It compared three models ARIMA, LSTM (Long Short-Term Memory neural network) and GRU (Gated Recurrent Units neural network) to predict hourly bike demand using data from Jersey City's Citi bike system. The models utilize factors like temperature, hour, humidity, season, weekday, weather, holidays, and wind speed. The study found that the GRU model outperforms ARIMA and LSTM in terms of efficiency, as evidenced by lower prediction errors. The stepwise regression technique was employed to select input variables, enhancing the accuracy of the forecasting models.

The paper authored by Chiotti (2023) investigated the applicability of machine learning models to forecast the number of occupied slots of a particular bike-sharing station in San Francisco (USA) and the number of bikes crossing the Fremont Bridge in Seattle (USA). It focused on analysing micromobility sharing services, particularly bicycle sharing, using machine learning models such as ARIMA, Linear Regression, Lasso, Ridge, Random Forest, and Gradient Boosting. The study aimed to predict bike availability at station-based sharing services and bike flux in specific areas. Results provide practical guidelines for setting up and tuning machine learning models, aiding businesses and local governments in improving service provision. The paper underscores the importance of enriching data with contextual features for accurate predictions and suggests avenues for future research, including incorporating contextual metadata, user data, exploring different mobility vectors, and handling the problem as a classification task.

The presented literature review indicates that time series analysis has been employed with a lot of success in predicting shared mobility and participation. Therefore, we also opted for the application of time series analysis, precisely ARIMA modelling.

### 3. FLUCTUO DATA AND CASE STUDY SETTING

Fluctuo is a tech company specialising in real-time data analysis for shared micromobility services such as bikes and e-scooters. Their platform tracks over 200 operators worldwide, covering millions of vehicles across cities in Europe (181 cities), North America (13 cities) and Asia-Pacific (8 cities). They provide data on bikes, mopeds, e-scooters, and cars shared on a daily, weekly, and monthly basis (Fluctuo, 2024).

A time series analysis was conducted to examine and forecast the number of trips per week on the e-scooter-sharing platforms in Bern. Specifically, the analysis focused on one out of the two operators: Tier. Data spanning from April 3<sup>rd</sup>, 2023, to April 1<sup>st</sup>, 2024, was collected from the Fluctuo platform, consisting of the weekly number of vehicles used. The prediction phase extended from April 8<sup>th</sup> to May 13<sup>th</sup>, 2024.

ARIMA (AutoRegressive Integrated Moving Average) models with parameters (p, d, q) and the Box-Jenkins methodology were employed to model the time series. The Akaike Information Criterion (AIC) served as the primary criterion for selecting the best model (Makridakis & Hibon, 1997). Stationarity of the time series was assessed using the Augmented Dickey-Fuller test (ADF), while autocorrelation was examined through the Durbin-Watson test (DW). Additionally, the presence of heteroskedasticity was evaluated using the ARCH test (Albijanić et al., 2023).

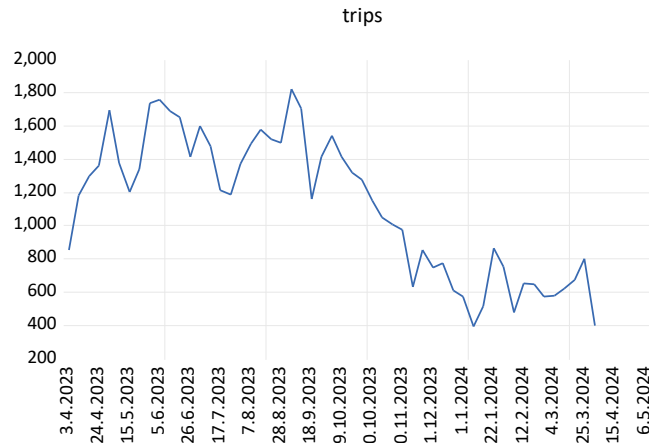
### 4. RESULTS

The first step in the time series modelling is the descriptive statistics analysis of the collected data and the visual inspection of the time series. In Table 1, we present the descriptive statistics of the number of weekly scooter trips offered by Tier in Bern in the observed one-year period. The mean number of trips per week was 1122.40, with a standard deviation of 421.484. A high median indicates that during half of the year Tier is having more than 1189 trips per week. The minimum number of trips was recorded on January 8<sup>th</sup>, 2024, just 394. However, such a low number of trips could have been expected with the winter season and weather in mind. On the other hand, the maximum number of weekly trips was made on September 4<sup>th</sup> 2023, as much as 1825. The interquartile range (IQR) is 774, which represents the middle 50% of the data, suggesting a moderate spread between the 25th and 75th percentiles. Looking at the skewness and kurtosis, the data extends more towards the lower values and is slightly less peaked than a normal distribution.

**Table 1:** Descriptive statistics of the number of weekly scooter trips offered by Tier in Bern

Mean	Std	Median	Min	Max	IQR	Skewness	Kurtosis
1122.40	421.484	1189.00	394	1825	774	-0.127	-1.299

Figure 1 shows that the number of weekly trips in the observed period. Even in the spring and summer months, there have been sharp declines (certain weeks in April, May and even July). As autumn starts, a decline in the number of trips can be noted, which is expected. Interestingly, in late January 2024, there was an unusual peak for the winter months, 863, which is more than the latest recorded value of 853 in April 2024.



**Figure 1:** Number of weekly scooter trips offered by Tier in Bern – Time series line graph

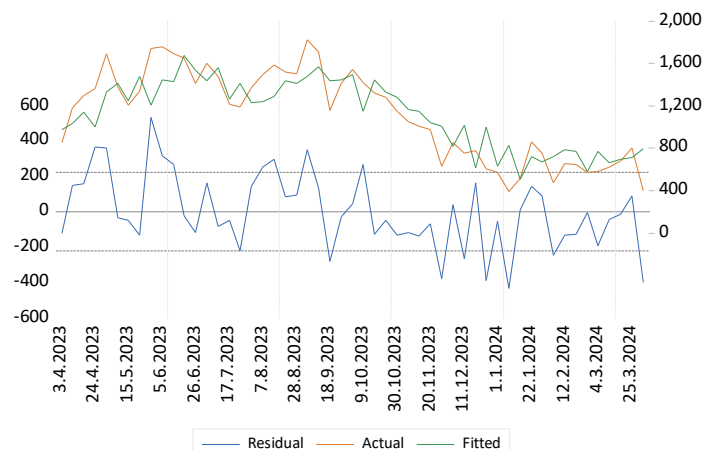
The line plots of the recorded time series suggest potential non-stationarity and exhibit observable trends within the data. To assess the stationarity of the gathered data, the Augmented Dickey-Fuller test and Box-Ljung tests were conducted. The results of the ADF test for the time series indicate that the series should be integrated once (Level:  $ADF = -0.460$ ,  $p > 0.05$ ; 1<sup>st</sup> difference:  $ADF = -7.419$ ,  $p < 0.01$ ). However, after the first difference, the correlogram showed that the time series is over differentiated, as AC in second lag was  $-0.323$ , close to  $0.5$  and statistically significant. Therefore, when modelling the time series, we tried models with both  $d=0$  and  $d=1$ . Several models were tested, and the best model was chosen based on the following criteria: lowest AIC, low residuals, as well as good predictive power. For example, model ARMA(2,1) was not chosen as the best model, even though it had the lowest AIC (13.535). We chose ARMA(3,1) as the best model, as it had a low AIC of 13.478 and its predictions and prediction intervals were positive. The ARMA(3,1) model specification is given in Table 2.

All three elements of the time series (the constant, AR and MA) are statistically significant. ARCH test indicated no presence of heteroskedasticity in the model, while the Jarque-Bera test showed that the residuals are normally distributed. The results of the Ljung-Box test indicate the presence of autocorrelation. The graph of residuals, actual values and fitted values is presented in Figure 2. Additional model characteristics include the  $R^2$  which is  $0.742$ , and the F-statistics ( $47.152$ ,  $p < 0.01$ ) which indicates that the model is statistically significant. Considering the model analysis, it can be concluded that the model is of good quality and that it can be used for forecasting.

**Table 2:** Analysis of the ARMA(3,1) model for the Bern weekly trips for scooters offered by Tier

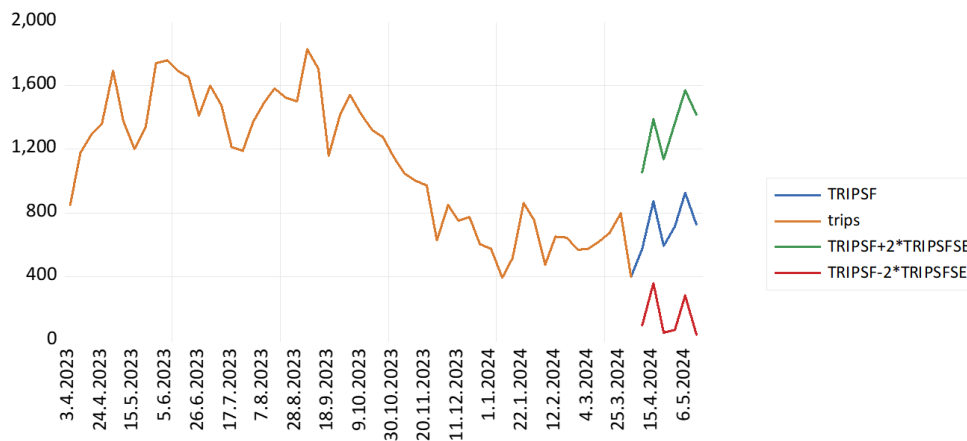
Test	Item	Statistics
z test of constant	1051.923	6.431**
z test of coefficient AR(3)	0.701359	4.869**
z test of coefficient MA(1)	0.537183	3.498**
Ljung-Box	Residuals - Autocorrelation	Present
ARCH test	Residuals - Heteroskedasticity	0.186
Jarque-Bera	Residuals - Normality	0.310

Note: \*\* $p < 0.01$



**Figure 2:** Residuals, actual values and fitted values of the ARMA(3,1) model

Considering that the ARMA(3,1) model has the best fit, assumptions of homoskedasticity are fulfilled, and the model is considered adequate for forecasting time series. The forecast graph is presented in Figure 3.



**Figure 3:** Historical and predicted values of the weekly number of trips for scooters offered by Tier in Bern

With regards to Figure 3, the blue line shows the projected weekly number of trips in April and May 2024, the orange line indicates historical values upon which the forecast was built, the green line presents the upper projection confidence interval, while the red line presents the lower confidence interval. According to the prediction, the number of weekly trips of Tier scooters will be volatile in the upcoming period.

## 5. DISCUSSION AND CONCLUSION

The presented study aimed to develop a model for e-scooter usage using ARIMA time series modelling in Bern, Switzerland. Several models were tested, and the best model was selected based on the following criteria: lowest Akaike Information Criterion (AIC), minimal residuals, and strong predictive performance. ARMA(3,1) was chosen as the optimal model due to its low AIC and good prediction intervals. Based on the model analysis, it can be concluded that the model exhibits good quality and is suitable for forecasting. According to the predictions, the number of weekly trips of Tier e-scooters is expected to be volatile in the upcoming period.

A potential future direction for the study could involve applying the approach taken by Dobrota et al. (2021), who developed a variety of time series models (e.g.,  $R(p)$ ,  $MA(q)$ ,  $ARMA(p,q)$ , ARCH, GARCH, BMMR, BMMRJD, GBM, GBMJD). Also, Holt-Winter Filtering could be applied as done in the study of Muller and Bogenberger (2015) who modelled booking data of a free-floating carsharing system in Berlin. Another future direction of the study could be the analysis of daily data or analysis of other indicators provided by the Fluctuo platform such as: *Vehicles available*, *Vehicles used*, *Trips per vehicle*, and others. Also, a comprehensive analysis of the whole e-scooters fleet in the observed city could be performed.

We hope that this study might serve as a source of insights into the temporal dynamics of shared mobility services, providing valuable information for urban transportation policy, planning, and management. By shedding light on the patterns and trends within shared mobility usage, our findings can be used as initial information for the development of more efficient and sustainable urban transportation strategies. Additionally, this research has the potential to catalyse further research on the topic of modelling and predicting the usage of shared mobility in various domains.

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# ARE WE REALLY ADDRESSING FAIRNESS IN MACHINE LEARNING ALGORITHMS?

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**Abstract:** *This study explores the effectiveness of neural network regularization functions in measuring fairness, particularly analyzing the disparity between true disparate impact and fairness regularization functions. Utilizing two standard fairness datasets, COMPAS and Adult, we investigate the gaps between fairness and actual outcomes, and assess the suitability of two fairness functions derived from literature. Through experiments, we find substantial variations in fairness outcomes as determined by disparate impact and probabilistic disparate impact, especially under varying the strength of the loss functions given to accuracy versus fairness. Results indicate that focusing solely on fairness metrics can lead to misleading outcomes, often disregarding individual merit and involvement. The findings highlight the complexity of implementing fairness in algorithmic decisions, suggesting a critical need for a deeper evaluation of fairness functions in predictive models.*

**Keywords:** *Fairness, Inequality, Machine Learning, Fairness Gap*

## 1. INTRODUCTION

Machine learning (ML) algorithms are now widely used for making decisions, like suggesting videos or products, or even predicting who might get or leave a job. However, it was just a question of time when such tools were to be applied to areas that affect social and economic well-being. Thus, one can find and read about issues when ML models were applied in hiring (Raghavan et al., 2020; Li et al., 2021) or education (Baker & Hawn, 2022).

For example, (Li et al., 2021) states that recruiters often overly rely on ML-enabled software to streamline candidate searches, especially for highly competitive roles like data science positions. Consequently, concerns arise when using such tools for hiring due to potential unfairness, discrimination, or limitations in accurately assessing candidate suitability. One of the examples highlighting that personal trait such as race or gender influenced the ML model about the hiring decision making is Amazon automated hiring tool that discriminated against women (Langenkamp et al., 2020; Dastin, 2022). While the previous example is striking, another one made a stronger effect in the society. In August 2020 due to COVID lockdowns and fears of spreading the virus, the UK government and regulatory body Ofqual implemented an algorithm to calculate / predict A Level students in England and Wales, replacing traditional school examinations (Heaton et al., 2023). Initially intended to address grade inflation, the algorithm faced public backlash due to favouring certain schools over others. In other words, students that went to schools that were historically good schools were more likely to obtain A Level prediction, while it was possible for a superb student from a historically poor performing school not to obtain A Level prediction (Heaton et al., 2023). Some even stated that usage of these tools highly contributes to the crisis of higher education throughout the world (Abdul-Alim, 2022). Having both examples in mind, evident consequences of applications of ML models in social environment are social divisions and a lack of trust in ML decisions (Kasy & Abebe, 2021).

However, ML models can process a lot of data quickly making them much faster than human decision maker. In addition, with a large amount of data ML algorithms can find subtle and general patterns in data making them more accurate than humans. Finally, ML models can be automated requiring only a server, consequently cheaper than human decision maker (Radovanović et al., 2023). Having that in mind, it is worthwhile to invest time and energy to address unfairness in algorithmic decision making.

There have been numerous efforts aimed at mitigating unfair decisions in ML algorithms. One commonly employed fairness metric is disparate impact. While the fairness measure does capture what people want for a fair ML model to achieve, employed fairness functions often approximate disparate impact. In other words,

existing approaches in literature typically offer linear approximations of fairness functions, which are acknowledged to be imprecise (Lohaus et al., 2020; Radovanović et al., 2022). In this study, we inspect whether neural networks with regularization functions do have a significant disparity between estimated and real fairness performance? More specifically, whether there is a difference between true value of fairness and fairness function used for optimization. Furthermore, we analyse results from two standard fairness datasets—COMPAS and Adult—revealing substantial gaps between the perceived and actual fairness, highlighting the need for a more meaningful examination of unfairness.

## 2. BACKGROUND

Fairness in decision making has long been a topic of discussions throughout the centuries. Early reflections on fairness can be traced back even to ancient Greek philosophical works like the Nicomachean Ethics (Crisp, 2014). However, in the realm of machine learning, the assessment of (un)fairness typically shifts from the individual level to the group level, which is common for modern justice theories (Barocas et al., 2023). This shift may have origins from certain groups facing greater barriers to getting the desired outcomes due to historical injustices. Consequently, individuals from these groups may not start from the same point or do not have equal opportunities as those unaffected by obstacles in the past. This disparity often leads to unequal outcomes between groups, prompting the need to adjust algorithms to mitigate such inequalities.

Group fairness is commonly defined as the difference in expected outcomes between two or more groups, typically distinguished by a *sensitive attribute* such as gender, race, or religion (Barocas et al., 2023; Caton & Haas, 2024). This attribute denotes whether an individual belongs to an advantaged or disadvantaged group, with advantaged members labelled as  $s = 0$  and disadvantaged members as  $s = 1$ . A widely used metric for evaluating the fairness of algorithmic decision-making models is *disparate impact*. Disparate impact compares the proportion of individuals receiving desired outcomes between disadvantaged and advantaged groups (Barocas et al., 2023; Caton & Haas, 2024). Mathematically, it is represented as:

$$DI = \frac{p(\hat{y} = 1 | s = 1)}{p(\hat{y} = 1 | s = 0)} \quad (1)$$

Disparate impact focuses solely on the outcome of decision-making procedures ( $\hat{y} = 1$ ), disregarding input attributes and individual merit, which is often critiqued in the community (Finocchiaro et al., 2021; Kasy & Abebe, 2021; Radovanović et al., 2022). Perfect fairness is achieved when both groups have equal proportions of individuals receiving desired outcomes ( $DI = 1$ ). Values below one indicates unfairness favouring the advantaged group, while values above one may suggest positive discrimination (Abebe et al., 2020).

An adaptation of the disparate impact measure, *statistical parity*, quantifies the absolute difference in proportions of desired outcomes between disadvantaged and advantaged groups. Due to its nature, it is more often used in ML fairness research. While various fairness notions exist, e.g. equal opportunity, this paper focuses primarily on disparate impact. Interested readers can explore further ML fairness measures, biases in the referenced literature (Caton & Haas, 2024).

## 3. MATERIALS AND METHODS

This section aims at explaining the data used in this paper with an explanation of why those datasets are chosen, followed by explanation of the methods used and experimental setup.

### 3.1. Data

For the purposes of this research, we utilized two datasets, namely COMPAS and Adult. The COMPAS and Adult datasets are frequently employed in ML fairness research due to their relevance to real-world scenarios and the presence of inherent biases, which make them suitable for studying fairness considerations in algorithmic decision-making. In other words, these datasets are perfect examples on how a racial or gender bias can be introduced into decision-making, leading ML algorithms to learn a model that amplifies human bias and makes unfair predictions (Abebe et al., 2020).

The COMPAS dataset (Barenstein, 2019) originates from a decision support system utilized within the criminal justice system. It predicts the likelihood of an individual committing a future criminal offense based on various personal and behavioral attributes. This dataset has attracted attention due to concerns regarding racial bias, particularly in the context of predictive algorithms influencing judicial decisions (Dressel & Farid, 2018; Barenstein, 2019). Researchers often utilize the COMPAS dataset to investigate and mitigate disparities in ML model predictions across different demographic groups, such as racial minorities. More specifically, the COMPAS decision support system offers risk scores predicting future criminal behavior. The dataset

comprises 6,617 individuals and 10 attributes, categorizing people of black race as disadvantaged and people of white race as advantaged.

The Adult dataset (Kohavi, 1996), on the other hand, is commonly employed as a benchmark for evaluating fairness in the context of employment and income. It contains information about individuals' demographic attributes, education, and employment status, with a focus on predicting whether an individual earns an income above a threshold of \$50,000 per year. Gender disparities in income are a prominent feature of this dataset, with male individuals typically earning more than their female counterparts. ML fairness research often utilizes the Adult dataset to study and address gender bias in predictive models, aiming to develop algorithms that promote gender equity in employment opportunities and income distribution (Caton & Haas, 2024). The dataset encompasses 30,162 instances and 96 attributes.

It is worth stating that both datasets present binary classification problems, meaning that individuals are categorized in one of two categories. For the sake of reproducibility and comparability of results, the data preparation procedures follow the methodology outlined in (Hertweck et al. 2022).

### 3.2. Methodology

To assess whether the fairness functions are appropriate replacement for the true disparate impact function, we'll conduct tests using a neural network with different activation functions where the goal function is adapted for accuracy and fairness at the same time. The setup of the goal function is the following. We will optimize the loss function  $L(\theta)$  as given in Formula (2). The goal function consists of a binary cross entropy loss function (accuracy loss), which is one of the most common loss functions in the binary classification setup. Accuracy loss is multiplied with  $\lambda \in \{0, 1\}$  that signals the strength of the accuracy loss. On the other hand, fairness loss represents how important fairness is to the overall loss function, and it is multiplied with  $(1 - \lambda)$ .

$$\min L(\theta) = \lambda \left( -\frac{1}{n} \sum_{i=1}^n (y_i \log(\hat{y}_i) + (1 - y_i) \log(1 - \hat{y}_i)) \right) + (1 - \lambda) \text{fairness} \quad (2)$$

We wanted to inspect two fairness functions coming from the literature. The first one is an adaptation of a fairness constraint from (Zafar et al., 2019) that model fairness as the covariance between the sensitive attribute  $s$  and the prediction  $\hat{y}$ . However, since the prediction  $\hat{y}$  is a non-linear function, it is replaced with the logit value  $\theta^T x_i$ . This fairness function is presented in Formula (3). Disparate impact, or more specifically statistical parity requires independence between the sensitive attribute  $s$  and the prediction  $\hat{y}$ , denoted  $s \perp \hat{y}$ , and an appropriate way to calculate independence between two attributes is covariance. If covariance is equal to zero, then two attributes are linearly independent. However, covariance can be both positive and negative denoting positive and negative correlation, thus we apply absolute value of the fairness function to signal that unfairness exists.

$$\text{fairness} = \left| \frac{1}{n} \sum_{i=1}^n ((s_i - \bar{s}) * \theta^T x_i) \right| \quad (3)$$

A different fairness function we utilized can be seen in (Radovanović et al., 2022), which calculates the difference in average values of logit scores for advantaged and disadvantaged groups. This fairness function is presented in Formula (4). Ideally, one would like to have the first moment (central tendency) of predictions distribution to be equal. This identically corresponds to the statistical parity formula with a caveat that application of decision threshold to the prediction would yield unstable optimization procedure (the entire procedure would be non-convex, and estimation of the gradient would have a high variance), therefore it is not used.

$$\text{fairness} = \left| \frac{1}{n_a} \sum_{i=1}^{n_a} \theta^T x_i - \frac{1}{n_d} \sum_{i=1}^{n_d} \theta^T x_i \right| \quad (4)$$

where  $n_a$  is the number of individuals in the advantaged group, and  $n_d$  is the number of individuals in the disadvantaged group.

An additional transformation was performed to help goal functions having the same scale. We precalculated the binary cross-entropy loss for predictions equal to 0.5 (binary cross-entropy would be  $\log(2)$ ) and used that as a baseline accuracy loss we used to divide the actual binary cross-entropy. For the fairness function we used the value of the fairness function where true value of the output attribute  $y$  was used instead of  $\hat{y}$ . By

doing this, we ensure that both accuracy and fairness function are represented in the same scale of values and that one cannot dominate over another in the overall goal function. However, this doesn't mean that they are of the same complexity. Still, fairness function is easier to optimize with a trivial solution where every prediction is the same (that can be achieved by making every coefficient equal to zero).

We are aware that these approximations of the fairness function are too loose (Lohaus et al., 2020) and one can be tricked that the fairness problem can be easily solved. More specifically, the fairness function can have a low value, while disparate impact can be rather high. The goal of this research is to inspect how well these functions approximate disparate impact with different neural networks.

### 3.3. Experimental Setup

To determine if the fairness function indeed optimizes disparate impact, we will evaluate two fairness functions described in Section 3.2. More specifically, one question we ask ourselves is *what fairness function is more appropriate for the given datasets*, and can we make more general claims about appropriateness of fairness functions. Although both are directly related to the disparate impact, perhaps one is more appropriate than the other.

We will experiment with varying the hyper-parameters  $\lambda$  represented in numbers spaced evenly on a log scale (a geometric progression) starting from 0.01 to 1 in 19 numbers with an addition of value 0. The reason for selecting this type of progression is the fact that fairness function is easier to optimize, and we would like to obtain a more fine-grained view on the tradeoff between accuracy and fairness. Equal distribution of points would result in missing the knee point on the Pareto frontier of accuracy-fairness tradeoff. This setup helps us answer the question *what is the difference between actual fairness and fairness functions and where one can observe the greatest difference?* To measure the accuracy of a prediction model, we used accuracy measure with a decision threshold of 0.5 (*Acc*). Regarding fairness, we measure the value of the fairness function, disparate impact where decision was made with the decision threshold of 0.5 (*DI*), as well as disparate impact by using the average prediction probability (*DI Prob*).

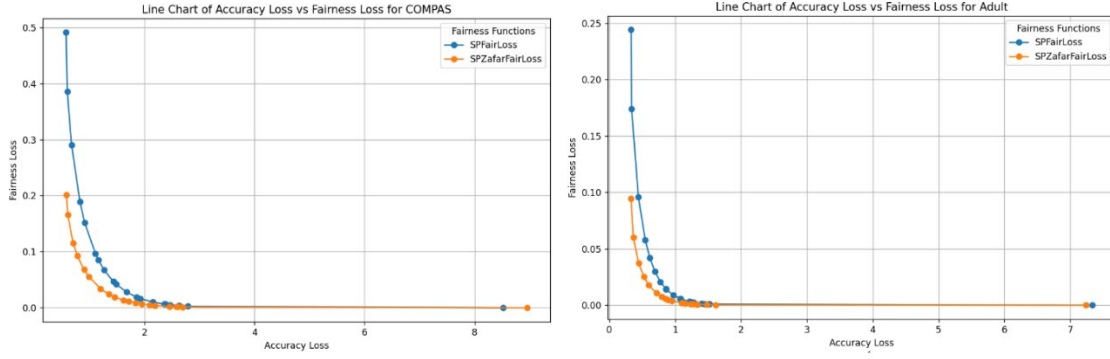
We trained neural networks with different number of neurons and with different activation functions. More specifically, we trained neural networks with one hidden layer consisting of 5, 10, 15, and 20 neurons for COMPAS (bear in mind that this dataset has 10 attributes) and 10, 20, 30, 40, and 50 neurons for Adult dataset (bear in mind that this dataset has 96 attributes). Regarding the activation functions for the hidden layer, we used rectified linear unit, leaky rectified linear unit with a negative slope 0.01, sigmoid and hyperbolic tangent. Due to the page constraints, we present the results with the highest number of neurons per dataset (20 neurons for COMPAS and 50 neurons for Adult) and with ReLU activation function.

We randomly divided our dataset to three subsets, where the training set consists of 75% of the data, validation set 15% of the data, and test set the remaining 10% of the data. Experiments are repeated five times for the greater validity of the results. Neural network training consisted of 1000 epochs with implementation of the early stopping mechanism where the training procedure would stop if there were no improvements in the goal function in 20 consecutive epochs. This was selected as the most appropriate number within the grid based values while observing the validation loss curve. It is worth noting that the vast majority of the training procedures ended up by being stopped by the early stopping mechanism. Every result presented in the following section is on the test subset.

## 4. RESULTS AND DISCUSSION

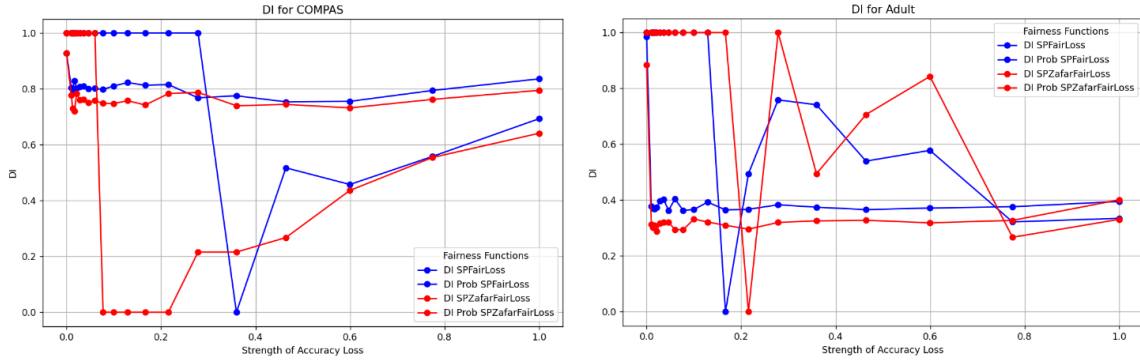
To answer the first question raised in the previous section, we shall inspect the Pareto frontier of accuracy-fairness loss (Figure 1). For the sake of clarity, we selected ReLU activation function with the highest number of neurons (20 for COMPAS and 50 for Adult dataset) and the same conclusion can be made for different setups as well. One thing that can be seen is that Zafar fairness function denoted *SPZafarFairLoss* (Zafar et al., 2019) looks better compared to one seen in (Radovanović et al., 2022) denoted *SPFairLoss*. However, a true sense on which one is better can be observed when plotting the *DI*.

However, the most important question of this paper is whether the loss functions actually measure the *DI*. To get an idea of the difference between *DI* and *DI Prob* we plot them side by side (Figure 2) for different values of  $\lambda$ . By focusing on the left side of the subplots ( $\lambda \leq 0.5$ ) where more attention is given to fairness function than to the accuracy function, one can see that *DI Prob* is relatively stable for every value of  $\lambda$ . More specifically, only the first value ( $\lambda = 0$ ) reached perfect or almost perfect values of *DI Prob* while for every other value it remains stable and around 0.8 for COMPAS and 0.35 for Adult dataset. This indicates that outcomes are relatively acceptable for COMPAS dataset, while for the Adult it signals a huge disparity in predictions.



**Figure 1:** Pareto frontier of accuracy-fairness loss

The story is totally different for  $DI$ . When focusing on fairness, one reaches perfect fairness. However, this value is a deceiving one. It is obtained where every individual either obtained or didn't obtain the outcome ( $\hat{y} \geq 0.5, \forall i \in [1, \dots, n]$ ). These solutions are called egalitarian solutions (Bringas Colmenarejo et al., 2022; Holm, 2023) stating that every individual should receive (or not receive) an outcome if there is enough resourced. While this seems like a compelling solution it doesn't take merit into account, which can lead to lack of involvement from individuals.



**Figure 2.** Effects of the  $\lambda$  on the  $DI$

To conclude with questions, we posed on *what is the difference between actual fairness and fairness functions and where one can observe the greatest difference?* We can observe in Figure 2 that the answer is inconclusive. For the COMPAS dataset focusing on the fairness loss may result in underestimation of  $DI$  as  $DI Prob$  is lower than  $DI$ . However, this is a result of giving (or not giving) the outcome to every individual and presents a place where the greatest difference is. This also explains the sudden drop from  $DI = 1$  to  $DI = 0$  and reverting to  $DI = 1$ . Once the  $DI$  stabilizes, which is around  $\lambda = 0.4$  for COMPAS and  $\lambda = 0.2$  for Adult, we can see that there is a high mismatch between  $DI$  and  $DI Prob$ . For the COMPAS dataset  $DI Prob$  is higher than  $DI$ , while for the Adult is other way around.

In this experiment, neural network architecture doesn't influence the accuracy-fairness tradeoff. In other words, the results are as expected. For both datasets, activation function results in very similar values for both accuracy and fairness, thus adding to the no free lunch theorem (Wolpert & Macready, 1997) that there is no single model that is dominant compared to others. On the other hand, adding more neurons in the hidden layer results in quadratic function of accuracy, but fairness remains the same. Simpler models (lower number of neurons) had small capacity to capture the complexity of the relation between input attributes and the output attribute. Adding more neurons improved the predictive performance to some point where adding more neurons didn't result in an improvement. This is due to the early stopping mechanism that was implemented, which solved the issue of overfitting. On the other hand, fairness performance remained unchanged with adding more neurons.

## 5. CONCLUSION

This research reveals significant disparities in the outcomes of fairness-focused neural network models, particularly when comparing the disparate impact to the fairness functions optimized for in the models. Using the COMPAS and Adult datasets, our analysis demonstrated that fairness functions from the literature, while achieving their intended theoretical objectives, do not consistently align with actual fairness outcomes. The investigation into two different fairness functions showed that neither could universally claim superiority across

the datasets. Moreover, a detailed examination of the relationship between  $DI$  and  $DI Prob$ , especially at lower values of  $\lambda$ , exposed a high mismatch, with  $DI Prob$  remaining relatively stable while  $DI$  exhibited substantial fluctuations. This inconsistency raises concerns about the potential for "egalitarian solutions," which may achieve numerical fairness but fail to account for individual merit, thus risking reduced participation and effort from individuals affected by such decisions. Overall, the study underscores the complexity of applying fairness constraints in machine learning and the necessity for more comprehensive approaches to evaluate and implement fairness in algorithmic decision-making. As a part of the future research, we plan to optimize for the "knee" on the accuracy-fairness Pareto frontier by utilizing the Karush-Kuhn-Tucker condition for Pareto optimal solution in multi-objective optimization.

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# INVESTIGATING THE EFFICIENCY OF CROATIAN HOSPITALS AT COUNTY LEVEL: DATA ENVELOPMENT APPROACH

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**Abstract:** *Clinical hospital centers and general hospitals are the main sources of debt in the healthcare sector. With regard to the financial sustainability, the Government of the Republic of Croatia is implementing a new organizational reform of the hospital system in 2024. According to the Healthcare Act, the state will take over the management of general hospitals. In addition, the new Public Health Protection Network is being established with the intention of bringing about structural and organizational changes that will centralize the planning of health resources, but will be based on the needs of the county. Therefore, the aim of this paper is to investigate whether there are differences in the technical efficiency of hospital operations at the county level and to identify the reasons for inefficiency. For this purpose, Data Envelopment Analysis (DEA) is used for the period 2019 – 2022. The differences between counties in terms of the efficiency of healthcare provision make it clear that targeted improvements and monitoring mechanisms are needed. Therefore, the new Public Health Protection Network seems to be a sensible way to achieve integrated and people-centred care.*

**Keywords:** *Croatian hospitals, efficiency, DEA analysis*

## 1. INTRODUCTION

At the beginning of 2022, the total debt in the Croatian healthcare sector amounted to 4.44 billion kuna (approx. EUR 585 million), more than half of which was accounted for by the hospitals' debts to pharmaceutical wholesalers. Until the early 2000s, Croatia had a fee-for-service (FFS) reimbursement system for hospitals, where hospitals were paid on the basis of the resources used for each procedure. Under the FFS schedule, hospitals had incentives to maintain high bed occupancy rates and extend length of stay. To increase efficiency in the hospital system in 2002 Croatia introduced broad case-based groupings called payment according to the therapeutic procedure (PPTP). This payment reform, instead of increase in technical efficiency of service provision, led to often more costly hospital procedures as the intensity of resource use for more complicated medical cases were underestimated. In 2009 diagnosis-related groups (DRGs) were introduced which are also used in most European countries. In their study Bogut et al. (2012) finds that DRGs payment systems have improved efficiency in acute hospital care as measured by a reduction in average length of stay, with little impact on the number of cases. These provider payment reforms had no adverse impact on quality as measured by readmissions (Bogut et al. 2012), and they resulted in similar hospital efficiency when the same diagnosis is considered (Dukić Samaržija et al, 2018). However, Kalanj (2021) recently concluded that ten years after the introduction of DRGs, Croatian hospitals have not shown any increase in cost efficiency, as hospital expenditure and staffing levels have increased on the one hand, and inpatient cases and DRG-weighted activity have decreased on the other.

Hospital activity in the Republic of Croatia takes place at the secondary (general hospitals and specialized hospitals) and tertiary level of health care (clinical hospitals and clinical hospital centers). The tertiary sector hospitals and the specialized secondary sector hospitals are under the control of the central government, while the general secondary sector hospitals are mainly owned by local governments (counties and cities). Clinical hospital centers and general hospitals are the main sources of debt, as they are also the largest healthcare facilities (Šimović et al., 2021). With regard to the financial sustainability of the healthcare system, the Government of the Republic of Croatia is carrying out a new organizational reform of the hospital system in 2024. According to the Health Care Act, the founding rights will be transferred from the counties to the state, i.e., the state will take over the management of general hospitals. In addition, the new Public Health

Protection Network will determine (at the level of counties and the City of Zagreb) the required number of healthcare facilities, the required number of beds by field of activity and the maximum possible number of healthcare teams and private providers of healthcare services. The new Network is intended to bring about structural and organizational changes in hospitals, including a reduction in the number of acute beds in justified cases and an increase in the capacity of day clinics and the number of beds for palliative care and long-term treatment. In view of the new reform, which has not yet been fully implemented, this paper examines the efficiency of hospital activity at county level in the Republic of Croatia in order to determine the current state of hospital efficiency in individual counties. The aim of this paper is therefore to investigate whether there are differences in the technical efficiency of hospital activities at county level and to identify the reasons for inefficiency. Data Envelopment Analysis (DEA) is used to assess the relative technical efficiency for the period 2019 – 2022.

## 2. LITERATURE REVIEW

The efficiency of hospitals in Croatia is of crucial importance due to the high financial requirements. It reflects the overall quality of the healthcare system and emphasises the need for efficient management (Vašiček et al. 2018), which has been shown to increase the efficiency of hospitals (Yousri et al. 2011, Collar et.al. 2012, Waring and Bishop, 2010).

Although the efficiency of hospitals in Croatia is not so frequently empirically studied, there are several studies on the efficiency of the healthcare system (Buljan & Šimović, 2022), the efficiency of healthcare at county level (Hodžić et al. 2019; Rabar, 2013) and the efficiency at the hospital level (Rabar 2010, Dukić Samaržija et al. 2018). The methods used in these studies provide valuable insights for evaluating and improving the performance and efficiency of hospitals in Croatia and contribute to the ongoing efforts to improve the quality and effectiveness of public health services in the country.

Buljan & Šimović (2022) examined the overall efficiency of the healthcare system in Croatia compared to 21 EU countries using a dynamic DEA window analysis. Croatia showed a lower efficiency of healthcare expenditure in relation to life expectancy, indicating room for improvement in resource allocation and health outcomes. They concluded that Croatia could achieve the same results with a lower level of intermediate resources. That is, reducing acute inpatient capacity in hospitals while strengthening outpatient facilities would help rationalize costs and ensure the financial sustainability of the healthcare system without compromising health outcomes. Hodžić et al. (2019) evaluate and analyse the efficiency of average healthcare expenditure in twenty Croatian counties using the DEA approach. The analysis was conducted for the period 2010-2017. The results showed differences in the efficiency of healthcare spending between Croatian counties. The results of the scale efficiency showed that out of the twenty Croatian counties, only six counties were efficient. The study by Kalanj (2022), which examined 33 hospitals as a sample between 2009 and 2018, is noteworthy because it examines the relationship between hospital performance and service reimbursement models. The study concludes that hospital working practices need to be reformed to prevent a further decline in efficiency.

Our study focuses on the efficiency of hospitals at the county level, which is similar to the study conducted by Rabar (2013) for the three-year period (2007-2009) using the BCC-DEA model. The comparison with the result from more than 10 years ago will show whether there have been changes in hospital performance between the counties, which will be addressed in the results and discussion.

## 3. METHODOLOGY

Data Envelopment Analysis (DEA) is a powerful non-parametric method that was primarily developed to measure efficiency in the public sector, but soon found application in the private sector due to its advantages. Unlike traditional statistical methods, DEA does not require specific functional forms for production or cost functions, making it suitable for different contexts. Two basic DEA models are the CCR model (Charnes, Cooper, Rhodes, 1978) and the BCC model (Banker, Charnes, Cooper, 1984). The CCR model assumes constant returns to scale (CRS), which means that the scale of operations has no impact on efficiency. It evaluates each DMU based on its ability to maximize outputs for a given level of inputs. In contrast, the BCC model allows for variable returns to scale (VRS) and recognizes that the relationship between inputs and outputs may not be proportional. The BCC model is more flexible as it allows for situations in which an increase in inputs does not lead to a proportional increase in outputs, which is why it is chosen.



It is also important to choose the appropriate model orientation. Given the nature of healthcare, which is very complex and subject to great uncertainty, the input-oriented DEA is chosen, in which inputs are minimized for a given level of output. Its formulation (Amminudin and Ismail, 2016) is shown in the following formula:

$$\begin{aligned}
 \text{Max } \theta &= \sum_{j=1}^m u_j y_{j0} + u_0 \\
 \text{subject to } &\sum_{i=1}^s v_i x_{i0} = 1 \\
 &\sum_{j=1}^m u_j y_{jk} - \sum_{i=1}^s v_i x_{ik} + u_0 \leq 0 \\
 &v_i \geq 0; u_j \geq 0; u_0 \text{ free in sign}
 \end{aligned} \tag{1}$$

The model given by the above formula is used to obtain the value of relative efficiency  $\theta_j$ , the optimal input weight,  $v_i$  and the optimal output weight,  $u_i$ .

## 4. DATA, RESULTS AND DISCUSSION

### 4.1. Data and model selection

This paper applies input-oriented BCC model for assessing the relative technical efficiency of Croatian hospitals at county level. Data was collected for the period 2019 - 2022 from the "Report - Operation of Hospitals in Croatia in 2019 - 2022" by the Croatian Institute of Public Health. One of the reasons why static BCC-DEA is preferred to dynamic Window DEA is that it provides projections to the efficiency frontier and provides a reference set in which inefficient DMUs are compared to their similar but efficient peers. The total number of DMUs in this paper is 21 (20 counties and City of Zagreb) and the total sum of inputs and outputs is 4. The analysis was carried out using the DEA Solver pro program.

The selection of inputs and outputs and their measurement can significantly influence the results, which can be overcome by selecting only fundamental inputs and outputs. Therefore, the number of beds and the number of physicians are defined as inputs as they reflect the capital and human capacity of the hospital. On the other hand, inpatient discharges and the number of hospital days are defined as outputs, as they represent the direct output of healthcare. Recognizing that inpatient services have special characteristics and require more resources compared to outpatient services, the term "inpatient/hospital days" is considered more medically consistent than "number of patients in hospital" and can provide more meaningful insights (Wang et al. 2017). Many studies that examine the efficiency of hospitals also use these variables for input and output (cf. Fazria & Dhamanti, 2021).

Table 1 shows descriptive statistics on the selected inputs and outputs of hospitals by Croatian county. The data indicate diversity among the selected counties. On average, hospitals per county have between 6,047 and 6,444 beds depending on the year, between 2,601 and 2,669 physicians, the number of in-patient discharges is on average between 199,779 and 254,875, while the number of days in hospitals is between 1,384,469 and 1,791,306 depending on the year.

**Table 1:** Statistics on Input/Output Data

<b>2019</b>	<b>No of beds</b>	<b>No physicians</b>	<b>of</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
Max	6,333	2,601		254,875	1,791,30
Min	94	13		2,208	24,254
Average	1,105.76	338.91		34,078	278,26
SD	1,326.48	532.61		51,495.1	365,87
<b>2020</b>	<b>No of beds</b>	<b>No physicians</b>	<b>of</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
Max	6,444	2,606		199,779	1,384,469

Min	94	14	1,737	21,551
Average	1,101.86	341.95	27,672	222,696
SD	1,340.17	534.61	40,393.3	285,249

<b>2021</b>	<b>No of beds</b>	<b>No of physicians</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
Max	6,047	2,669	213,361	1,448,115
Min	94	17	1,785	24,061
Average	1,077.05	352.66	29,988.9	232,903
SD	1,254.89	548.19	43,388.5	294,507

<b>2022</b>	<b>No of beds</b>	<b>No of physicians</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
Max	6,117	2,651	228,518	1,496,800
Min	94	15	2,069	22,105
Average	1,081.76	352.71	31,342.3	242,028
SD	1,271.14	545.73	46,561.5	305,884

When selecting input and output variables for the DEA, it is imperative that all inputs and outputs are positively correlated with each other and have non-negative values. The correlation matrix for the selected inputs and outputs is shown in Table 2.

**Table 2:** Correlation matrix

<b>2019</b>	<b>No of beds</b>	<b>No of physicians</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
No of beds	1	0.95885	0.96624	0.99002
No of physicians	0.95885	1	0.99468	0.97292
In-patient discharge	0.96624	0.99468	1	0.98172
Length of stay in hospital	0.99002	0.97292	0.98172	1

<b>2020</b>	<b>No of beds</b>	<b>No of physicians</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
No of beds	1	0.96539	0.97369	0.99375
No of physicians	0.96539	1	0.99537	0.96819
In-patient discharge	0.97369	0.99537	1	0.97818
Length of stay in hospital	0.99375	0.96819	0.97818	1

<b>2021</b>	<b>No of beds</b>	<b>No of physicians</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
No of beds	1	0.96729	0.97171	0.99216
No of physicians	0.96729	1	0.99477	0.97919
In-patient discharge	0.97171	0.99477	1	0.9828
Length of stay in hospital	0.99216	0.97919	0.9828	1

<b>2022</b>	<b>No of beds</b>	<b>No of physicians</b>	<b>In-patient discharge</b>	<b>Number of hospital days</b>
No of beds	1	0.96675	0.97226	0.99084
No of physicians	0.96675	1	0.99641	0.97013
In-patient discharge	0.97226	0.99641	1	0.97549
Length of stay in hospital	0.99084	0.97013	0.97549	1

One of the prerequisites for the application of DEA is that the data fulfil the condition of isotonicity (Wang, Nguyen, & Tran, 2015), which means that the output grows with the growth of the input. It can be seen that all input and output variables are positively correlated with each other, which means that the isotonicity condition is fulfilled.

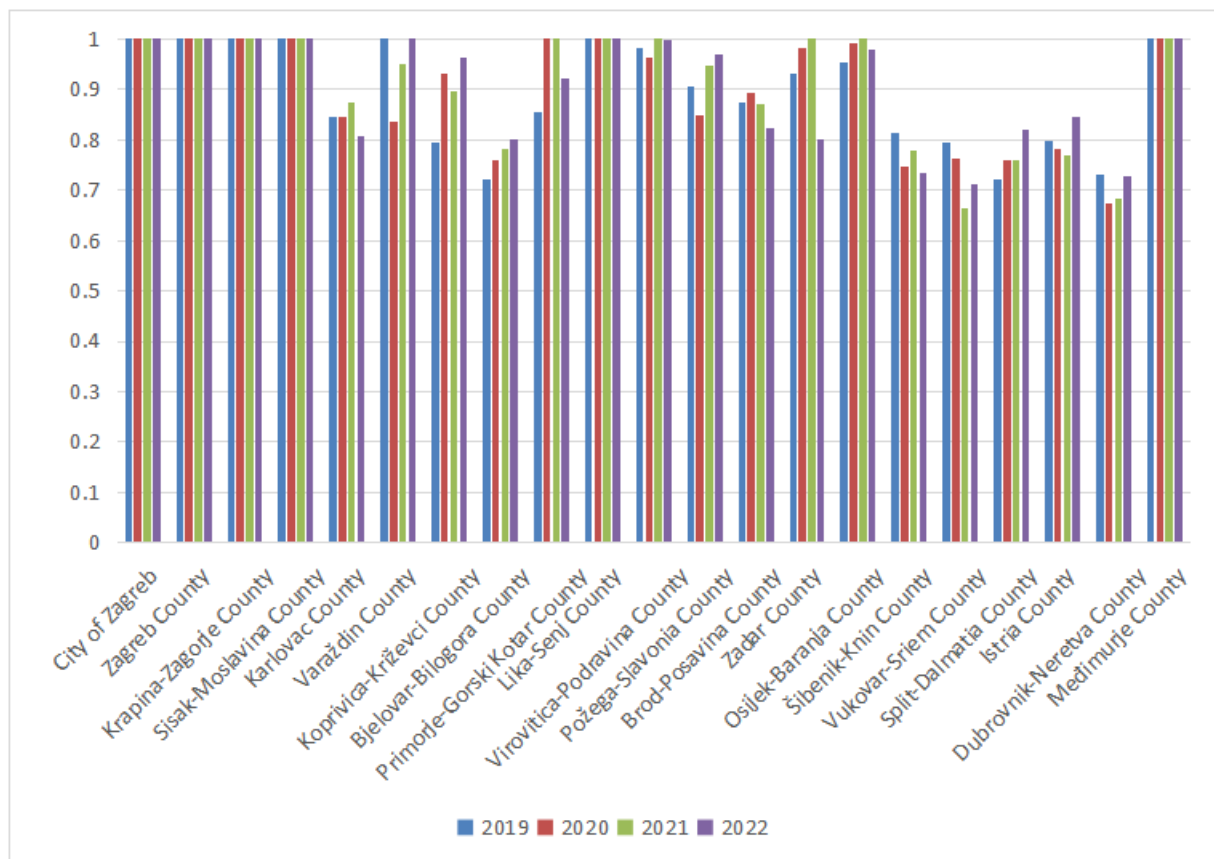
## 4.2. Results and discussion

After the descriptive statistics and the correlation matrix of the selected inputs and outputs, the following table shows the results of the analysis using the BCC model. A DMU is 100% efficient compared to the other DMUs in the sample if  $\theta = 1$ . Results below 1 ( $0 \leq \theta < 1$ ) indicate relatively inefficient DMUs.

**Table 3:** Results of relative efficiency per county from 2019 to 2022

DMU	2019	2020	2021	2022	Average per county
<b>City of Zagreb</b>	1	1	1	1	1
<b>Zagreb County</b>	1	1	1	1	1
<b>Krapina-Zagorje County</b>	1	1	1	1	1
<b>Sisak-Moslavina County</b>	1	1	1	1	1
Karlovac County	0.8469	0.8463	0.873	0.8065	0.8432
Varaždin County	1	0.8374	0.9495	1	0.9467
Koprivica-Križevci County	0.7939	0.9306	0.895	0.9629	0.8956
Bjelovar-Bilogora County	0.7224	0.7586	0.7823	0.8008	0.7660
Primorje-Gorski Kotar County	0.8542	1	1	0.9202	0.9436
<b>Lika-Senj County</b>	1	1	1	1	1
Virovitica-Podravina County	0.9808	0.9642	1	0.9983	0.9858
Požega-Slavonia County	0.9044	0.8481	0.9484	0.9688	0.9174
Brod-Posavina County	0.8756	0.893	0.871	0.8239	0.8659
Zadar County	0.9321	0.9812	1	0.8008	0.9285
Osijek-Baranja County	0.9526	0.9919	1	0.9793	0.9810
Šibenik-Knin County	0.8135	0.7461	0.7801	0.7343	0.7685
Vukovar-Sriem County	0.7956	0.7634	0.6646	0.7123	0.7340
Split-Dalmatia County	0.7227	0.7593	0.7608	0.8205	0.7658
Istria County	0.7974	0.7816	0.7683	0.8453	0.7982
Dubrovnik-Neretva County	0.7301	0.6741	0.6831	0.7273	0.7037
<b>Međimurje County</b>	1	1	1	1	1
<b>Average</b>	0.8915	0.8941	0.9036	0.9001	
<b>Max</b>	1	1	1	1	
<b>Min</b>	0.7224	0.6741	0.6646	0.7123	
<b>St Dev</b>	0.104	0.1109	0.1169	0.1075	

Table 3 shows that the relative efficiency of hospitals varies from county to county, but also changes over the observed period. Only six counties show the technical efficiency of their hospitals over the observed period: City of Zagreb, Zagreb County, Krapina-Zagorje County, Sisak-Moslavina County, Lika-Senj County, Međimurje County. The results of the relative efficiency were determined using the BCC model, which includes the VRS. The results from Table 3 are shown in Figure 1.



**Figure 1:** Results of relative efficiency per county from 2019 to 2022

The results allow the creation of projections for each inefficient DMU. This means that for each DMU it can be determined by how much a given input should be reduced to reach the efficiency frontier. Considering that the input orientation was used in this paper, which means a decrease in inputs while keeping the outputs constant. Table 4 shows projections for each individual county as well as the average projections for the inputs of all counties studied. In addition, Table 4 shows the reference set and the frequency of the efficient counties in the reference set. The reference set contains relatively efficient Croatian counties from the perspective of the operation of the hospitals located in them, which serve as a model for each individual inefficient DMU. At the same time, each efficient county from the sample also represents a model for itself, which is why it is listed in its own reference set (Yasar. 2016).

**Table 4:** Projections and reference set for 2022

DMU	No of beds - Diff. (%)	No of physicians - Diff. (%)	Reference set
Karlovac County	19.35	19.35	Krapina-Zagorje County; Sisak-Moslavina County; Međimurje County
Koprivica-Križevci County	3.70	3.70	Krapina-Zagorje County; Lika-Senj County; Međimurje County
Bjelovar-Bilogora County	31.27	19.92	Krapina-Zagorje County; Lika-Senj County
Primorje-Gorski Kotar County	20.56	7.98	City of Zagreb; Krapina-Zagorje County; Varaždin County
Virovitica-Podravina County	0.16	0.16	Krapina-Zagorje County; Lika-Senj County; Međimurje County
Požega-Slavonia County	3.12	3.12	Krapina-Zagorje County; Lika-Senj County; Međimurje County
Brod-Posavina County	17.60	20.79	City of Zagreb; Sisak-Moslavina County; Međimurje County
Zadar County	19.92	19.92	Zagreb County; Krapina-Zagorje County; Sisak-Moslavina County; Međimurje County
Osijek-Baranja County	2.07	2.07	City of Zagreb; Krapina-Zagorje County; Međimurje County
Šibenik-Knin County	26.57	33.21	Zagreb County; Sisak-Moslavina County; Međimurje County

Vukovar-Sriem County	28.77	28.77	City of Zagreb; Krapina-Zagorje County; Međimurje County
Split-Dalmatia County	17.94	17.94	City of Zagreb; Krapina-Zagorje County; Međimurje County
Istria County	15.47	15.47	City of Zagreb; Krapina-Zagorje County; Međimurje County
Dubrovnik-Neretva County	27.27	27.27	Krapina-Zagorje County; Lika-Senj County; Međimurje County
<b>Average</b>	11.13	10.46	
<b>Max</b>	31.27	33.21	
<b>Min</b>	0	0	
<b>St Dev</b>	11.71	11.46	

Looking at the hospital sector in Croatia in 2022, the number of beds should be reduced by 11.13% and the number of doctors by 10.46% in order to be efficient. Results provide projections, not only on average level, but also for each county. For example, least efficient county in 2022 is Vukovar-Sriem County. To be efficient, the number of beds and physicians should be reduced by 28.77%. The counties that can serve as a reference are City of Zagreb, Krapina-Zagorje County and Međimurje County.

If we compare our results with those of Rabar (2010) between 2007 and 2009, it is interesting to note that the hospitals in Vukovar-Sriem County were among the most efficient between 2007 and 2009. Hospitals in Koprivica-Križevci County, Požega-Slavonia County, Brod-Posavina County, Split-Dalmatia County and Istria County also all showed at least one efficient result between 2007 and 2009, while they all performed inefficiently in our study. On the other hand, hospitals in Međimurje County were efficient from 2019 to 2022, while they had an inefficient result from 2007 to 2009. To gain a clear insight into the state of hospital efficiency at the county level, we compared our results with those of Rabar (2010) and formed four different categories (Table 5): counties showing an increased level of hospital efficiency, counties showing a decreased level of hospital efficiency, counties showing a relatively constant level of hospitals efficiency, and counties showing a relatively constant level of hospitals inefficiency.

**Table 5:** The efficiency of hospitals by county compared to the results of Rabar (2010)

Increase in efficiency	Decrease in efficiency	Relatively efficient	Relatively inefficient
Zadar County	Karlovac County	City of Zagreb	Šibenik-Knin County
Međimurje County	Koprivica-Križevci County	Zagreb County	Dubrovnik-Neretva County
	Bjelovar-Bilogora County	Krapina-Zagorje County	
	Požega-Slavonia County	Sisak-Moslavina County	
	Brod-Posavina County	Varaždin County	
	Split-Dalmatia County	Primorje-Gorski Kotar County	
	Istria County	Lika-Senj County	
	Vukovar-Sriem County	Virovitica-Podravina County	
		Osijek-Baranja County	

What is worrying is the proportion of countries that show a decline in relative efficiency as opposed to those that show an increase in efficiency. These results only confirm that the efficiency of Croatian hospitals is a topic of concern, as noted in various studies. While Croatia has relatively good efficiency at the macro level, there is still room for improvement, especially in increasing efficiency at the hospital level, without jeopardizing equity in access to healthcare (Cerović et al. 2017). Compared to other EU countries, Croatian hospitals show low efficiency in transforming resources into health outcomes, with systemic efficiency at 48% in 2018 (Buljan & Šimović, 2022). Efforts have been made to identify the best performing public acute care hospitals in Croatia, presenting a multi-criteria decision-making approach to evaluate hospital performance (Kadoić et al. 2021). However, only some hospitals in Croatia define financial and non-financial strategic goals and monitor their achievement, indicating a gap in the goal setting and tracking processes in these institutions (Budimir et al., 2020).

## 5. CONCLUSION

In light of the recent [health](#) reform, this study examines how efficiently hospitals operate at county level in Croatia. The aim of the study is to determine whether there are differences in the efficiency of hospital

operations at this level and to identify the causes of inefficiencies. The study uses a DEA input-oriented BCC model to assess the relative technical efficiency in the period from 2019 to 2022.

The analysis of the hospital landscape in Croatia in 2022 shows that a reduction in the number of beds by 11.13% and the number of doctors by 10.46 is necessary to operate efficiently. These results not only offer projections at an aggregate level, but also provide insights for individual counties. The results allow for the development of estimates for each inefficient county that show the necessary reductions in specific inputs to approach the efficiency frontier. To better understand the state of hospital efficiency at the county level, we compared our results with those of Rabar (2010). The proportion of counties that show a decline in the relative efficiency of their hospitals is greater than the proportion of counties that show an improvement in efficiency, with only two counties achieving better results, while eight counties show a decline in efficiency.

The DEA also has its limits. It assumes that all hospitals work under the same technical conditions, which is not always the case. In addition, external factors such as the epidemiology of the population or management decisions are not taken into account. However, the differences between Croatian counties in terms of hospital efficiency highlight the need for a more comprehensive approach to the planning and management of health resources at county level. Therefore, the new Public Health Protection Network, which takes into account a number of criteria such as bed occupancy and performance for 2019, 2022 and the first six months of 2023, the type and number of activities in each hospital facility, the state of human resources, the severity of patients by county and the geographical location of the hospital in relation to the regional center, seems to be a reasonable way forward. This could also be a step towards integrated and people-centered care, linking different services, providers and facilities within the care system by coordinating service delivery and population health planning.

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# TWO-STAGE FRAMEWORK FOR DIGITAL CONTENT OPTIMIZATION AND SCHEDULING

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**Abstract:** *Rapid changes in technology and consumer preferences continue to change the way things are done. As a result, all communication flows should include strategies to adapt to the way things are done in a digital environment. There is a lot of data in the digital space that describes the behavior of people in the market and influences the best strategies to follow for success. Current research determines how linear programming can be applied for solving problems in digital marketing to find optimal solutions for the best marketing results. Platforms like Facebook, Instagram, LinkedIn and TikTok significantly shape the way people relate to the content created by the marketing team. By analyzing some of the trends established by using such platforms, it is possible to arrive at a more effective content planning that is in line with the market trend. Our research highlights the importance of customized content and optimal placement in maximizing marketing effectiveness in the digital domain.*

**Keywords:** *digital marketing, social media, linear programming, portfolio, scheduling*

## 1. INTRODUCTION

In recent decades, the marketing field has embraced the idea that comprehending consumer behavior entails considering social influences alongside individual actions, rather than studying individuals in isolation (Haenlein, 2013). Billions of people worldwide now integrate internet, social media, mobile apps, and other digital communication technologies into their daily routines. (Dwivedi et al., 2020).

Developing social media strategies for organizations poses significant challenges within a changing landscape where consumers wield more power and cultural norms are increasingly recognized (Kietzmann et al., 2011). In response to shifting consumer behavior, organizations have integrated digital and social media as crucial elements of their marketing strategies. (Stephen, 2016). By utilizing digital tools and social media, organizations can achieve deeper engagement with their target markets.

The digital landscape generates a wide range of data, including clickstream data, customer reviews, blogs, tags, social interaction data, responses to marketing efforts, and insights on collaborators and competitors (Kannan & Li, 2017). Digital marketing plays a pivotal role in the digital business transformation journey, integrating novel marketing approaches rooted in information and communication technologies (Veleva & Tsvetanova, 2020). Digital marketing initiates crucial shifts in both business and consumer behavior. It provides companies with a unique platform to understand customer requirements and create timely, location-specific opportunities. (Minculete & Olar, 2018).

Research in the field of digital marketing, besides deepening theoretical understanding of this dynamic field, also provides valuable guidelines for effective utilization of digital platforms for marketing purposes. While reviewing the literature in this field, various approaches to solving optimization problems in marketing activities were explored. The first approach focused on statistical inference (Alamsyah et al., 2021), while the other two delved into linear programming techniques, with one employing binary linear programming (Bigler et al., 2019) and the other investigating AHP (Analytic Hierarchy Process) - based goal linear programming (Robielos & Awit, 2020).

This study seeks to introduce a two-phase framework designed to boost the advertising success of startup companies using digital marketing tools. The framework comprises two integer linear models. The first model determines the optimal number of posts within specific categories for advertising across various social media platforms, aiming to maximize advertising-generated profit. The second model focuses on maximizing user



recognition by strategically scheduling previously acquired posts within a designated timeframe, typically spanning a week.

The paper is structured as follows: in chapter two, stage one presents the proposed model for selecting the optimal advertising portfolio intended for specific social media platforms, followed by stage two, which introduces the model for scheduling posts within the observed interval. Chapter three illustrates both models through a case study example, while chapter four offers a discussion of the results. Conclusions and potential future research directions are presented in the final chapter.

## 2. FRAMEWORK

In this study, the approach of linear integer programming was selected for addressing optimization and decision-making issues around digital media selection and post scheduling. Linear programming is a mathematical modeling technique used to solve real-world problems and generate optimal solutions. In both theory and practice, numerous problems can be transformed into linear programs to leverage their solution using efficient algorithms (Cohen et al., 2021). Linear programming (LP) stands out as a distinctive technique utilized in operations research to adjust linear characteristics through equalities and inequalities, aiming to reach optimal outcomes like revenue maximization or cost minimization within a specified mathematical framework defined by linear equations (Akpan & Iwok, 2016; Kalwar et al., 2022). Considering the values derived from the proposed framework, particularly the number of posts in various categories and the daily post frequency on a specific platform, the choice has been made to utilize integer linear programming (ILP). ILP represents a specialized branch of linear programming tailored to address problems featuring integer constraints on decision variables (Ammar & Emsimir, 2020).

The proposed framework consists of two stages. In the initial stage, Model 1 is applied to generate an optimal social media content portfolio. This optimal solution, from stage one, serves as the input parameter for the second stage, where Model 2 is utilized to devise and schedule an optimal arrangement of portfolio content within the specified time interval.

### 2.1. STAGE ONE

An integer linear programming (ILP) model is proposed to select the optimal number of posts from various categories for publication on a specific social media platform. The objective of the Model 1 (1-5) is to maximize the profit attained through a well-suited portfolio of posts made for social media advertising.

$$\max(\sum_{j=1}^n \sum_{i=1}^m (d_{ij} - c_{ij})x_{ij}) \quad (1)$$

s. t.

$$\sum_{j=1}^n \sum_{i=1}^m c_{ij}x_{ij} \leq C \quad (2)$$

$$q_j(\sum_{i=1}^m x_{ij}) \geq r_j \quad j = 1, 2, \dots, n \quad (3)$$

$$\sum_{j=1}^n \sum_{i=1}^m a_{ijs}x_{ij} \leq m_s \quad s = 1, 2, \dots, t \quad (4)$$

$$u_{ij} \leq x_{ij} \leq v_{ij} \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m \quad (5)$$

$$x_{ij} \geq 0 \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m$$

where:

$n$ : number of social media platforms used for advertising,  $m$ : number of categories of posts,  $t$ : number of specialist profiles. The task is to optimise  $x_{ij}$ : number of posts of category  $i$  intended for social media platform  $j$ , taking into account the following parameters:  $d_{ij}$ : revenue per post of category  $i$  intended for social media platform  $j$ ,  $c_{ij}$ : cost of creating one post of category  $i$  created for social media platform  $j$ ,  $C$ : advertising budget,  $q_j$ : average user engagement per post on social media platform  $j$ ,  $r_j$ : minimal average user engagement on social media platform  $j$ ,  $u_{ij}$ : minimum number of posts of category  $i$  intended for social media platform  $j$ ,  $v_{ij}$ : maximum number of posts of category  $i$  intended for social media platform  $j$ ,  $a_{ijs}$ : required time for a specialist of profile  $s$  to create one post of category  $i$  intended for social media platform  $j$  and  $m_s$ : available capacity of specialist profile  $s$ .

In the objective function, profit is expressed as the difference between the revenue and the creation costs per post of the corresponding category intended for the selected platform (1). The first constraint provides that entire social media advertising costs must be kept below the predetermined budget (2).

In the context of this model, user engagement includes activities such as liking, sharing, commenting, downloading, and other interactions that signify active participation and interest from users. The quantified user engagement must meet or exceed the designated platform minimum (3). The last two constraints (4,5) involve the upper limit of availability of individual specialist profiles engaged in content creation, as well as the threshold values that determine advertising frequency. Advertising frequency represents a range of values that dictate the number of posts of category created for the chosen platform.

Obtained optimal content structure for social media publication serves as input parameters for Model 2. This ensures that Model 2 schedules posts in alignment with the acquired values.

## 2.2. STAGE TWO

Model 2 (6-9), an integer linear programming model, is employed to schedule the posts within the portfolio throughout a designated time interval. The objective of the model is to maximize the total reach of the content published on social media platforms.

$$\max(\sum_{j=1}^n \sum_{i=1}^m \sum_{k=1}^d e_{ijk} y_{ijk}) \quad (6)$$

*s. t.*

$$\sum_{k=1}^d y_{ijk} = x_{ij} \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m \quad (7)$$

$$\sum_{i=1}^m y_{ijk} \leq b_{jk} \quad j = 1, 2, \dots, n, k = 1, 2, \dots, d \quad (8)$$

$$u_{ijk} \leq y_{ijk} \leq v_{ijk} \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m, k = 1, 2, \dots, d \quad (9)$$

$$y_{ijk} \geq 0 \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m, k = 1, 2, \dots, d$$

where:

$d$ : number of time units in the observed interval. The task is to optimise  $y_{ijk}$ : number of posts of category  $i$  posted on social media platform  $j$  during time unit  $k$ , taking into account the following parameters:  $e_{ijk}$ : reach per post of category  $i$  within social media platform  $j$  over time unit  $k$ ,  $x_{ij}$ : obtained from Model 1 output; optimal number of posts of category  $i$  intended for social media platform  $j$ ,  $b_{jk}$ : maximum number of posts posted on social media platform  $j$  during time unit  $k$ ,  $u_{ijk}$ : minimum number of posts of category  $i$  posted on social media platform  $j$  during time unit  $k$ ,  $v_{ijk}$ : maximum number of posts of category  $i$  posted on social media platform  $j$  during time unit  $k$ .

The objective function aggregates the reach of posts for each category-platform combination in the portfolio for the observed time interval (6). In the observed time interval, the total number of posts must equal the optimal number defined within the portfolio (7).

Number of posts on a specific platform must remain below the designated maximum for the observed time unit. (8). Constraint (9) establishes the bounds for the number of posts that can be published within a particular unit of time during the observed time interval.

## 3. CASE STUDY

"WheelDeel" is a startup that enables car owners to rent out their vehicles to other users. The core idea is to utilize existing owner cars and provide users with affordable mobility options without the need for purchasing or long-term vehicle rentals. While "WheelDeel" offers a practical and economical alternative to traditional car rental, the challenge lies in attracting car owners to join the platform and promote their vehicles while simultaneously attracting users to utilize the platform's services. Therefore, it is necessary to employ specific promotion channels.

Promoting the platform can be done through various social media networks, including Instagram, Facebook, LinkedIn, and TikTok, utilizing creative content such as photos, videos, and user stories. To maximize profit from promotion, "WheelDeel" faces several constraints. The primary constraint is the budget available, which significantly impacts the realization of set goals. In addition to the budget, it's crucial to monitor user

engagement, advertising frequency, and the availability of specialist profiles. Average user engagement on a specific platform incorporates interactions users have with "WheelDeal's" social media content, primarily through actions like liking, sharing, and commenting.

For this study, data were acquired through discussions with the founders of the mentioned startup and utilizing materials they provided. These materials offered insight into the available resources for engaging content creators and the research budget. As the startup's social media platforms are still in their early stages, data on user engagement were gathered from secondary sources. The mentioned sources include user engagement on the social media platforms of other well-established marketing startups. The optimal portfolio for WheelDeal's publications, along with the scheduling of posts on a weekly basis, were determined by using Excel Solver for solving Model 1 and Model 2. The results are displayed in tabular format alongside a concise overview.

**Table 1:** Optimal portfolio of different category posts on social media platforms

Category Platform	Text posts	Image post	Video post	Carousel post	Story post	Giveaway	Survey
Facebook	4	3	1	1	2	0	2
Instagram	2	4	2	2	6	1	1
LinkedIn	5	2	1	0	0	0	0
TikTok	0	0	5	2	0	0	0

Obtained portfolio emphasizes that most of the advertising should focus on Instagram and Facebook platforms, around 67%, while LinkedIn and TikTok have lower engagement rates. Concerning Instagram, the emphasis should be on story posts, whereas the best results for Facebook would be achieved through textual posts. Giveaway posts are best executed through Instagram, whereas advertising surveys demonstrate optimal performance on Facebook.

It has been decided that the obtained portfolio will be distributed on specific days of the week, considering the reach that would be achieved with such scheduling. Below are the results of the scheduling optimization.

**Table 2:** Posts scheduling by weekdays

Category-platform \ Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Cumulative number of posts
Text post on Facebook	1	0	1	0	1	1	0	4
Image post on Facebook	0	0	1	0	1	1	0	3
Video post on Facebook	0	0	1	0	0	0	0	1
Carousel post on Facebook	0	0	1	0	0	0	0	1
Story post on Facebook	1	0	0	0	1	0	0	2
Survey on Facebook	1	1	0	0	0	0	0	2
Text post on Instagram	0	0	2	0	0	0	0	2
Image post on Instagram	2	0	1	0	1	0	0	4
Video post on Instagram	0	1	0	0	1	0	0	2
Carousel post on Instagram	0	1	0	0	1	0	0	2
Story post on Instagram	0	2	0	0	1	1	0	6
Giveaway on Instagram	0	0	1	0	0	0	0	1
Survey on Instagram	1	0	0	0	0	0	0	1
Text post on LinkedIn	0	2	2	1	0	0	0	5
Image post on LinkedIn	0	1	1	0	0	0	0	2
Video post on LinkedIn	0	1	0	0	0	0	0	1
Video post on TikTok	0	2	0	1	1	1	0	5
Carousel post on TikTok	0	0	0	1	1	0	0	2

After analyzing the obtained values (Table 2), the recommendation is to distribute most of the content during the workdays. Major advertising efforts are focused on Wednesday and Friday, accounting for approximately 43.5% of the overall content distribution, followed by Monday, Tuesday and Thursday. The weekend sees reduced engagement, particularly on Sundays, which is advised for a complete absence of social media

activity. On Saturday, it's recommended to keep activities minimal, with just a few scheduled posts for publication, making up approximately 8.7% of the total portfolio.

#### 4. RESULT DISCUSION

Social media allows regular internet users to share their experiences and opinions online, giving them a platform to have their voices heard by a wide audience (Li & Xie, 2019). Upon analyzing the findings of the presented case study, it becomes evident that over 53% of the total posts distributed on Facebook fall into the category of textual posts (4 of them) and image posts (3 of them). This observation aligns with some studies (e.g. Peruta & Shields, 2018) indicating that Facebook users generally lean towards simple and familiar messages accompanied by photos and text, as opposed to content requiring them to click on links or watch videos.

As noted by Rejeb et al. (2022), Instagram's user base surpasses 1 billion monthly and 500 million daily active users, solidifying its position as a primary platform for information exchange and communication. Roughly 38% of the content created for advertising purposes by the mentioned startup should be crafted for Instagram, emphasizing the platform's widespread presence and its impact on the brand's success. Recognizing the widespread popularity of Instagram story posts, we can conclude that their substantial presence in the acquired portfolio is justified. Belanche et al. (2019) study supports this by implying that unique characteristics of inventive advertising formats, such as Instagram stories, have the potential to enhance the efficacy of a social media advertising campaign.

Examining the study findings reveals that the model has effectively promoted a category of posts on the LinkedIn platform that doesn't demand significant user interaction. Moreover, the length of these textual posts can be tailored to suit user preferences. This observation is consistent with Robson & Banerjee (2023) insight on LinkedIn, particularly concerning start-ups, where likes seem attainable through concise posts without any unnecessary interactivity, such as clicking a link. The revelations from this research, as outlined in Guarda et al. (2021), provide further confirmation of TikTok's dominance as the social network of the moment. Its focus on short-format videos, diverse sound options, and creative tools align perfectly with the platform's skyrocketing popularity.

The findings suggest that Facebook content is best posted primarily on Wednesday, followed by Mondays and Fridays. Regarding Instagram, Monday, Wednesday, and Friday are equally favored for sharing created content, with each of these days having four posts distributed. In contrast, based on the Singh et al. (2023) study conducted for Great Deal Tires, a regional company in Pennsylvania (USA), the Facebook page experiences higher engagement on Tuesdays and Wednesdays, while Instagram sees increased activity on Fridays. Observing the results obtained for Facebook, we notice that it's preferable to share content on weekdays rather than weekends, as suggested by the research performed by Drossos et al. (2023). This contrasts with the results of Villamediana et al. (2019) study, which highlight Thursday and Saturday as the optimal days for content publication, despite the suggestion to post zero times on Thursday and only twice on Facebook on Saturday in this study.

#### 5. CONCLUSION

This paper addresses the issue of choosing an adequate structure and frequency of content to present the optimization of advertising for startups in a more credible manner, aiming at maximizing profit. By applying the mentioned method, an optimal promotion portfolio has been obtained across various social media platforms. Utilizing content creators, social media advertising specialists, and social media SEO specialists, WheelDeel will build awareness of its platform, stimulate user engagement, thereby increasing the number of registered car owners and vehicle bookings.

In future research directions, a deeper exploration of content personalization could be a focal point. This would entail studying how individual user characteristics, including interests, preferences, and demographic data, can be integrated into the decision-making process regarding content structure and frequency. By analyzing user behavior data and employing machine learning algorithms, it's possible to create personalized advertising strategies for individual users. Future studies could explore the incorporation of multiple aspects of time within the observed interval. For instance, beyond considering only the weekday as proposed in this example, researchers could also examine the specific time of day on that day.

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# EXPLORING THE IMPACT OF PREFERENCE FUNCTIONS ON RISK PERCEPTIONS IN PROMETHEE METHOD

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**Abstract:** *This paper investigates the relationship between various PROMETHEE preference functions and risk attitudes in decision making. By employing a simulation-based approach, we varied preference function parameters across a range of alternatives to examine their effects on net flow and corresponding risk perceptions. The study aligns PROMETHEE outputs with theoretical models of rational, risk-neutral behaviour to compare how different settings influence decision-maker risk attitudes. Initial findings reveal that specific preference functions can significantly shape perceptions of risk, promoting either risk-averse or risk-seeking behaviours depending on the function configuration and the number of alternatives. The results contribute to an understanding of how multicriteria decision-making methods like PROMETHEE can be tailored to align with decision-makers' risk preferences, thereby enhancing decision quality.*

**Keywords:** *Decision-Making, Risk Attitudes, PROMETHEE Method, Preference Functions*

## 1. INTRODUCTION

Understanding the relationship between the preference functions in decision-making methods and attitudes toward risk has been a topic of discussion in many research papers (Warren et al., 2011; Barseghyan & Molinari, 2023). Understanding how different preference functions influence the perception of risk and the decision-making process is crucial in fields where strategic decisions must be made, such as finance, environmental policy, and engineering (Suknović et al., 2021). By quantifying and analysing these relationships, decision-makers can choose more suitable methods that align with their risk preferences, enhancing the effectiveness and reliability of their decisions. One prominent multicriteria decision-making method PROMETHEE (Brans & De Smet, 2016) is selected for this research. The main reason why this method is selected is because it ranks alternatives based on their positive and negative flows, which indicate overall preferences of the decision maker, further loosely related to the concept of utility, both cardinal and ordinal (Moscati, 2021).

One of the core challenges of this study is the possibility to choose different PROMETHEE preference functions. Each function might embody distinct risk attitudes—risk-averse, risk-seeking, and risk-indifferent—and their selection influences the decision outcomes. The question we ask is what decision analyst should do to observe what kind of risk attitude decision maker has. Furthermore, quantitatively defining and measuring risk within the mathematical framework of PROMETHEE has its own obstacles. Traditional approaches in economics and decision theory offer methods to measure utility and risk; however, adapting these concepts to fit within PROMETHEE's framework involves adjustments, particularly in normalizing and scaling data to ensure comparability across a single criterion. In addition, varying the number of alternatives and the influence of different preference functions on risk attitudes within PROMETHEE are not fully explored.

We propose a simulation-based approach that generates datasets with a range of alternatives, systematically varying preference function parameters to investigate their effects on net flow and, consequently, on perceived risk attitudes. Further, we compare normalized PROMETHEE outputs (net flows) with a theoretical model of rational, risk-neutral behaviour, allowing us to align various preference settings with risk attitudes. Initial findings suggest that preference function choice markedly influences perceived risk, with certain functions leading consistently towards more risk-averse or risk-seeking behaviours. Additionally, the number of alternatives appears to affect these attitudes, with a larger number of alternatives leading to S-shaped behaviour, which is in line with the findings in the prospect theory (Kahneman & Tversky, 2013; Ruggeri et al., 2020). Our research in this area can open new ways to inspect risk attitude in different models as well.

Despite these advances, the research acknowledges limitations, notably the reliance on simulation and normalization techniques may not fully capture the diversity and complexity of real-world decision-making scenarios. Nonetheless, this study enriches our understanding of decision-making processes according to different risk attitudes, providing insights for both theoretical exploration and practical application.

## 2. BACKGROUND

The PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations) method is a decision-making approach used to evaluate various alternatives based on multiple criteria (Brans & De Smet, 2016). It helps in ranking or choosing the best alternative among a set of options by calculating their utilities (Moscati, 2021), which indicate the overall preference for each alternative.

To begin, each alternative is assessed across several criteria, and the importance of each criterion is weighed by assigning a weight. The evaluation includes pairwise comparisons of all alternatives under each criterion. For every pair of alternatives, a difference is calculated, and a preference function is applied to transform these differences into preference degrees ranging from 0 to 1. A preference degree of 0 means no preference, while 1 indicates a strong preference for one alternative over the other.

Preference functions commonly used are named from I to VI (Suknović et al., 2021) and they express a decision maker's view on the differences between two alternatives. Thus, type I is a straightforward preference function, where no preference (0) is given unless one alternative is better than the other. In other words, any improvement, however minimal, is significant. Type II preference function, often called step function, introduces a threshold  $q$ , below which no preference is given (0), and beyond which full preference (1) is assigned. This function is suitable when only differences that exceed a certain threshold are considered significant. Type III preference function represents a linear function that grows from no preference to full preference as the difference increases from 0 to  $p$ . Type IV function is designed to model scenarios where differences below  $q$  result in no preference (0), differences between  $q$  and  $p$  result in a moderate preference (0.5), and differences above  $p$  lead to a full preference (1). This function captures decision contexts where a moderate preference is recognized before reaching full preference. Type V function includes a range of indifference defined by  $q$  and gradually increases to full preference as the difference reaches  $p$ . One can see Type V preference function as a generalization of Type I, Type II and Type III preference functions, as those can be obtained by setting parameters  $p$  and  $q$ . For the purposes of this paper, we will stay at these five preference functions, and interested readers are encouraged to read (Behzadian et al., 2010; Suknović et al., 2021) for a detailed discussion on preference functions in PROMETHEE method.

Following the calculation of preference degrees, the method aggregates these values for each alternative across all criteria, taking into account the weights of the criteria. This results in a positive and a negative flow for each alternative. The positive flow represents the strength or advantage of an alternative, indicating how much it is preferred over other alternatives. Conversely, the negative flow shows its weaknesses, indicating how much other alternatives are preferred over it. Finally, the net flow for each alternative is calculated by subtracting the average negative flow from the average positive flow. Alternatives are then ranked based on their net flows, from the highest to the lowest. The alternative with the highest net flow is considered the most preferred, as it maximizes strengths and minimizes weaknesses compared to other alternatives. (Suknović et al., 2021)

The choice of the preference function clearly signals the opinion of the decision maker about the values. The setup of the preference function provides a clear differentiation between no preference, moderate preference, and full preference, which influences the final decision. Thus, it is of great importance to observe what kind of effects these choices can have (Ishizaka & Siraj, 2018). Having the previous in mind, the idea of this paper is to experimentally show what is the relationship between the type of preference function and relationship of the net flow to risk.

From the decision-making theory (Ishizaka & Nemery, 2013; Suknović et al., 2021) attitudes towards risk are categorized to describe how individuals make choices, especially under uncertainty. By observing choices or by interviewing, a decision maker can express different attitudes towards risk. Those are namely, *risk-seeking*, *risk-averse*, *risk-indifferent*, and *S-shaped* utility function. *Risk-seeking* behaviour corresponds to someone who prefers outcomes with uncertainty over those with certainty, even when the expected returns are similar. This means that given the choice between a guaranteed outcome and a gamble with a potentially higher payoff but also higher risk, a risk-seeking person would choose the gamble. A *risk-averse* decision maker prefers certainty to uncertainty. They would choose a guaranteed outcome over a gamble with a potentially higher payoff but greater uncertainty, even if the expected value of the gamble might be higher. This attitude is driven by a preference for stability and predictability. *Risk-Indifferent* decision maker is indifferent between sure things and gambles as long as the expected values are the same. They make decisions based purely on the expected

outcome, without regard to the variability or risk involved. This type of behaviour is often idealized in economic models where the decision-maker is considered to be perfectly rational, focusing solely on maximizing expected returns regardless of the risk (Simon 1965; Colman 2003). Finally, *S-shaped* utility function is a concept from prospect theory, which describes how people actually make decisions under risk, as opposed to the idealized version presented by traditional utility theory (Kahneman & Tversky, 2013; Ruggeri et al., 2020). This function reflects that people are typically risk-averse for gains and risk-seeking for losses. The function is concave (curving downwards) for gains, indicating risk aversion: as wealth increases, the additional utility derived from each additional unit of wealth decreases. Conversely, the function is convex (curving upwards) for losses, reflecting risk-seeking behavior: as losses increase, the pain from losing each additional unit decreases.

### 3. METHODOLOGY

To achieve the previously mentioned task, we conducted a simulation. More specifically, we randomly select according to the Uniform distribution with values between zero and one and calculate net flow for a single criterion. The random number generation process ranged from three to ten values. Consequently, we generated a single criterion dataset containing from three to ten alternatives. For a given dataset we calculated net flow using preference functions explained in the previous section, namely Type I, Type II, Type III, Type IV, and Type V preference functions. For Type II and Type III preference functions, we ranged parameters  $q$  and  $p$ , respectively from zero to one using linear progression with a step 0.1. Preference functions Type IV and Type V required setup of both parameters  $q$  and  $p$ , thus we set  $q$  to be a value from 0 to 0.5 with linear progression with step 0.1, while  $p$  to be a value from 0.5 to 1 with linear progression with step 0.1. Simulations are repeated 1000 times so the conclusions would be more reliable. It is worth stating that we assume that every criterion is of benefit type. We are aware that criterion can be of cost type as well, however, this will not change the conclusions as the PROMETHEE procedure is the same regardless of the criterion type, except for the calculation of difference between two values (Brans & De Smet, 2016), where for a benefit criterion is a difference between observed value and compared value, while for a cost criterion it is a difference between compared value and observed value.

The research question we ask is what the relationship between choice of preference function and risk is. While PROMETHEE's net flows can loosely be interpreted as a measure of utility, they are not utility in the traditional sense as understood in economic or classical decision theory. However, net flows do share some properties with utility, such as the ability to rank alternatives based on their scores. A higher net flow indicates a more preferred alternative, similar to how a higher utility score would indicate a more preferred outcome. Thus, in a practical sense, net flows function similarly to utility values by providing a basis for ranking and selecting alternatives. Having that in mind one can inspect the attitude toward the risk in relation to design choice of the PROMETHEE method. Another question we aim to answer is the effect of the number of alternatives on the attitude toward risk.

To be able to answer the above stated question, we need to compare the net flow to a rational behaviour. Net flow is a number between minus one and one. On the other hand, rational behaviour can be interpreted as risk neutral or risk indifferent, which can be obtained using any normalization technique. We opted for max-min normalization as it scales data to a uniform range of 0 to 1 and because it is commonly used decision-making theory to ensure that different criteria are comparable by transforming all feature scales (Suknović et al., 2021; Delibašić et al., 2023). More specifically, we scaled both the data used as an input to PROMETHEE and the obtained net flows. Further, to obtain the relation of the transformed net flows to the risk, we inspected the data as follows. If all the values in transformed net flows and transformed input data are the same, then the decision maker followed the *risk-indifference* attitude towards risk. If all the values in transformed net flows and transformed input data are the greater or equal than zero than the utility function is above the indifference line, and attitude toward the risk is interpreted as *risk-averse*. Otherwise, if the differences are lower or equal than zero then the utility function is below the indifference line, and attitude toward the risk is interpreted as *risk-taking*. Finally, if some differences are positive, some negative, then attitude toward the risk is interpreted as *S-shaped*.

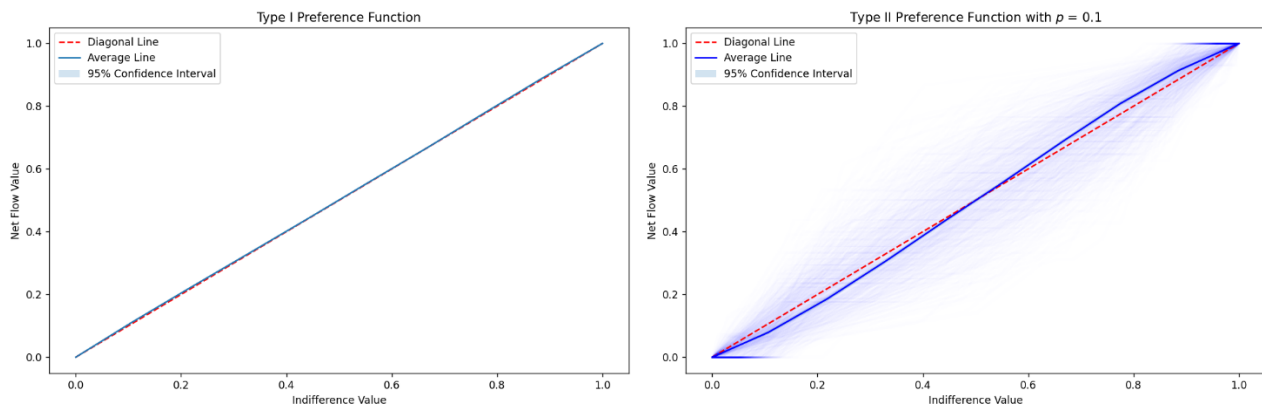
### 4. RESULTS

Having calculated the risk indifferent behaviour and transformed net flows, we can plot how both relate to observed utility. We do the following for each preference function. However, due to spatial constraints of the paper we will use only one setup per preference function. More specifically, we select ten as a number of alternatives, unless specified otherwise.

The first preference function for inspection are Type I and II with  $p = 0.1$ . As one can observe in the left panel of Figure 1, no risk behaviour is achieved with Type I preference function. Thus, one might use this to mimic

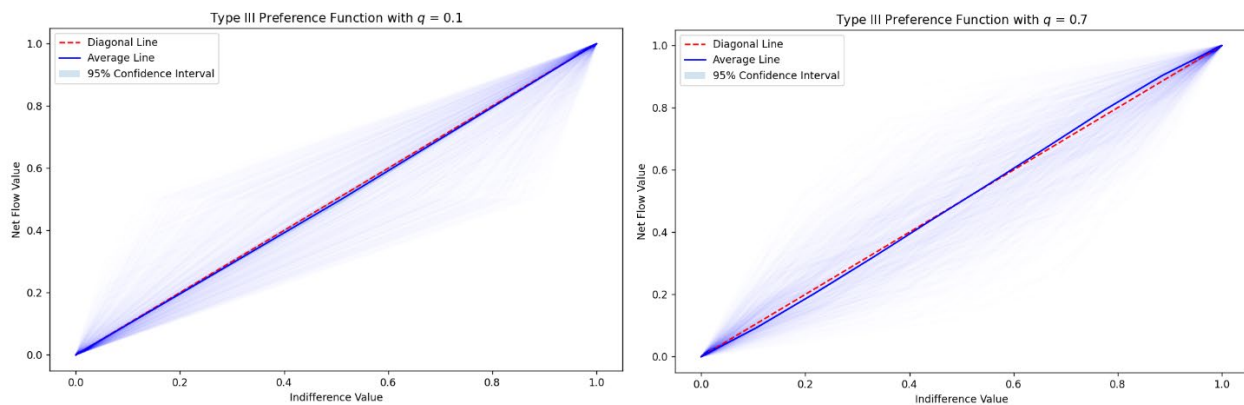


risk-neutral behaviour. This behaviour is expected as one only prefer alternative over another when there is a clear difference. However, as one introduces a gap in preference relation such as in Type II preference function (right panel of Figure 1), net flow behaviour changes to a *S-shape*. In the cases of smaller number of alternatives this corresponds to very slight risk-averse or very slight risk-seeking behaviour rather than risk-neutral.



**Figure 1.** Relation between transformed net flow and risk for Type I and II preference functions

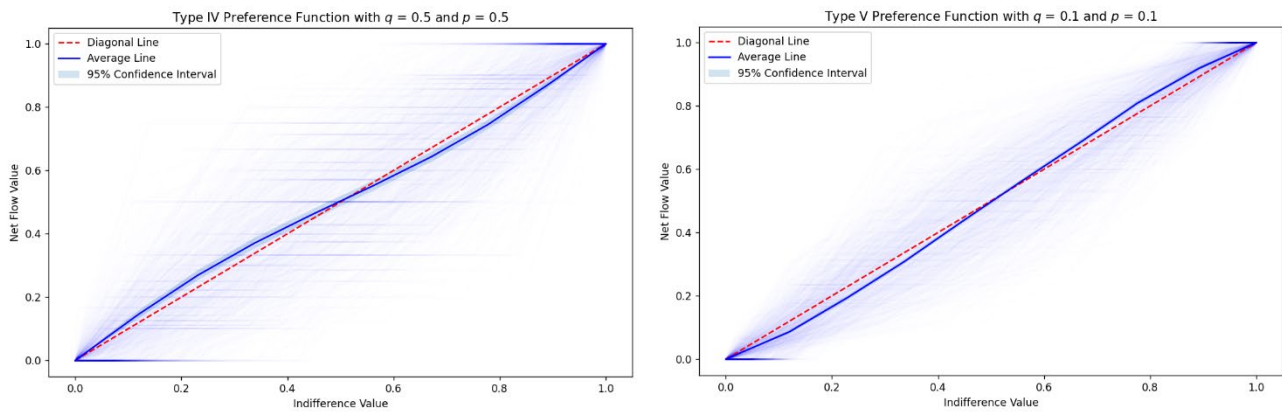
For Type III preference function (Figure 2), we intentionally selected only 3 alternatives to show the difference between the what appears to be a slight risk seeking behaviour that is achieved on most occasions for  $q = 0.1$  compared to what looks like S-shape with  $q = 0.7$ .



**Figure 2.** Relation between transformed net flow and risk for Type III preference function

However, this preference function can lead to risk-neutral or slight risk-averse attitudes as it linearly increases the preference with increasing differences, applying a consistent valuation of risk. Lower values of  $q$  leads to a function that is very similar to Type I and II preference function, thus it results in risk neutral behaviour, or very slight risk-aversion or risk-seeking behaviour. The higher the value of  $q$  the behavior shifts from risk-seeking to risk-averse or risk-neutral attitudes or in many alternatives scenarios shifts more toward S-shape behaviour.

Type IV preference function might appeal to risk-averse decision-makers, as it caps preferences to three possible values, thereby limiting the influence of extremely high criterion differences. The results are suggesting that as one can see in Figure 3 (left panel). However, this can lead to an unorthodox behaviour not previously observed. While S-shaped risk is common human behaviour, the function shows signs of risk-seeking for smaller values and risk-aversion for larger. In this case, for  $q = 0.5$  and  $p = 0.5$  is the opposite. This kind of behaviour is seen in the literature (He et al., 2017) in the selection of the optimal portfolio, however not yet in multicriteria decision making.



**Figure 3.** Relation between transformed net flow and risk for Type IV and V preference function

On the other hand, Type V preference function shows expected human decision maker behaviour as seen in Figure 3 (right panel).

The following part of the paper focuses on the inspection of number of alternatives on the type of the attitudes toward risk. We show Type I preference function in Table 1, where rows represent number of alternatives, while columns represent type of the attitudes toward risk. Values within the table represent row-wise percentage of cases when a simulation ended in a specific attitude toward risk. While none of the combinations resulted in risk neutral behaviour for three alternatives, a detailed inspection revealed that net flows are very close to the normalized values. Thus, conclusions related to the Type 1 preference function stated above holds. It is interesting to note that as the number of alternatives rises, net flow starts turning to S shape more and more. This conclusion holds for every PROMETHEE preference function.

**Table 1:** Type I and II preference function and attitude toward risk

Num. alternatives	Type I			Type II		
	Risk-averse	Risk-seeking	S shape	Risk-averse	Risk-seeking	S shape
3	49.20%	50.20%	0.00%	25.25%	25.40%	49.35%
4	29.70%	34.90%	35.40%	18.11%	17.42%	64.47%
5	24.70%	25.10%	50.20%	14.23%	14.15%	71.62%
6	20.70%	20.40%	58.90%	11.44%	11.55%	77.01%
7	17.80%	17.10%	65.10%	9.63%	9.14%	81.24%
8	14.10%	14.30%	71.60%	8.11%	8.14%	83.75%
9	12.60%	12.70%	74.70%	6.67%	6.67%	86.65%
10	10.90%	12.90%	76.20%	6.36%	6.03%	87.61%

The rise is even bigger when observing Type II preference function, starting from almost 50% with the smallest number of alternatives and consistently rising to almost 88%. Similar pattern is observed for Type III and V (as well as for IV) preference functions, which are presented in Table 2. What is different with these preference functions is that they have indifference as an attitude toward risk. More specifically, Type III has the highest observed indifference toward risk attitude from all the preference functions. This mostly happens when the parameter  $p = 1$  when indifference happens around 82% for smaller number of alternatives. This result is expected as linear relationship over the entire span of values model indifferent behaviour of the decision maker.

**Table 2:** Type III and V preference function and attitude toward risk

Num. alternatives	Type III				Type V			
	Indiff.	Risk-averse	Risk-seeking	S shape	Indiff.	Risk-averse	Risk-seeking	S shape
3	29.15%	35.13%	35.73%	0.00%	2.20%	39.93%	39.07%	18.80%
4	18.64%	26.35%	27.88%	27.13%	1.27%	26.38%	24.85%	47.51%
5	7.58%	25.10%	26.20%	41.12%	0.38%	21.18%	21.58%	56.85%
6	4.05%	22.16%	22.15%	51.65%	0.17%	17.23%	17.28%	65.33%
7	2.06%	19.51%	18.85%	59.57%	0.06%	14.81%	15.08%	70.06%
8	3.86%	15.99%	16.68%	63.46%	0.06%	13.44%	13.23%	73.27%
9	1.25%	15.46%	14.05%	69.24%	0.01%	10.87%	11.29%	77.83%
10	0.96%	13.60%	14.36%	71.07%	0.00%	11.09%	10.50%	78.41%

## 4. CONCLUSION

The study conclusively demonstrates that the choice of preference functions within the PROMETHEE method markedly influences perceived risk attitudes among decision-makers. Preference functions that vary in their approach to risk—such as risk-averse, risk-seeking, or risk-neutral—lead to different decision outcomes. For instance, Type I and II functions can mimic risk-neutral behaviour under certain configurations, whereas functions with higher parameter settings (Type III, IV, V) exhibit more pronounced risk-averse or risk-seeking behaviours. Moreover, the impact of the number of alternatives on risk attitudes was significant, with a larger set leading to S-shaped behaviour patterns, aligning with prospect theory (Ruggeri et al., 2020). This research underscores the importance of selecting appropriate preference functions to align with the risk preferences of decision-makers, suggesting that a tailored approach in the application of PROMETHEE could enhance decision-making effectiveness across various fields such as finance, environmental policy, and engineering (Brans & De Smet, 2016). Future studies could explore the implications of these findings in real-world decision-making scenarios, providing a practical framework for integrating risk preferences into multicriteria decision analysis.

In the future research we plan to explore the application of alternative multicriteria decision-making methods beyond PROMETHEE, such as AHP, TOPSIS (Đukić et al., 2022), or VIKOR (Dodevska et al., 2023), to compare how different methodologies might influence risk attitudes and decision outcomes in similar settings. Additionally, incorporating real-world case studies from diverse sectors like healthcare, finance, and public policy could validate the practical implications of preference function choices on decision-making under uncertainty. One interesting line of research could be related to inspecting the relationship between fairness (Radovanović et al., 2023) and risk attitudes in decision-making.

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# SENSITIVITY ANALYSIS OF THE ARWU RANKING: EFFECTS OF INDICATOR REMOVAL

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**Abstract:** *University rankings play a crucial role in shaping the perceptions of academic institutions and influencing decisions made by stakeholders. The Academic Ranking of World Universities (ARWU), known as the Shanghai Ranking, is one of the most influential global university rankings currently published. Due to that, the methodology behind this ranking often comes under scrutiny. Two methodological steps of the ARWU ranking that attract researchers' attention are the weighting scheme and indicator selection process. In this paper, we conduct a sensitivity analysis of the ARWU ranking by systematically removing individual indicators and distributing their weight to the remaining indicators. Our results show that the ranking is sensitive to the removal of the indicator related to the number of staff of an institution winning Nobel Prizes and Fields Medals (Award). At the same time, removing the indicator related to the institution's per capita academic performance (PCP) led to slight or no changes in the ranks.*

**Keywords:** *University rankings, ARWU, weighting scheme, indicator selection process, sensitivity analysis*

## 1. INTRODUCTION

It is inherent in human nature to rank and be ranked (Marginson & Van der Wende, 2007). Therefore, rankings in fields such as sustainability, well-being, safety, and ease of doing business were created to rank institutions, cities, regions, and countries. One specific group of rankings which intrigues different stakeholders are the university rankings (Anowar et al., 2015). University rankings evaluate and rank higher education institutions based on various quantitative and qualitative criteria. University rankings offer a lens through which institutions and stakeholders can assess academic quality and reputation.

When it comes to university rankings, four main stakeholder groups can be identified (Goglio, 2016). The first group of stakeholders comprises students and their families, who often rely on university rankings as a criterion when selecting their academic pursuits. The reputation of a university is indisputably a crucial factor in making decisions about joining the academic community, and ranking lists certainly contribute to this reputation (Wut et al., 2022). The second stakeholder group involves universities, where top executives like vice chancellors and presidents are the main users of university rankings. These institutions anticipate advantages such as improved prestige, heightened student interest, and increased financial support, especially if they achieve high rankings. Universities also receive rankings as tools for self-assessment and improvement, allowing them to identify strengths and weaknesses. The problem that can arise when universities strive to position themselves higher on certain lists and achieve better rankings is that they may focus primarily on publishing research papers and engaging in external activities, neglecting the quality of teaching and student interaction in the process (Shin & Toutkoushian, 2011). The governmental sector constitutes the third stakeholder group. Governments derive benefits from university rankings through benchmarking for international comparisons and informed policy-making. Similar to universities, governments prioritise institutional autonomy and the use of reliable and transparent data rankings. Additionally, they consider broader university outcomes beyond research, such as graduate employability and technology transfer (Goglio, 2016). The fourth group of stakeholders includes ranking providers, such as companies or research centres, who are heavily invested in this domain. They benefit from the popularity and success of their rankings regarding business growth and revenue. However, they also prioritise maintaining independence and ensuring the transparency and reliability of their data to uphold their reputation. Recently, there has been increasing concern regarding the potential threat to institutions that create and publish rankings due to the varying nature of the relationship between them and the companies collecting, providing and analysing data for them (Chen & Chan, 2021). While dominant ranking providers currently set the standards, there is a need for critical oversight to address methodological shortcomings and misleading information. A large number of institutions developed methodologies for global university

rankings. In terms of relevance and public interest, three methodologies stand out: Academic Ranking of World Universities (ARWU), The Times Higher Education (THE) World University Rankings, and the QS World University Rankings (Johnes, 2018).

The ranking methodology we scrutinise in this paper is the ARWU ranking. In addition to ranking a large number of renowned universities, its popularity stems from being the first global methodology for ranking world universities. The ARWU ranking is calculated as the weighted sum of six indicators, taking into account the quality of education, quality of faculty, research output, and per capita performance. Besides attracting the attention of students, academia, and policy-makers, the ARWU ranking is captivating the attention of experts in the field of ranking. So far, numerous studies were written on the topic of ARWU methodology scrutinisation. The mentioned criticisms are fundamentally rooted in issues that generally arise with all composite indices (Greco et al., 2018), however, issues related to the weighting scheme and indicator selection are the ones which attract the most attention (Jeremic et al., 2011). One key problem is how the ARWU ranking (or any composite indicator) is calculated. The question arises about the transparency and comprehensibility of the methodology, which can impact its credibility. Additionally, since university rankings describe complex phenomena, it is important to appropriately select sub-indicators and determine their weighting coefficients. The weighting scheme should reflect the significance of each indicator within the ranking but approaches to its determination can often be subjective (Greco et al., 2018). The current ARWU methodological appendix does not provide any detail on the weighting scheme determination approach or the indicator selection process (ShanghaiRanking, 2024).

The analysis conducted in this paper focuses on the examination of the stability of ARWU rankings. The ARWU methodology should be insensitive to weight coefficient changes to ensure the rankings' reliability and credibility. Therefore, we strived to explore will and how the rankings change if an indicator is removed from the ranking and its weight distributed among the remaining indicators. After the introduction, we outline the ARWU ranking methodology and its criticism. Next, we describe the research methodology and the sensitivity analysis that was conducted. In section four, we present the research results, while we finish the paper with the discussion and concluding remarks.

## 2. SHANGHAI RANKING'S ACADEMIC RANKING OF WORLD UNIVERSITIES (ARWU)

The Academic Ranking of World Universities, known as ShanghaiRanking or ARWU ranking, represents a ranking or a composite indicator developed by researchers at Shanghai Jiao Tong University. The first edition of the ARWU ranking was published in 2003, and since then, it has captured and attracted the attention of students, researchers, academics, and policymakers. Another proof is that despite more or less similar methodologies published, the ARWU Ranking remains among the most relevant. At first, the institution published just one ranking, the Academic Ranking of World Universities. In the years that came, they extended the scope and are currently providing four rankings: Academic Ranking of World Universities, Best Chinese Universities Ranking, Global Ranking of Sport Science Schools and Departments, and Global ranking of Academic subjects (ShanghaiRanking, 2024). As this paper focuses on ARWU ranking, we outline the structure and methodology in the following paragraphs.

For the year 2023, for which the data was collected, the ARWU ranked more than 2500 universities and the results for the best 1000 were published. Within its ranking, ARWU considers universities with notable achievements, such as Nobel Laureates, Fields Medalists, Highly Cited Researchers, and papers published in prestigious journals like Nature & Science. Additionally, institutions with a significant number of papers indexed by major citation databases are also included. Data for the ranking is sourced from reputable institutions and organisations, including Nobel Prize records, the Web of Science database, and national or regional agencies providing staff data (ShanghaiRanking, 2024).

The Shanghai Ranking (ARWU) evaluates academic performance using six criteria to provide a comprehensive assessment. Each criterion is assigned a benchmark score of 100 based on the best-performing university in that category. Universities are ranked according to their overall score, which is a weighted sum of their performance across these categories. The criteria include measures *Alumni* and *Award*, which track the number of Nobel prizes and Field medals awarded to a university's alumni or faculty members. The next three indicators (*HiCi*, *N&S*, and *PUB*) gauge research output, observing the number of highly cited researchers, publications in top journals (Nature and Science), and the number of articles published in the Science Citation Index Expanded and the Social Science Citation Index journals. The final indicator, *PCP*, calculates a weighted average of scores from the previous categories, divided by the number of full-time academic staff members. Each indicator contributes to the overall score according to the predefined weight (Jeremic et al., 2011). *Award*, *HiCi*, *N&S*, and *PUB* are weighted by 20%, while *Alumni* and *PCP* have slightly less importance with the weight of 10% (ShanghaiRanking, 2024).

## 2.1. Methodological issues with the ARWU ranking

Although the ARWU ranking is reputable and often cited in the media, its methodology has been criticised in the academic literature. Within this section, we provide a literature review of the papers which tackled the ARWU methodology, especially its weighting scheme. Maricic and co-authors (2017), in their study on the ARWU ranking, provide a useful timeline of research on the ARWU methodology. The first study they identified was the paper by Florian (2007), who pointed out that the results of the ARWU ranking were irreproducible and that reproduction attempts did not lead to the same results as official. Several years later, Jeremic and co-authors (2012) applied the I-distance to the ARWU ranking indicators to propose an alternative ranking and data-driven indicator weights. In their paper, Dobrota and Dobrota (2016) strived to assess the rank sensitivity of ARWU and proposed an alternative ARWU ranking using the Composite I-distance Indicator (CIDI). They concluded that the ARWU ranking is more sensitive to weight alterations than the alternative ranking. Maricic and co-authors (2019) applied the Hybrid Enhanced Scatter Search—Composite I-Distance Indicator (eSS-CIDI) methodology to the ARWU ranking. Their results showed that the weighting scheme of the ARWU ranking can be altered while improving the stability of the metric. Recently, Safon and Docampo (2020) considered the impact of reputation bias on the ARWU ranking and showed that bias exists in *N&S* but not in *HiCi*. Fernández-Cano and associates (2018) did a comprehensive literature review on the ARWU methodological issues and grouped them into the following segments: Omitted indicators, Supposed validity of the indicators used, Anomalous reliability, Questionable weighting of indicators, Confusing indicators, Over-emphasized citation indicator, Simplistic standardisation, as well as Selection bias or sample threat.

In conclusion, research on the ARWU ranking methodology has been ongoing throughout the years, with studies highlighting its issues with irreproducibility, sensitivity to weight alterations, and the impact of reputation bias. Various alternative approaches have been proposed, showing potential for improving the stability and accuracy of the ranking, signalling the ongoing need for critical evaluation and refinement in this domain.

## 3. RESEARCH METHODOLOGY

The JRC handbook on composite indicator creation states that there is no straightforward answer to the composite indicator methodology and that each of the ten methodological steps can be done by taking different approaches (Joint Research Centre, 2005). Therefore, the methodological frameworks of composite indicators are very often the subject of debate and discussion, as there is a whole series of choices to be made during their formation (Saltelli et al., 2007). Accordingly, it is necessary to determine the level of confidence in the formed methodological framework, representativeness and stability. The reliability of a composite indicator is measured through the analysis of the effects of changes in the methodological framework on the final ranks (Maricic et al., 2019). Regarding robustness analysis, uncertainty and sensitivity analysis are the most commonly applied (Paruolo et al., 2013). The uncertainty analysis includes the assessment of the impact of alternative methodological frameworks of the composite indicator on the ranking of the entity. Each alternative methodological framework is, in fact, a different composite indicator in which some of the methodological steps are changed within the defined scope and range (Dobrota, 2015). The uncertainty analysis can be done for just one methodological step (Dobrota et al., 2016) or several steps simultaneously (Cherchye et al., 2008). On the other hand, sensitivity analysis looks at how the uncertainty in the input factors affects the uncertainty in the output factors of the model (Saltelli et al., 2007).

The research methodology we employed in this paper is as follows. We wanted to explore whether and how ARWU university rankings change if an indicator is removed from the ranking methodology while the associated weight is distributed among the remaining indicators. For example, if the indicator *Awards* is removed from the ranking, its weight of 10% will be evenly distributed among the five remaining indicators. The precise distribution of weights for each run iteration is presented in Table 1. Within each iteration, new ARWU values and ranks were calculated. Spearman's correlation between the new and official ranks was calculated to assess the effects of indicator removal.

**Table 1:** Weights assigned to ARWU indicators within each iteration

Iteration	Weight assigned to a particular indicator					
	Alumni	Award	HiCi	N&S	PUB	PCP
Sin Alumni	0	0.22	0.22	0.22	0.22	0.12
Sin Award	0.14	0	0.24	0.24	0.24	0.14
Sin HiCi	0.14	0.24	0	0.24	0.24	0.14
Sin N&S	0.14	0.24	0.24	0	0.24	0.14
Sin PUB	0.14	0.24	0.24	0.24	0	0.14
Sin PCP	0.12	0.22	0.22	0.22	0.22	0

## 4. RESULTS

The approach presented in the section above was repeated six times for each ARWU indicator removal. We observed the top 100 universities ranked by ARWU for the year 2023. After each iteration, we calculated the new ARWU values and ranking and compared them with the official ARWU results. In Table 2, we present the top 10 universities on the original ARWU list and the rankings of these universities when individual indicators are removed. The label "Sin" in the column name indicates that the ranking shown in that column is calculated without that specific indicator, which was assigned a weight coefficient of 0, and its original weight is evenly distributed among the other indicators.

**Table 2:** Ranks for top 10 universities – original ranks and ranks after each indicator removal iteration

University	ARWU rank	Sin Alumni	Sin Award	Sin HiCi	Sin N&S	Sin PUB	Sin PCP
Harvard University	1	1	1	1	1	1	1
Stanford University	2	2	2	2	2	2	2
Massachusetts Institute of Technology	3	3	3	4	4	3	4
University of Cambridge	4	4	4	3	3	4	3
University of California, Berkeley	5	5	5	6	5	5	5
Princeton University	6	7	12	5	6	6	7
University of Oxford	7	6	6	8	7	8	6
Columbia University	8	9	7	10	9	10	8
California Institute of Technology	9	8	8	7	10	7	13
University of Chicago	10	10	19	9	8	9	9

The same university occupied the first position on the original list and throughout six iterations: Harvard University. This university's performance can also represent an outlier as the indicator values of Harvard University are much higher than those of the next best university. The second-ranked university, Stanford University, was also stable in all six iterations. Looking down the list, the largest change compared to the original rank is observed in the case of the University of Chicago, whose rank drops to nineteenth place when the indicator *Award* is removed, compared to its original 10<sup>th</sup> place on the list. This occurred because this university has a high value for *Award* indicator, while it has considerably lower values for other indicators than the neighbouring universities on the original ranking list. Similarly, a visible change in rank is observed for Princeton University (from the original 6<sup>th</sup> to 12<sup>th</sup> without the *Award* criterion).

We encounter a similar situation in the table below (Table 3) where we present the bottom 10 universities on the original ARWU list and the rankings of these universities when individual indicators are removed. However, we can notice that the oscillations are visibly larger, and the rankings of all ten universities differ after each iteration. The reasons for rank change are similar to those for the top ten, but we can conclude that the sensitivity is more pronounced. This is expected as the bottom ranked entities are more sensitive to methodological changes (Saisana et al., 2011). The values of individual indicators (criteria) in this part of the list vary among universities, which can be considered the cause of the mentioned oscillations. The largest change in rank is observed for McMaster University when the indicator *PUB* is removed. This university moved from its original last position to within the top 80 universities on the list. We can also see a big rank improvement for Stockholm University, which moved from rank 98 to 74 when the indicator *PUB* is excluded.

**Table 3:** Ranks for bottom 10 universities – original ranks and ranks after each indicator removal iteration

University	ARWU rank	Sin Alumni	Sin Award	Sin HiCi	Sin N&S	Sin PUB	Sin PCP
University of Alberta	91	90	91	86	82	91	85
Huazhong University of Science and Technology	92	81	69	89	87	99	81
Nanyang Technological University	93	82	68	100	90	88	95
Seoul National University	94	95	67	82	94	96	86
Central South University	95	87	73	98	80	100	94
Nanjing University	96	86	72	93	100	97	97
Purdue University - West Lafayette	97	96	98	84	96	86	91
Stockholm University	98	99	99	79	97	74	96
Brown University	99	100	94	76	93	78	99
McMaster University	100	97	95	96	81	79	98

Another way to analyse the effect of indicator removal is to calculate the correlations between official and newly obtained ranks. In Table 4, we provide the values of Spearman's correlation coefficient between ranks after each iteration and the official ARWU ranks.

**Table 4:** Correlation analysis between official ranks and ranks after each iteration

	Sin Alumni	Sin Award	Sin HiCi	Sin N&S	Sin PCP	Sin PUB	ARWU
Sin Alumni	1						
Sin Award	0.896**	1					
Sin HiCi	0.878**	0.738**	1				
Sin N&S	0.924**	0.835**	0.929**	1			
Sin PCP	0.951**	0.866**	0.946**	0.968**	1		
Sin PUB	0.818**	0.636**	0.911**	0.848**	0.855**	1	
ARWU	0.967**	0.866**	0.951**	0.970**	0.989**	0.888**	1

Note: \*\*p<0.001

The table indicates that all obtained coefficients are positive, statistically significant, and above 0.83. Looking at the correlation between official ARWU ranks and alternative ranks, it can be noted that the smallest correlation is observed between the original rankings and those calculated without the *Award* indicator, 0.866. This might indicate that the ranking is highly dependent on the *Award* indicator. On the other hand, the highest correlation is measured between the original rankings and those calculated without the *PCP* indicator, 0.989. According to our analysis, removing this indicator would not significantly change or distort the rankings.

## 5. DISCUSSION AND CONCLUSION

The ARWU methodology has been extensively analysed and criticised since its first publication in 2003. Analyses and critiques can serve as assistance in refining the methodology and enabling more objective ranking. The aim of this paper was to closely observe how the university rankings change if an ARWU indicator is removed from the methodological framework.

The analysis showed that the rankings (especially the top-ranked universities) depend marginally on the chosen weights and indicators. Rolland and Cugliari (2019) came to the same conclusion by employing Ranking Sensitivity Index (RSI) analysis. However, more rank distortions can be seen in the lower part of the ranking, which can be expected (Saisana et al., 2011). The measured Spearman's correlation coefficient between the official ARWU and alternative rankings indicated that removing the indicator *Award* leads to the largest rank changes. Previous studies signalled that if the indicator *Award* is removed, the ranking becomes more stable (Dobrota & Dobrota, 2016). Besides observing the impact of the indicator *Award* on the rankings, the measurement aspect should also be taken into account. For example, how accessible are the awards calculated within the *Award* and *Alumni* indicators to all university staff worldwide, are there certain barriers for university staff and alumni to receive them, do the received awards belong to the universities the winner completed or to the university the winner is affiliated to (Zornic et al., 2014).

Future directions of the study could be defined. First, the number of observed universities can be enlarged, having in mind that the ARWU ranking provides ranking for 1000 institutions. Such analysis would be useful, having in mind the results of a previous study which signaled that methodological differences should be implemented for different rank groups (Maricic et al., 2017). Within the presented sensitivity analysis only two methodological aspects were taken into account. Therefore, a more comprehensive sensitivity analysis should be conducted in the future to more comprehensively encapsulate the effect of methodological changes on the ARWU rankings. Nevertheless, it is hoped that the conducted analysis could help researchers as a starting point for deeper analysis on the ARWU uncertainty and sensitivity analysis.

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# AIRBNB ADOPTION AMONG STUDENTS: INSIGHTS FROM SERBIA

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**Abstract:** *This research was conducted to investigate the adoption rates and intents towards Airbnb platform among students in Serbia. A total of 201 students and millennials participated in the research. Findings show that only 59.6% used the services of this platform, mostly 1-2 times, predominantly for international travel. The main reasons include lower price. Respondents believed the accommodation's location and surroundings could threaten their safety, but not their hosts. Students mostly find using the platform fun and modern and are willing to recommend it further. In assessing students' future Airbnb involvement, we investigated how location, host, and accommodation safety, along with extra costs, lower quality, and complaints, influenced participation. Unexpectedly, location insecurity positively impacts future platform usage, while poor accommodation safety predictably diminishes it. Our findings highlight the growing popularity of Airbnb among Serbian students for international leisure travel, yet safety and privacy concerns remain. Despite this, most respondents enjoy using Airbnb and intend to continue.*

**Keywords:** *Sharing economy, shared accommodation, Airbnb, consumer behaviour*

## 1. INTRODUCTION

The sharing economy involves exchanging material and non-material resources among individuals in both global and local environments. This exchange often utilizes digital platforms instead of intermediaries, reducing user transaction costs. However, the absence of intermediaries can mean that risks are transferred to the individuals exchanging resources instead of the central authority (Felländer, Ingram, & Teigland, 2015).

The sharing economy has emerged as a crucial global market segment, primarily due to its diverse shared accommodation and transportation (Jovanović, Ignjatović, & Jeremić, 2023) options, personalized to users' and service providers' varied needs and preferences (Puschmann & Alt, 2016). Among the numerous manifestations of the sharing economy, such as accommodation, transportation (mobility), goods, skills, food, and clothing sharing, accommodation sharing stands out as one of the most significant, with Airbnb being the most prominent (Andreu et al., 2020; Guttentag, 2019; Negi & Tripathi, 2023; Zervas et al., 2017), subject to further analysis in this study.

In Serbia, the increasing use of accommodation-sharing platforms caters to travellers seeking lodging and hosts offering their spaces. However, despite this rise, research on user perceptions and satisfaction levels is lacking, particularly regarding platforms like Airbnb. Understanding user experiences is crucial to grasping shared accommodation platforms' advantages, drawbacks, and opportunities and identifying critical success factors. Analyzing user adoption factors, such as education level, property status, and travel type, will provide insights into their preferences and concerns when booking accommodation. Examining safety, pricing, amenities, and future usage intentions is essential to tailor services effectively and enhance user satisfaction.

This research culminates in thoroughly investigating Airbnb adoption among students, including previous studies and present-day developments, followed by practical research and its resulting discoveries and conclusions. It carefully delineates the drawbacks, benefits, and prospects of using accommodation-sharing platforms. This research aims to offer substantial insights into the user experience of shared accommodation platforms in the Republic of Serbia.

The following section gives a literature review of the topic. The research methodology employed in this study is presented in Section 3, encompassing details regarding sample collection methods, sample size, and respondents' demographic, economic, and social profiles. Furthermore, insights into the approach taken for processing collected data and correlating the characteristics and preferences of surveyed users with the result findings are provided in Section 4. Finally, concluding remarks are given.

## **2. FACTORS IMPACTING THE PARTICIPATION IN THE SHARED ACCOMMODATION**

As a flexible, crisp concept, the sharing economy paradigm has a transformative potential that tends to affect various industries. Moreover, shared accommodation, as its variant, emerges as a business model that answers to the high demand for accommodation in the market. It provides reliable, neat, good-for-value accommodation for a heterogeneous population with distinctive socio-demographic characteristics. Therefore, to better understand the underlying mechanisms that propelled shared accommodation platforms, carefully scrutinizing the factors influencing participation in shared accommodation is of particular interest. Following the conceivable growth rate of the penetration of shared accommodation in the tourism industry, understanding the consumer behaviour of shared platform users is necessary for academia, practitioners, policymakers, and other interested parties (Aruan & Felicia, 2019).

In essence, it is crucial to demystify consumers' motivations for participation in shared accommodation practice. Numerous authors have navigated the landscape of such behaviour, and here are some of the conclusions. On the one hand, an economic factor, resulting in a significant monetary benefit compared to traditional accommodation services, has an unequivocally predominant influence on the final decision on participation in shared accommodation practice (Maricic et al., 2023b). On the other hand, a substantial effect is generated from an intrinsic and altruistic desire of any individual to try something innovative, different, and undoubtedly beneficial.

A particular research interest related to the segmentation of the participants in shared accommodation, both locally and globally, can signal the factors which impact their decision to participate in the concept. Namely, Maričić and co-authors (2023c) segmented European countries based on shared accommodation users' characteristics, revealing differences in consumer behaviour across socio-economic backgrounds and regions, indicating socio-geographical impacts.

In another study, Wang and Wang (2022) assessed 22 580 reviews left on Airbnb rentals in Beijing, Shanghai, and Hong Kong and observed how geography, environment, human, and housing factors impact user experience. After detailed analysis encompassing multiple regression analysis, DEMATEL method, and Analytic Network Process (ANP), they found that green users have a more apparent emotional tendency to human and geographical factors. Their result signals that the human factor in shared accommodation is highly valued.

Zhang and co-authors (2023) turned to analyzing user behaviour from an interesting perspective. Namely, they observed how hosts' information on online accommodation-sharing platforms determines consumers' booking behaviour. Their in-depth analysis reveals that subject diversity, perspective-taking, and facial attractiveness regarding social distance positively influence guest booking behaviour. At the same time, instant bookability positively impacts booking behaviour in temporal distance. However, response time exhibits a negative effect on booking behaviour.

Drinjak and co-authors (2023) recently conducted an econometric analysis of shared accommodation participation. The authors implied that besides the financial and social components, careful notice should be put on behavioural factors influencing consumers' decision to participate in shared accommodation. Interesting results were derived from the created linear regression model, which signified GDP per capita and participation in online shopping as significantly influential in the rate of shared accommodation usage.

The literature review indicates that participation in shared accommodation is a multidimensional problem, requiring analysis and observation from different angles, encompassing multiple factors.

### **2.1 Participation in shared accommodation in Serbia**

Examination of shared accommodation within regional contexts represents a significant avenue for expanding the current body of knowledge in this domain and understanding regional behavioural differences. Particularly noteworthy in recent discourse is the analysis of data sourced from prominent shared accommodation platforms, notably Airbnb.

Three notable studies have delineated the current state of development in this field within the Republic of Serbia. Specifically, Kuzmanović and Langović (2018) delved into the determinants of online booking intentions and behaviours, motivations behind Airbnb selection, preferences regarding Airbnb properties, and the consequential impacts on the hotel industry and traditional accommodations. This study clarifies the growing influence of Airbnb within the Serbian hospitality industry, along with its implications for stakeholders and policymakers. Remarkably, extant users exhibit high levels of satisfaction and propensity for repeat usage, while the promise of unique experiences and local engagement draws prospective users. Nonetheless,

challenges such as mistrust, uncertainty, and language proficiency warrant serious consideration for future research endeavours.

Furthermore, an additional compelling study underscored the significance of providing an in-depth analysis of shared accommodation within the same geographical locale. Specifically, Kalinić and Novaković (2019) examined the impact of the Internet on travel arrangements, with a specific focus on digital accommodation platforms and the attitudes and behaviours of Serbian consumers toward online travel purchases. Given the popularity of Booking.com and Airbnb among Serbian consumers, the authors propose managerial strategies to bolster trust in local booking websites, particularly when targeting specific demographic segments in digital marketing initiatives. Consequently, this study advocates for concerted efforts to address security apprehensions among female travellers and to cultivate trust in local booking platforms.

Prominent is the report done within the project *PANACEA - Setting foundation for capacity building of sharing community in Serbia* (Živojinović et al., 2022). The mentioned report focused on mapping the sharing community in Serbia and closely observed their level of participation in the shared accommodation. The results indicated that in the observed period, 2017-2019, the overall level of participation in shared accommodation was on the rise, that the populations aged 25-34 and 35-44 were those participating the most, and that the highly educated individuals in Serbia participated in the shared accommodation more than the European average.

### 3. CONDUCTED SURVEY

As discussed above, our study aimed to investigate the adoption rates of Airbnb among students in Serbia. The research was conducted from December 2023 to March 2024 using Google Forms. The goal populations were millennials and university students. The survey was distributed on LinkedIn profiles of authors and LinkedIn groups related to sharing economy practices. The survey consisted of three main sections: demographic questions, travelling behaviour, and previous experiences and attitudes towards the Airbnb platform. All participants completed the first two sections, while the third segment was designed only for those who have previously used shared accommodation via Airbnb. The questions in the second section encompassed questions like "How often do you travel for work?", "How often do you travel touristically?" and "Which destination do you most commonly travel to?". The questions in the third segment were taken from the study of Golubovic and associates (2023), who explored the experiences of BlaBlaCar users in Serbia. The questions were adapted to shared accommodation.

### 4. RESULTS

A total of 201 respondents participated, of which 68.3% were female, which was expected considering that women are more prone to participating in surveys (Smith, 2008). The majority of respondents were born between 2000 and 2003; therefore, the mean age of the respondents was 23.174, with a standard deviation of 3.231. Regarding educational attainment, most respondents indicated that they are currently studying (55%), and over 90% of respondents currently reside in Belgrade. Most respondents reported monthly incomes below 25,000 dinars, while 23.2% did not disclose their income. Nearly half of the respondents stated that they frequently travel for leisure annually but rarely for business, with European metropolises such as Paris, Rome, and Barcelona being the most commonly chosen destinations.

Although 87.7% of respondents had heard of the Airbnb platform, only 59.6%, or 80 respondents, used the services of this platform. Most of this cohort used Airbnb one to two times (55.0%) and three to five times (26.3%). The platform has been predominantly used only for international travel (63.7%), with fewer respondents using it to travel within Serbia and internationally (25.0%). The rest of the respondents in Serbia only used Airbnb when travelling. About three-quarters of respondents did not consider becoming a provider and renting their property through the Airbnb platform. This indicates that the respondents are more open to being users than providers in the concept.

We asked the respondents to list the main reasons for choosing Airbnb. The question was defined as a multiple-choice question. Most of the Airbnb users' respondents said that the main reason they opted for shared accommodation was the lower price (37.1%), better-equipped accommodation (22.0%), and larger accommodation capacity (18.9%). Respondents most commonly travelled with one or more accompanying persons (48.8%), while only two said they used the platform's services for solo trips. Over half of the respondents sought hotel accommodation before using shared accommodation services. This indicates that traditional accommodation is the respondent's first choice.

In the next section of the survey, respondents ranked their agreement or disagreement with the statements on a scale of 1 to 5 (1 if they strongly disagree and 5 if they strongly agree). When asked whether they believed that the location and surroundings of the accommodation could pose a threat to their safety, most respondents

agreed with the statement, while for the statement that the host of the accommodation could pose such a threat, most respondents either disagreed or partially agreed. While 28% of respondents claim that privacy in accommodation cannot be compromised due to poor sound isolation or hidden cameras, 35.4% of respondents claim the opposite. Nearly half of the respondents do not believe they will receive lower quality than promised, and a slightly smaller percentage believe that the platform or the host will consider their complaints.

In the next segment, respondents indicated their level of agreement with statements related to their impression of using accommodation-sharing platforms. Most respondents believe that using the Airbnb platform is fun and modern, and more respondents disagree that using this platform is complicated and demanding. On the other hand, 60 respondents claim that using these platforms is not meaningless, and a slightly smaller number of respondents believe that it provides them with new experiences. Finally, we explored the possibilities for further use and recommendations for the Airbnb platform. We found that more than half of the respondents will continue to use this platform, while an equal number are likely to recommend its use to their friends and acquaintances.

Within this research, we strive to explore how perceptions of Airbnb accommodation usage impact future participation in the concept. To do so, a multiple linear regression (MLR) model was created using the backwards method. Backwards regression was used to develop less complex and statistically significant models. The explanatory variables were the following six items: 'The location and surroundings around the accommodation may pose a threat to my personal safety' (Location Safety), 'The accommodation host may pose a threat to my personal safety' (Host Safety), 'My privacy in accommodation may be compromised' (Acc Safety), 'I am afraid that the actual costs of using this type of accommodation will be higher than what the sharing platform showed me' (Additional Costs), 'I believe that I will receive a lower quality of shared accommodation than what was promised to me' (Lower Quality), and 'I believe that my complaints and requests regarding shared accommodation will not be accepted and taken into account by the platform and the host' (Complaints). The final model assessment is given in Table 1.

**Table 1: MLR model assessment of the statement 'I will continue to use the services of the Airbnb platform in the future'**

Dependent variable	Explanatory variable	Coefficient	t-test	F-test	Adj R square
<i>I will continue to use the services of the Airbnb platform in the future</i>	Constant	4.532	11.360***		
	Location Safety	0.295	2.858***		
	Host Safety	-0.097	-0.944	3.707***	0.121
	Acc Safety	-0.232	-2.474**		
	Complaints	-0.066	-0.781		

Note: \*\*\*p<0.001, \*\*p<0.05

Following the SPSS analysis, Table 1 shows that the Adjusted R square is 0.121, meaning 12.1% of the future Airbnb usage variability is explained by location safety, host safety, accommodation safety, and complaints. The relatively modest value of this indicator is likely due to numerous alternative factors that influence future platform usage. It is important to consider the multitude of other factors contributing to the dependent variable's variability, resulting in this small value. The F-test of the MLR confirms the model's significance. A surprising result shows that, even with the potential insecurity of the location, respondents are likely to persist in using this platform in the future, possibly due to lower prices or better-equipped accommodation. Conversely, poor accommodation safety decreases the likelihood of future platform use, highlighting its importance.

## 5. DISCUSSION AND CONCLUSION

The rising popularity of accommodation-sharing platforms in Serbia adapts travellers searching for lodging and hosts offering their spaces. Understanding user experiences is vital for comprehending the benefits, drawbacks, and opportunities of such platforms, as well as identifying critical factors for success, including analyzing adoption factors such as education level, property status, and travel preferences to tailor services effectively and improve user satisfaction.

This research presents an overview of the adoption rates and intents towards Airbnb platform among students in Serbia. The study, conducted from December 2023 to March 2024, encompasses 201 students and millennials. Most respondents were female, from 20-25 years old, primarily studying and residing in Belgrade. They mainly were leisure travellers to European cities like Paris, Rome, and Barcelona, but no more than once a year.

Even if nearly 90% of respondents knew of Airbnb, only 59.6% had utilized its services, primarily for international travel and typically 1-2 times. Additionally, most respondents had not considered renting their property through the platform. The main draws for using Airbnb were affordability, well-equipped accommodations, and greater capacity, with respondents often travelling with companions and initially considering hotel options before switching to shared accommodation services.

Most respondents expressed concerns about safety regarding the location and surroundings of accommodations, while opinions varied on whether hosts posed threats. There was a split regarding privacy, with 28% believing it could not be compromised due to poor sound isolation or hidden cameras, while 35.4% claimed the opposite. Nearly half did not expect lower quality than promised, but a slightly smaller percentage believed the platform or host would address their complaints. In the subsequent segment, most respondents found using Airbnb enjoyable and modern, with fewer finding it complicated and demanding. A notable group considered it fruitful and appreciated the opportunity for new experiences. More than half of the respondents will continue to use and recommend this platform.

Regarding the respondents' future participation in Airbnb, we examined how it was affected by the safety of the location, host, and accommodation itself, as well as additional costs, lower quality, and complaints. MLR model was statistically significant with a relatively modest coefficient of determination. Safety was an essential factor influencing participation intention, similar to the findings of Mody and his coworkers (2023). Surprisingly, the location's potential insecurity positively affects the future usage of the platform. The most probable reasons may include lower prices (Maričić et al., 2023a) or better-equipped accommodation. The poor accommodation safety, as expected, negatively affects the future usage of the platform. This is in accordance with the findings that trust is an essential factor when talking about the use of shared accommodation, and it is precisely the lack of trust in the providers presented as the critical reason that influenced respondents not to use the services sharing economy (Maričić, Drinjak, & Popović, 2023d). Two other factors included in the model proved not to be individually statistically significant, *Host safety* and *Complaints*. However, the two were left in the model, as they all together with the constant and other two predictors, create a statistically significant model. Both coefficients are negative, indicating that the more the respondent agrees with the statement, the less he/she will continue to use the services of the Airbnb platform in the future.

Our findings have some practical implications. They suggest that accommodation-sharing platforms like Airbnb have gained significant traction among students and millennials in Serbia, particularly for international leisure travel. However, there are notable concerns about safety and privacy among users, indicating a need for platforms to address these issues to enhance user satisfaction. Despite these concerns, most respondents found using Airbnb enjoyable and plan to continue using and recommending the platform, highlighting its enduring appeal despite potential drawbacks. This finding underscores the importance of Airbnb and similar platforms prioritizing safety measures and addressing user concerns to maintain their popularity and trust among users in Serbia and beyond.

The conducted research has several limitations which should be noted. First, is the sample size and its potential bias. Therefore, to obtain more generalisable results, the survey should be disseminated extensively not only in Belgrade, whereas in other regions of Serbia. The second, the survey instrument could be extended by adding aspects of financial risk, physical risk, word of mouth and similar. Future research could focus towards understanding the factors influencing property owners' decisions to list their properties on accommodation-sharing platforms like Airbnb and explore strategies to address safety and privacy concerns among younger users. It could also investigate the long-term implications of shared accommodation services on travel behavior and preferences.

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# RELASHIONSHIP BETWEEN COLD CALLING AND WARM CALLING: A CASE STUDY OF A STUDENT ORGANIZATION

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**Abstract:** *This paper investigates the relationship between cold calling and warm calling within a student organization, employing Ivanovic's distance method for ranking students in their cold calling and warm calling tasks. The Spearman correlation test is used for examining the correlation between cold calling and warm calling tasks. The study has 32 individuals from various offices, focusing on their performance in initiating business contacts (cold calling) and securing partnerships (warm calling). Results indicate a moderate positive correlation (0.554) between cold calling and warm calling, suggesting that skills in one area tend to translate into the other. The findings also reveal significant variations in performance across different offices, with the Niš office exhibiting exceptional efficiency in both tasks. This study underscores the importance of targeted training programs while addressing the unique demands of each calling task, aiming to optimize organizational performance and establish effective partnership strategies.*

**Keywords:** *Ivanovic distance, Spearman correlation, student organization, cold calling, warm calling*

## 1. INTRODUCTION

In researching what makes an organization outstanding, Collins (2009) and Sharifirad et al. (2012) examined various aspects. They found that the key to exceptional organizational performance lies in factors like having a forward-thinking leadership, fostering a culture that encourages creativity, and consistently focusing on fulfilling customer needs. Success in business is influenced by combining various factors like clear vision and efficient operations. A key element is the ability to form and grow new partnerships. These collaborations drive organizations towards success, boosting profits and allowing for expansion into new markets. By partnering, companies leverage mutual strengths, gain insights from a diverse workforce, and sharpen their competitive advantage, leading to a thriving and evolving business environment (Giesecke, 2012).

Forming successful alliances with new organizations can be efficiently accomplished through collaborative efforts, engaging individuals with complementary expertise to attain common ground and foster novel creations (Schrage, 1990). This approach emphasizes the importance of the individuals involved in the process. There is a distinction between individuals who initiate contact through cold calls to arrange a first meeting and those who negotiate and conclude agreements in meetings. The former are adept at establishing initial connections and generating interest, while the latter excel in detailed negotiations and finalizing deals (Volkema et al., 2011).

Can the same individuals handle both cold calling and in-person deal negotiations? It's not straightforward. Some organizations start their staff with cold calling before moving them to deal-making meetings (Blount, 2015). Our study has examined whether success in cold calling leads to success in sealing deals. We were evaluating the effectiveness of both activities to understand this approach better.

What makes a good candidate for this position initially? Per Downing (2011), some of the skills employers love to see when interviewing candidates for this role are :

- Attentiveness, also known as ability, to use short, affirmative words and sounds to indicate that (s)he was listening to interlocutor.
- Perceptiveness, also known as ability, to continually attempts to understand what interlocutor is trying to say.
- Responsiveness manifested the ability to provide comprehensive and detailed responses rather than brief answers such as a simple "yes" or "no."



In our inquiry, the requirement for participating in the study was to have these qualities expressed.

This study also investigates whether the skills needed for cold calling are also crucial for closing deals. We were using a student organization as a case study to explore the relationship between success in cold calling and warm calling.

Often referred to as "the other education," extracurricular activities help students use what they learn in the classroom in real-life situations and build skills useful for life after graduation (Montelongo, 2002). Student organizations and the projects they undertake serve as invaluable platforms for students to apply their classroom learning to real-world situations, also potentially gaining crucial research material and economic benefits, enriching their academic pursuits. (Prigge, 2005) Projects often span multiple sectors including Human Resources (HR), Public Relations (PR), Logistic and Corporate Relations (CR). The primary role of the CR team involves promoting the organization to external entities, seeking new partnerships, and ensuring the satisfaction of external stakeholders by addressing their needs and concerns. The work of the CR team is examined in this paper.

The following section is providing a more detailed explanation of the problem, variables used, and the methodology employed for measurement. Subsequently, the third section is analyzing the results obtained from this model. Future directions is outlined, and the paper is concluded in the fourth section.

## 2. METODOLOGY

In a study conducted between February and June of 2023, multiple CR teams within a student organization undertook various tasks. This organization had offices distributed throughout Serbia, including multiple locations in Belgrade at the Faculty of Organizational Sciences (FON), Faculty of Economics and Business (EF), Metropolitan University (Metropolitan), and Singidunum University (Singidunum), with additional single offices in Novi Sad, Kragujevac, and Niš. Prior to team formation, prospective members underwent interviews to assess their perception, responsiveness, and attentiveness, ensuring only qualified candidates joined. Initially, their primary activity involved cold calling a wide range of companies to forge new business relationships. Following this, the teams engaged in efforts to secure partnerships through one or more warm meetings with various firms.

Ivanovic's distance, also known as the I-distance, is a method of n-dimensional space. The initial idea was to rank countries based on their level of development, incorporating multiple different indicators into this research. These indicators were then aggregated into a single value, which would subsequently represent the rank of each country (Ivanovic, 1977) .

Since then, the I-distance method has found application in various spheres. It has been used in ranking universities (Jeremić et al., 2011; Jovanović et al., 2012), measuring the healthcare systems of European countries (Jeremić et al., 2012), measuring global food security index (Maricic et al., 2016), the development of information and communication technologies (Dobrota et al., 2012). It has also been utilized in examining the gross domestic product and gross national income of countries (Milenković et al., 2014), bank efficiency (Radojicic et al., 2015), sport management (Radovanović et al., 2013), and sport analytics (Jeremic & Radojicic, 2010).

For a given vector of variables  $X^r = (X_1, X_2, \dots, X_k)$  chosen to represent entities (students being ranked), the I-distance between two entities  $e_r = (x_{1r}, x_{2r}, \dots, x_{kr})$  and  $e_s = (x_{1s}, x_{2s}, \dots, x_{ks})$  is defined as:

$$D(r, s) = \sum_{i=1}^k \frac{|d_i(r, s)|}{\sigma_i} \prod_{j=1}^{i-1} (1 - r_{ji.12\dots j-1}) \quad (1)$$

where  $d_i(r, s)$  the distance between the values of variable  $X_i$  of entity  $e_r$  and  $e_s$  and , i.e., the discrimination effect,  $d_i(r, s) = x_{ir} - x_{is}$ ,  $i \in \{1, \dots, k\}$ ,  $\sigma_i$  standard deviation from  $X_i$ ,  $r_{ji.12\dots j-1}$  is Partial correlation coefficient from  $X_i X_j$ , ( $j < i$ ).

Calculating the value of I-distance is iterative and is carried out through several stages:

- The value of the discrimination effect for indicator  $X_1$  (the most important indicator, the one that provides the most amount of information about the observed phenomenon) is calculated;
- The value of the discrimination effect of indicator  $X_2$ , which is not covered by indicator  $X_1$ , is added;
- The value of the discrimination effect of indicator  $X_3$ , which is not covered by indicators  $X_1$  and  $X_2$ , is added;
- The procedure is repeated for all indicators.

### 3. ANALYSIS AND RESULTS

The study included 32 individuals with expertise in areas such as economics, engineering, linguistics, and graphic design. Their activities were segmented into two primary categories: cold calling and warm calling. To evaluate performance in cold calling, the following metrics were applied: 1) Total count of companies registered; 2) Ratio of companies that received board approval (expressed as a percentage of registered companies); 3) Proportion of companies successfully contacted (expressed as a percentage of registered companies); 4) Rate of received responses from companies (expressed as a percentage of registered companies). For the evaluation of warm calling performance, the criteria included: 1) Percentage of meetings arranged relative to registered companies; 2) Percentage of meetings held relative to registered companies; 3) Total number of contracts successfully concluded.

There are no records of studies on the correlation between cold calling and warm calling related to student organizations. Consequently, there is no established method that perfectly measures this dependency. One method that can be used for ranking is Ivanovic's distance. It is a ranking method capable of integrating multiple variables into a singular numeric score. This facilitates the assessment and ranking of students in their cold calling and warm calling activities.

All statistical analyses were conducted using the IBM SPSS Statistics 27 software tool. The I-distance method was separately applied to cold calling and warm calling tasks, with the results presented in Table 1 with added office for each student.

**Table 1: I-distance for Cold Calling, Warm Calling and the Office for each Student**

Student	Office	I-distance Cold Calling	Rang Cold Calling	I-distance Warm Calling	Rang Warm Calling
S1	FON	2.69884	18	2.031949084	10
S2	FON	2.02687	25	0.452652943	24
S3	FON	1.89277	29	0.873556682	18
S4	FON	2.8666	16	0.358259094	26
S5	FON	1.98682	26	0.582864242	20
S6	FON	2.06335	24	0	32
S7	EF	3.87006	8	7.049391655	1
S8	EF	2.91615	14	1.330455473	16
S9	EF	3.15171	11	2.397518495	7
S10	EF	2.88237	15	0.443581742	25
S11	EF	3.15026	12	0.35740533	27
S12	EF	2.80294	17	2.062791169	9
S13	EF	1.9824	27	0.556639456	23
S14	METROPOLITAN	2.36576	22	2.779577218	6
S15	METROPOLITAN	2.58864	20	0.614120326	19
S16	METROPOLITAN	1.24486	30	2.381351482	8
S17	SINGIDUNUM	0.97944	32	0.002853086	30
S18	SINGIDUNUM	2.21768	23	0.001491386	31
S19	SINGIDUNUM	3.20163	10	3.004543009	4

S20	SINGIDUNUM	1.03529	31	0.580556881	21
S21	NOVI SAD	4.58976	5	1.511262131	15
S22	NOVI SAD	3.63023	9	0.884442124	17
S23	NOVI SAD	3.106	13	1.904952266	12
S24	NOVI SAD	4.08805	7	3.030849493	3
S25	KRAGUJEVAC	2.61556	19	0.228594272	28
S26	KRAGUJEVAC	2.41792	21	0.21408035	29
S27	KRAGUJEVAC	1.97287	28	0.565135839	22
S28	NIŠ	6.86811	1	3.757452714	2
S29	NIŠ	6.51689	2	1.868667461	13
S30	NIŠ	5.97107	3	1.755277446	14
S31	NIŠ	5.65119	4	2.956465642	5
S32	NIŠ	4.13445	6	1.951215393	11

The analysis of cold calling revealed that all four indicators have significant positive correlations with the calculated I-distance. The total count of registered companies ( $r = 0.852$ ,  $p < 0.001$ ) is the most crucial, followed by the ratio of approved companies ( $r = 0.792$ ,  $p < 0.001$ ), proportions of companies contacted ( $r = 0.734$ ,  $p < 0.001$ ), and the proportion of companies that gave a response ( $r = 0.653$ ,  $p < 0.001$ ). For warm calling, the proportion of held meetings ( $r = 0.819$ ,  $p < 0.001$ ) is the most important indicator, followed by the proportion of arranged meetings ( $r = 0.791$ ,  $p < 0.001$ ), and the proportion of concluded agreements ( $r = 0.708$ ,  $p < 0.001$ ). These correlations highlight the significant role each indicator plays in assessing the effectiveness of calling strategies (Dobrota et al., 2016).

From the results, it is evident that students do not have equal rankings in the cold calling and warm calling segments. Looking at the rankings, we can see some intriguing patterns. Student S28, for instance, excels remarkably, securing the top spot in cold calling and almost replicating this success in warm calling with second place. This near alignment in performance is also echoed by Student S2, albeit further down the rank list, with a 25th place in cold calling and an adjacent 24th rank in warm calling. However, not all rankings run this close. Student S16 presents a contrasting scenario, with a notable discrepancy between a 30th position in cold calling and a significantly better 8th place in warm calling. A similar breadth of difference is seen with Student S14, who ranks 22nd in cold calling while climbing up to the 6th rank in warm calling, showcasing a stark variation in their standing across the two domains. Then there's the curious case of Student S11, who finds themselves in a middle ground with a 12th rank in cold calling but a drop to the 27th position in warm calling, illustrating a flip in performance between the two categories. These examples highlight the diverse range of skills and proficiencies among the students.

To determine if there is a correlation between these cold calling and warm calling, it is necessary to compare the ranks obtained from the I-distance method for cold calling tasks with those from the warm calling tasks. The Spearman correlation test is utilized for this comparison. The correlation coefficient between ranks in cold calling and warm calling is 0.554, indicating a moderate positive correlation. (Cohen, 2013) This means that students with higher ranks in cold calling tend to also have higher ranks in warm calling, although the relationship is not perfectly linear. Based on these results, we can conclude that there is some association between students' performances in cold calling and warm calling.

The reason for this correlation could be attributed to underlying skills or competencies that are common to cold calling skills, such as attentiveness, perceptiveness, and responsiveness could also be common to warm calling skills (Downing, 2011). However, the moderate nature of the correlation suggests that there are also distinct elements at play in each task, which could be related to the specific demands or strategies associated with cold calling versus warm calling.

Reviewing the performance by offices, it becomes evident that the office in Niš stands out for its exceptional performance, boasting an impressive average rank of 3.2 in cold calling and 9.0 in warm calling, positioning itself as the top-performing office in this assessment. Meanwhile, the offices of FON, Kragujevac and Singidunum show a consistent pattern, with their average rankings hovering in the low to mid-twenties across both cold calling and warm calling. The Metropolitan office presents an interesting dichotomy; while their average rank in cold calling sits at 24, suggesting room for improvement, they exhibit a notable strength in

warm calling, with a much-improved average ranking of 11.0, indicating a particular adeptness in this area. Other offices generally display a balanced competence, with average ranks for both cold calling and warm calling falling between 9 and 14. This reflects a solid performance across the board, with no significant disparities between their cold calling and warm calling capabilities.

The forthcoming analysis is investigating the presence of a correlation between the performances of individual offices in cold calling and warm calling. The Kruskal-Wallis test is employed for this purpose. First, we will conduct a Kruskal-Wallis test for cold calling ranks. Then, we will use post-hoc comparisons to analyze the offices, presenting their statistics, significance levels, and Bonferroni adjusted statistics in Table 2.

**Table 2 - Pairwise comparison of Offices, Test Statistics, Significance and Bonferroni adjusted significance for cold calling**

Offices	Test Statistics	Significance	Adjusted Bonferroni Significance
NIŠ - NOVI SAD	-5.300	0.400	1.000
NIŠ - EF	11.657	0.034	0.710
NIŠ - KRAGUJEVAC	19.467	0.004	0.094
NIŠ - FON	19.800	0.000	0.010
NIŠ - METROPOLITAN	20.800	0.002	0.050
NIŠ - SINGIDUNUM	-20.800	0.001	0.020
NOVI SAD - EF	6.357	0.280	1.000
NOVI SAD - KRAGUJEVAC	14.167	0.048	1.000
NOVI SAD - FON	14.500	0.017	0.349
NS - METROPOLITAN	15.500	0.031	0.641
NS - SINGIDUNUM	-15.500	0.019	0.409
EF - KRAGUJEVAC	-7.810	0.228	1.000
EF - FON	-8.143	0.119	1.000
EF - METROPOLITAN	-9.143	0.158	1.000
EF - SINGIDUNUM	-9.143	0.120	1.000
KRAGUJEVAC - FON	0.333	0.960	1.000
KRAGUJEVAC - METROPOLITAN	-1.333	0.862	1.000
KRAGUJEVAC - SINGIDUNUM	-1.333	0.852	1.000
FON - METROPOLITAN	-1.000	0.880	1.000
FON - SINGIDUNUM	-1.000	0.869	1.000
METROPOLITAN - SINGIDUNUM	0.000	1.000	1.000

The Kruskal-Wallis test revealed a test statistic of 21.826 with a significance level of 0.001, indicating that there are significant differences among the distributions of the offices. From the pairwise comparisons, it appears that most comparisons do not show a significant difference post-Bonferroni adjustment. However, there are notable exceptions where significant differences were found. The significance level for the comparison between FON and Niš offices is less than 0.001, which is adjusted to 0.010, demonstrating a significant difference even after accounting for multiple comparisons. Also, the significance between Singidunum and Niš offices is 0.001, adjusted to 0.020, highlighting a significant difference even after the Bonferroni correction. After this, Kruskal-Wallis test for warm calling ranks was done. The test statistic was 11.597 with a significance level of 0.072, which suggests homogeneity in performance across offices.

#### 4. CONCLUSION

The goal of this paper was to explore the relationship between cold calling activities and their impact on warm calling outcomes. This study focused on a student organization in Serbia, where 32 individuals with varied

expertise and organizational roles undertook assignments from cold calling to negotiating partnerships. Their tasks were assessed in cold calling and warm calling categories, encompassing metrics like company engagement success and meeting outcomes. The aim was to explore the correlation between cold calling skills in initiating contacts and success in finalizing deals.

The findings of this investigation, grounded in Ivanovic's distance method and validated by Spearman correlation, displayed a fascinating array of skill diversity. The Spearman correlation coefficient, at 0.572, reveals a moderate positive correlation, suggesting that those who excel in cold calling tasks tend to also perform well in warm calling. Each area requires a unique set of competencies and perhaps a specialized focus to truly excel.

This study also revealed that the Niš office excelled with top performance in cold calling and warm calling, while FON, Kragujevac, and Singidunum showed average abilities. The Metropolitan office exhibited a significant disparity between lower cold calling and higher warm calling performance, indicating uneven expertise. Other offices displayed balanced competencies in both areas, reflecting a well-rounded skill set conducive to both initiating and closing deals.

The Kruskal-Wallis test indicated significant performance differences between offices in cold calling, particularly between FON-Niš and Singidunum-Niš pairs. However, the same test for warm calling did not show significant differences, suggesting consistent performance across all offices.

In conclusion, this study has shed light on the subtle variances of performance within a student organization. It has been revealed that while there is a correlation between cold calling and warm calling success, each domain retains its distinct set of challenges and demands. The variability observed in the data reflects the diversity of talents and the need for targeted development strategies to cultivate these competencies. Organizations should consider differentiated training programs that address the specificities of each role, including operational and sales tasks. Recognizing the unique requirements of these tasks allows organizations to better prepare their members for the varied demands they will encounter. While the same individuals can be used for both cold calling and in-person negotiations, it is essential that they receive comprehensive training tailored to each activity. Moreover, the exceptional performance of certain offices like Niš offers valuable insights into best practices that could be leveraged to elevate overall organizational performance. It also presents an opportunity for benchmarking and the adoption of effective strategies across other offices.

Future research could extend this inquiry to include a more extensive data set, encompassing a broader range of student organizations to validate these findings. By continuing to explore the interplay between these essential facets of organizational operations, student organizations can refine their strategies to optimize both their outreach efforts and their ability to seal partnerships, thus achieving a comprehensive model of efficiency and success.

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# **DESIGNING ORGANIZATIONS FOR DIGITALLY TRANSFORMED BUSINESS ECOSYSTEMS**

# INCEPTION OF HUMAN-MACHINE TEAMS: A PRISMA-COMPLIANT VISUALIZATION, ANALYSIS AND REVIEW OF BIBLIOMETRIC DATA

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**Abstract:** *How humans and machines interact has substantially transformed, especially in areas where they work together and collaborate on tasks and objectives. This led to the formation of so-called human-machine teams, which are now seen in manufacturing organizations in assembling and disassembling processes as well as in service industries where employees are paired with chatbots and artificial intelligence (AI) technologies. Motivated by these new workplace teams and the surrounding opportunities, challenges, and positive, and negative aspects, the objective of this article is to synthesize and analyse the emerging literature by identifying the current publication trends, research themes, and hotspots, as well as paths for future research related to human-machine teams. Moreover, the article is grounded in a multitechnique bibliometric analysis of Scopus-retrieved data paired with a structured and rigorous review following the PRISMA protocol. In turn, the findings have significant implications for the scientific community, which will further expand this topic in the future as well as practitioners and managers who express a growing interest in incorporating human-machine teams in the organizational structure.*

**Keywords:** *Human-machine team, Human-AI team, Bibliometric analysis*

## 1. INTRODUCTION

Prompted by 4.0 technologies, contemporary working arrangements, and rapid digitalization, employees have found themselves “sharing a work desk” with other non-human colleagues as machines join as team members. In this sense, human-machine teams, also known as human-machine partnerships or collaborations, refer to the integration of humans and machines working together towards a common goal or task (Walliser et al., 2019). These teams leverage the unique strengths and capabilities of both humans and machines to enhance performance, efficiency, and effectiveness across various domains (Yorks et al., 2020).

Subsequently, human-machine teams can take various forms, ranging from simple collaborations between humans and basic automation tools to more sophisticated partnerships involving advanced artificial intelligence (AI) systems, robotics, and autonomous technologies, such as human-robot teams in manufacturing, collaborative decision-making between humans and AI algorithms in healthcare diagnostics, and human-AI partnerships in creative fields like art and design (Koponen et al., 2023). Contemporary management has not been immune to this impact, too (Haesevoets et al., 2021).

Yet, researchers point out that the foundation of these human-machine teams lies in designing seamless interactions, clear communication channels, and effective task allocation between humans and machines (La Torre et al., 2023). This often involves integrating technologies that support natural language processing, machine learning, computer vision, and human-computer interfaces to facilitate smooth collaboration and mutual understanding (Kazancoglu & Ozkan-Ozen, 2018).

From the managerial point of view, in human-machine teams, humans typically contribute cognitive abilities such as creativity, intuition, complex problem-solving, and contextual understanding, while machines provide computational power, data processing capabilities, speed, and precision (Ulfert et al., 2023). Besides the traditional uses of machines at work, these features can help managers in their tasks of managing the workforce. Thus, by combining the cognitive flexibility of humans with the computational power and efficiency of machines, these teams can tackle complex challenges that neither humans nor machines can handle



alone. Besides these benefits of enhanced productivity, decision-making, greater accuracy and precision, human-machine teams can result in job displacements, widening skill gaps, rising ethical concerns, loss of autonomy, socialization, and resistance to change (Habib et al., 2021; Alhaji et al., 2020). This juxtaposition between the positive and the negative aspects of human-machine teams makes it a compelling topic to further analyse in the context of managing these groups in the contemporary organizational context.

AI and intelligent machines have become prevalent worries in everyone's professional life as they are increasingly rising in popularity and becoming embedded in organizations (Nardo et al., 2020). While machines have been utilized for automating routine tasks in logistics and operations, recent advances in technology and computational power, new machine learning tools, and large quantities of data enabled managers to use machines for managerial tasks such as job crafting, for example (Cheng et al., 2023). This leads to a future where machines are an integral part of managerial decision-making. Hence, studies point out that while around 50% of managers prefer humans to still have the upper hand and the majority vote opposed to machines, the acceptance rates recently have hiked up to the point where it becomes acceptable for managers to control 70% of the decision-making, leaving the rest (30%) to computational intelligence (Haesevoets et al., 2021). We believe this further underscores the significance of human-machine teams as the "new work partnership" since the managers' work will be further augmented and backed up with credible data and sophisticated algorithms.

As a result, the rising opportunities and challenges of these teams have motivated the authors to carry out this research endeavour with the objective of analysing and synthesizing the research trends in the literature so far regarding human-machine teams in the context of managerial and organizational sciences, identifying hotspots, and charting directions for future research. This was achieved with a structured literature review, analysis and visualization of bibliometric data following the rigorous PRISMA protocol. The data was retrieved from the Scopus database and refers to articles in peer-reviewed journals until the end of 2023. Hence the authors set out to answer the following research questions (RQ):

RQ1. What are the most influential works and publication trends in human-machine teams literature?

RQ2. What are the emerging hotspots and research trends dominating human-machine teams literature?

RQ3. What does the future research agenda of human-machine teams literature look like?

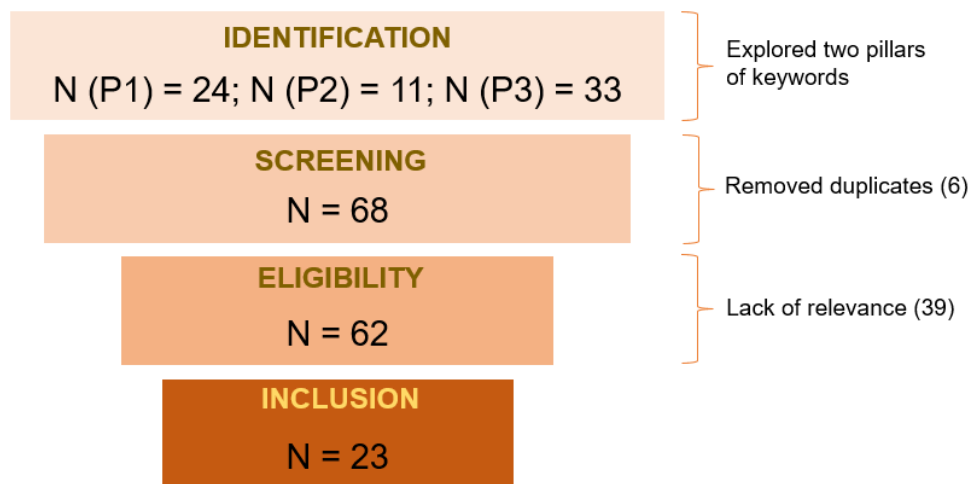
## 2. METHOD AND DATA

To synthesize the first initial findings related to human-machine teams, the authors conducted a systematic review of the literature supported by a bibliometric analysis of the articles published related to this topic. It is proven that the method can be used to trace the development of a topic, including in its first stages by pointing out the key terms and intellectual relations that shape the scientific conversation (Zupic & Čater, 2015). In cases of fresh topics, this method is even more helpful for setting a future research agenda (Donthu et al., 2021). Although bibliometric analyses and systematic reviews are usually suitable for larger sample sizes, contemporary research streams stress that this type of analysis is beneficial for niche and emerging topics such as human-machine teams in the workplace (Roger et al., 2020; Wang et al., 2023).

Furthermore, the data for the analysis was retrieved from the Scopus database as one of the leading global databases for quality research, during December 2023. The authors decided to use three search queries or pillars, the first being "human-machine team\*" (P1) in the title, abstract, and keywords of the articles. Afterward, the second set of keywords included "human-AI team\*" (P2), concluding with the third set of keywords "human-robot\* team\*" (P3).

The authors decided on a set of inclusion criteria: 1) the articles had to be published in scientific peer-reviewed journals, 2) the language of the articles had to be English, 3) the publication period was set until 2023 (2024 is not considered as it is still ongoing), 4) the article had to analyse these collaborative teams from a management perspective.

To achieve a more rigorous process, the PRISMA protocol (Figure 1) was followed from the phase of identification up until the inclusion phase (Moher et al., 2015). Eventually, 23 articles were considered in the final sample after duplicate articles were deleted and all the articles were manually evaluated for relevance; in other words, they outline the managerial point of view of managing human-machine teams as a contemporary workplace challenge. Hence, the abstract keywords that were omitted from the analysis are provided in the Annex.



**Figure 1:** Used PRISMA protocol for a systematic literature review and bibliometric analysis

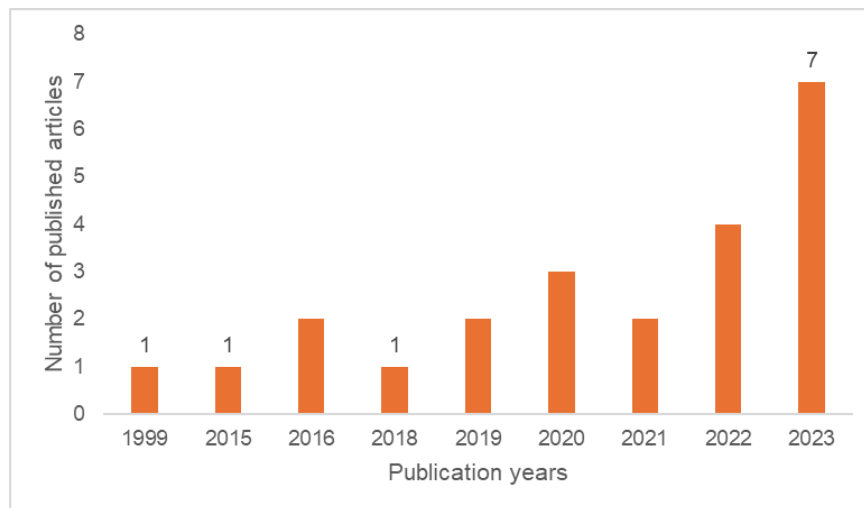
To further analyse the articles and their connections, the VOSviewer software was utilized. This tool helps research with building and visualizing networks of keywords and connections between them based on textual and bibliometric data (Van Eck & Waltman, 2014), which in this case represented the abstracts of the articles. Additionally, the tool has been used for a variety of studies in organizational sciences and management.

For data analysis, a multitechnique bibliometric analysis is performed with the final output being a synthesis of the findings in several key research streams. Namely, the used bibliometric techniques are country co-authorship, bibliographic coupling, and keyword co-occurrence. The *country co-authorship analysis* presents a map of countries where the authors come from, meaning that if a circle is larger than the rest, there is a higher number of authors hailing from this country and vice versa (Zupic & Čater, 2015). Additionally, the closer the countries are, the more the authors collaborate with each other (Zupic & Čater, 2015). *Bibliographic coupling* assesses how similar two articles are based on the references they share; so, the connection between two circles is stronger if they share similar references (Zupic & Čater, 2015). Finally, for studying the content, the *keyword co-occurrence analysis* is the only type of analysis that constructs a similarity measure by extracting keywords from the article (Bunjak et al., 2022). If the keywords are close to one another and there are more publications in which these keywords appear, their link is stronger and thus they appear larger on the map with more mentions (Bunjak et al., 2022).

### 3. RESEARCH RESULTS AND SYNTHESIS

The research results are outputs of the descriptive analysis of the published literature as well as three bibliometric techniques: country co-authorship, keyword co-occurrence, and bibliographic coupling. The findings pointed out by the visualization maps are synthesized in research streams and clusters.

The first article on the topic of human-machine teams appeared at the end of the previous century in which Hasegawa and Yoshimura (1999) developed a model for mitigating the influence of emotion in employee behaviour from the point of view of human-machine cooperation, putting this term in the back of the organizational focus. While other relevant articles have sporadically appeared through the years, the peak has been reached in 2023 with seven published articles, riding on the wave of rising accessibility of technology, data analytics, robotics, and the birth of ChatGPT (Demir et al., 2020). Moreover, the yearly publishing trends are presented in Figure 2.



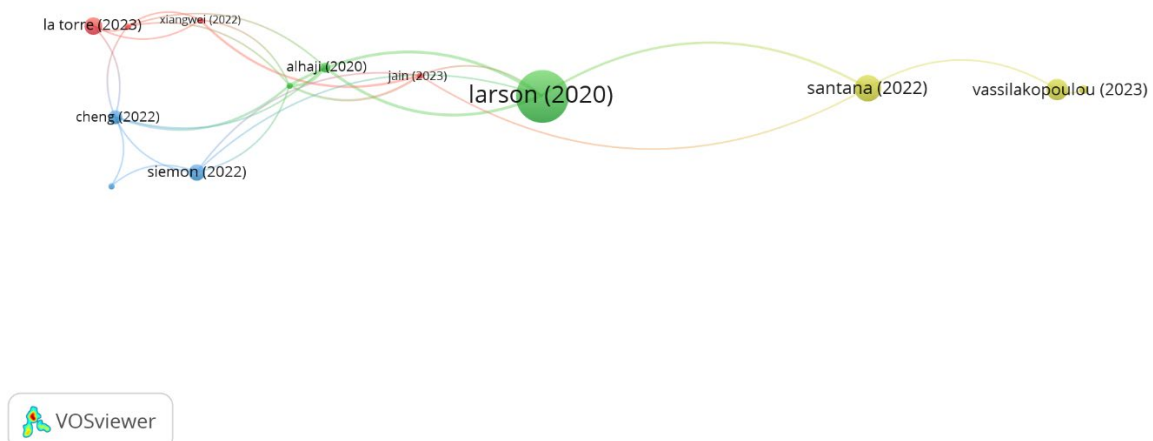
**Figure 2:** Yearly trends of published articles on the topic of interest

Speaking of the highest cited articles, the top three ones include:

- “Leading teams in the digital age: Four perspectives on technology and what they mean for leading teams” by Larson & DeChurch, published in 2020 in the *Leadership Quarterly* (120 citations),
- “Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL” by Kazancoglu and Ozkan-Ozen, published in 2018 in the *Journal of Enterprise Information Management* (107 citations),
- “Workforce reconfiguration strategies in manufacturing systems: a state of the art” by Hashemi-Petroodi, Dolgui, Kovalev, Kovalyov and Thevenin, published in 2021 in the *International Journal of Production Research* (46 citations).

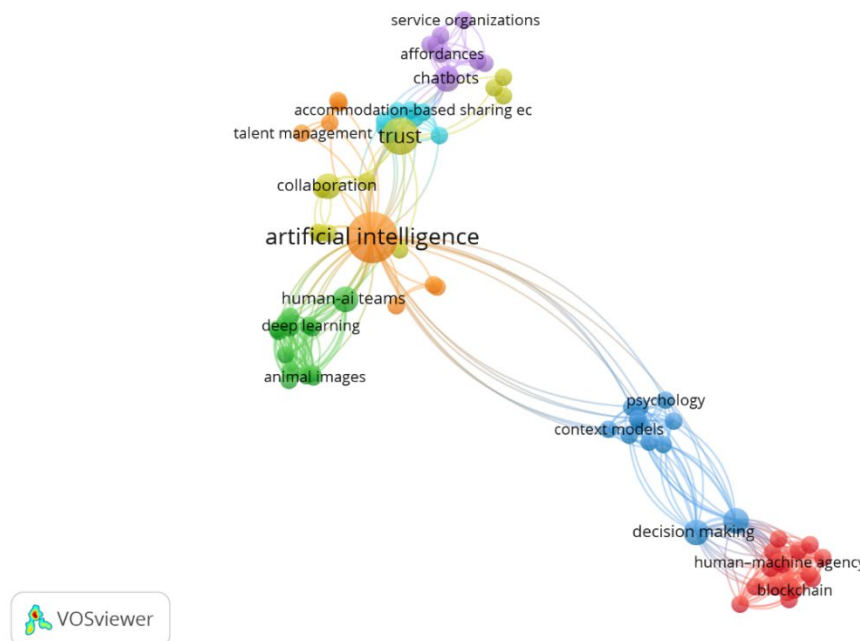
Interestingly, almost all identified articles were written by two or more authors. More precisely, the authorship landscape is a pretty diverse one, yet it still mostly focuses on Europe and the United States of America. Connected to this, using the country co-authorship analysis, it was shown that the authors from the United States of America are at the same time the most productive, leading with the highest number of publications and with the highest number of citations, which equals 174. In terms of the number of published articles, Finland and the Netherlands join in, making up the top three countries in this aspect, followed by Germany, China, and France with two articles each. The situation is slightly different when we analyse the authors from the aspect of citations. Despite American authors again climbing to the top, Turkish authors take the second spot with 107 citations with French (60 citations), Belarussian (46 citations), Finnish (41 citations), and Spanish authors (30 citations) behind them.

Afterward, the bibliographic coupling map was generated (Figure 3) with the aim of evaluating current trends in the field of interest concerning human-machine teams, detecting rising topics, and opportunities for new research. Namely, the map reaffirms Larson & DeChurch (2020) as the leading article whose references also appear in other flagship articles. Due to the lower number of articles, the circles are not closely connected, yet the links between the newer articles are evident including Jain et al. (2023), Alhaji et al. (2020), and more.



**Figure 3:** Bibliographic coupling map of bibliometric data

The keyword co-occurrence analysis identified seven distinct clusters of keywords interconnected with strong and less strong links. Undoubtedly, the keyword that appears the most is “artificial intelligence” (7 occurrences, 48 links, and 50 total link strength), followed by ‘trust’ (4 occurrences, 18 links, 19 total link strength). An overview of this analysis is provided in the network visualization map (Figure 4).



**Figure 4:** Network visualization map based on keyword co-occurrence analysis

The orange cluster dubbed “The role of artificial intelligence in human-machine teams” centres around the keyword “artificial intelligence” coupled with others such as “branding”, “middle manager”, “talent management”, “work characteristics”, and more. Literature pinpoints middle managers at the highest risk of layoffs as a result of digitalization in an effort to streamline the technology-mediated communication and coordination between first-level and top management (Leavy, 2023), especially in the service industry. Further, the articles in this research stream reaffirm the need for including social and relationship work characteristics in a new organizational workplace context where artificial intelligence can be perceived as both a tool and a coworker in the sense of a feeling and thinking AI (Koponen et al., 2023).

The yellow and light blue clusters represent “Facilitating and hindering factors of human-machine teams” focusing on “trust” which appears the most with a total link strength of 19, then “collaboration engineering”, “collaboration”, “trustworthy decision making”, “uncertainty”, “team composition”, and more. In this sense, trust lies at the heart of this new workplace collaboration in the form that employees should nurture trust that automated machines and intelligence can complete the tasks at hand efficiently and effectively while fulfilling the desired objective (La Torre et al., 2021). Illustratively, a prime example of that is seen in self-driving automobiles where drivers trust the vehicle will safely take them from point A to point B. Yet, trust is seen as a two-way street, meaning that machine intelligence should trust that the other side will complete the objective, too (Alhaji et al., 2020). Hence, researchers outline that perceived helpfulness, ease of use, and task-process fit can be impactful antecedents to trust in human-machine teams (Cheng et al., 2022).

The red cluster of keywords called “Decentralized human-machine collaboration” encompasses terms which are closely related such as “blockchain”, “dao”, “peer to peer networks”, “token”, “decentralization”, and similar. As blockchain technology gained ground, this meant that roles between teams could be more easily split, leading to higher rates of autonomy and decentralized decision-making (Santana & Albareda, 2022). This has led to the emergence of advanced human-machine agency, yet the new form of organizations called decentralized autonomous organizations or DAO, for short, enlist cloud storage and smart contracts that require human input (Beniiche et al., 2021). This highlights the need for an advanced and more fluid coordination between humans and technology, while still maintaining the crucial role of human employees.

Other notable keywords that are frequently interconnected with the rest are “chatbots” with a total link strength of 18 and “human-AI teams” with a total link strength of 17. Again, referring to service-oriented organizations, chatbots have been proven to increase the augmentation and automation of repetitive and mundane tasks, leading some researchers to view them as customer-service colleagues (Cheng et al.,

2022). Their appearance has resulted in new roles for AI-based teammates such as doers, creators, perfectionists, and coordinators (Siemon, 2022). It was deduced that humans and AI or chatbots can work together as a hybrid group where the technology contributes with a fast processing of information while humans are the ones that show empathy in the communication, assess the context, and act in accordance with it (Vassilakopoulou et al., 2023).

#### 4. FUTURE RESEARCH DIRECTIONS

The multitechnique bibliometric analysis and the review of the literature can result in the formulation of the following five opportunities for future research. Firstly, an *increased validation of models of human-machine trust and reliance* is needed considering that reciprocal trust and reliance shape the behaviour of both humans and machines in this workplace partnership (Ulfert et al., 2023). Consequently, if one party does not rely on the other and double-checks the work, this will slow down the collaboration process, leading to under-reliance; yet over-reliance may lead to the parties becoming less attentive and mindful of the mutual tasks (Vassilakopoulou et al., 2023).

Secondly, future researchers can dive deeper into *the team dynamics, interaction, and communication of human-machine teams*. Studying how team composition, communication strategies, and leadership styles influence the performance and well-being of human-machine teams, including research on team formation, coordination, and conflict resolution can be of further interest to the scientific and practitioners' communities (McNeese et al., 2021). This also ties in with exploring how humans and AI systems can interact more seamlessly and effectively, touching upon topics of natural language processing, gesture recognition, and other forms of human-computer interaction (Demir et al., 2020).

Thirdly, further research on *anticipating and acting on human perceptions and behaviours* can be a valuable contribution to the discourse keeping in mind the prevailing negative public perception and attitudes towards technology (Araujo et al., 2020). Since these attitudes, perceptions, and intentions shape the behaviours of the employees, it would be useful to find out what they are and how organizations that promote human-machine teaming can anticipate and model them to achieve great team fit.

Fourthly, future research on *ethical and social implications* can tackle the ethical, legal, and societal implications of human-machine teams, including research on privacy, bias, fairness, accountability, and the impact on employment and inequality (Turchin et al., 2019). These aspects consider the bigger picture surrounding these new types of teams and can deal with why and how these teams are formed with respect to widely acknowledged human rights.

Eventually, human-machine teaming research can transcend the current frameworks and boundaries so that the insights from the research on *integrated team formation across disciplines and in real-world scenarios* can be tested and applied to real-world domains such as healthcare, transportation, manufacturing, entertainment, and education (Wilkins et al., 2024).

#### 5. CONCLUSION

The research objective of this article was to analyse and synthesize the research trends in the literature so far regarding human-machine teams, through the identification of publication trends, emerging themes and hotspots, as well as directions for future research. This was achieved with the selected method of a structured literature review, analysis, and visualization of bibliometric data from the Scopus database following the rigorous PRISMA protocol. Considering the newness of the topic, the article provides useful implications for detecting the emerging research strands of the inception of human-machine teams in the workplace. It was found that the largest number of articles were published in 2023, confirming the rising trend in the topic. Furthermore, the themes surrounding this type of team so far have centred around AI as a common partner to human colleagues and trust as a factor that ties this collaboration together. The article also stresses five distinct areas for future research.

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## **ANNEX – OMITTED KEYWORDS FROM ANALYSIS (IN ALPHABETICAL ORDER)**

clinical research, design, developed model, index, industrial research, literature review, multidisciplinary, research champion, research work, review, state of the art, survey, theoretical study, types of research design

# THE IMPORTANCE OF DIGITAL TRANSFORMATION FOR THE MODERN CONSULTING INDUSTRY

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**Abstract:** *The development of new technologies and digital tools initiates certain changes in all business spheres. Modern organizations are faced with the challenges that begin to take different and more complex forms, so they often fail to cope with them without the help of consultants, from whom they expect advices and recommendations both on a strategic and operational level. On the other hand, the role of consultants is also evolving, because they must anticipate changes and identify business chances for their clients, but at the same time they must adapt their own business to digital trends in order to keep up and maintain competitiveness. This paper is based on a review of relevant literature related to this topic and it presents the key challenges for consulting organizations in the digital age, as well as the most significant changes in their approach during the consulting projects.*

**Keywords:** *Business Consulting, Digital Transformation, Changes, Challenges*

## 1. INTRODUCTION

The progress of technology in the second half of the 20th and at the beginning of the 21st century has provoked complex changes in the business environment, and therefore made significant impact on the role and importance of consultants in modern business systems. Currently the development of Industry 4.0 leads to the emergence of digitalization in various spheres and as such enables companies to orient themselves towards digital transformation (Krivokapić et al., 2023), which causes changes in the work methods, roles distribution and business offer that are results of the application of digital technologies in the organizations or in their environment (Parviainen et al., 2017).

Digital transformation affects the change in the value proposition of organizations (Piepponen et al., 2022) and/or their way of functioning, and thus creates preconditions for their development but also makes pressure for them to evolve quick enough in order to keep up with the complex demands from their business environment. Thanks to the use of modern technologies, organization should expect rationalization in some operational activities, which will lead to a reduction in the waste of available resources and consequently to the increase in productivity.

Bearing in mind the aforementioned characteristics of digital transformation, it is obvious that the challenges that the modern organizations are faced with have also changed, which led to the redefinition of the relationship between the consultants and their clients. As a result, consultants increasingly take on the task of designing a new way of working based on the application of new technologies and tools in client organizations. However, the consultants also need to adapt and improve their own approaches, capacities and knowledge so that they do not fall behind the modern trends arising from their business environment.

## 2. DEVELOPMENT OF THE CONSULTING INDUSTRY

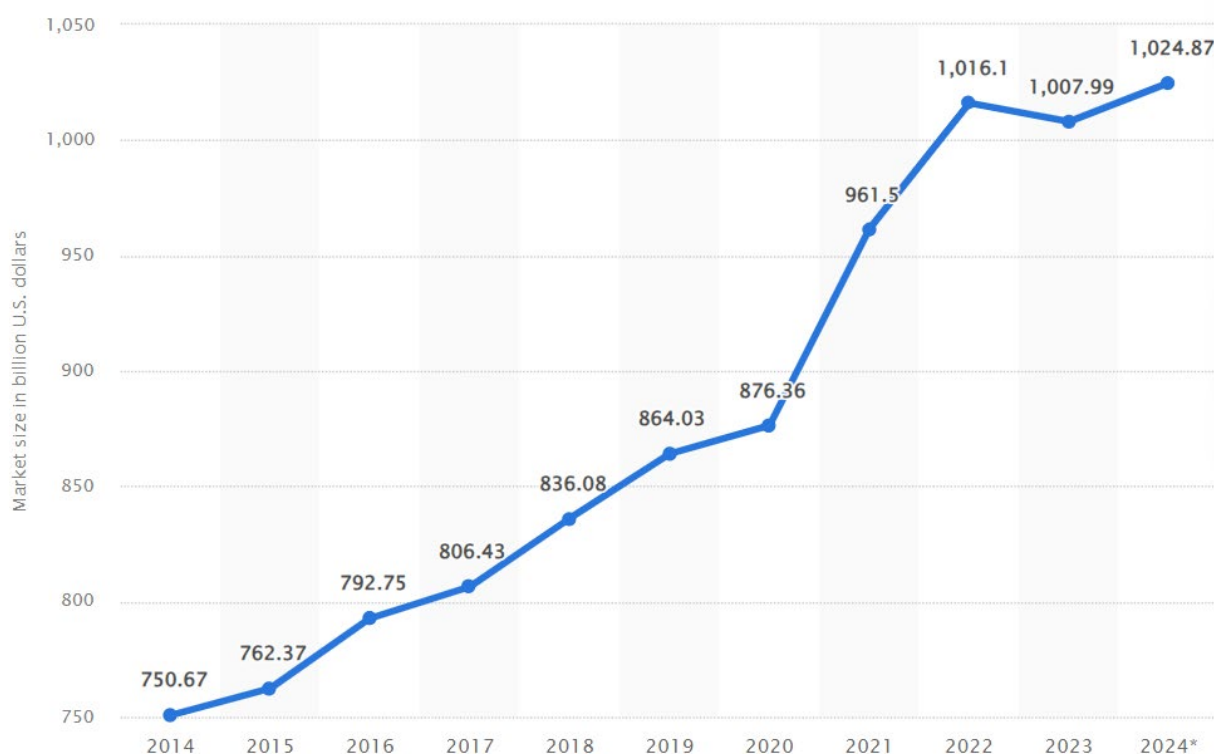
Although it is considered that the advice giving is practically as old as human society (Jerónimo et al., 2019) it can be said that consulting has had for a long time significantly different characteristics compared to what this term represents today. In ancient times and even in the Middle Ages consultants mainly had a role in providing specific advice to the rulers in order to facilitate their management and to help them make better decisions, primarily in a political sense. However, in the last couple of centuries, and especially after The First Industrial Revolution there has been a big turn in economic relations, which also affected the change in the role and importance of consultants (McKenna, 2006).



In the second half of the 19th century the pioneers of scientific management have based business development on the rational use of available resources and on the improvement of work processes, which consequently led to the increase in productivity. In that period consulting gains particular importance, and the growing number of published articles, books or practical experiments which were applicable in different organizations indicates high demand for the external experts that should provide certain help in designing and improving methods of work (Baaij, 2022). Although at the very beginning there was not too much attention related with the human factor, numerous studies have confirmed that the incentives that employees receive if they perform their work in an appropriate manner can be crucial in improving business performance (Jaško et al., 2013), which also influenced the change in the role of consultants at the time.

The consulting industry have experienced expansion after the Second World War, especially in war-torn Europe. Since the war has caused the reduction of not only material but also intellectual resources, organizations have increasingly decided to hire external experts from whom they expected to help in achieving and maintaining positive business results. During this period business consulting has gone through international expansion, and its main characteristics were a wider and more diverse range of services, growing competition, as well as the use of technologies and sophisticated analytical methods in the analysis and design of work methods (Kubr, 2002).

At the end of the 20th century the revolution in the IT sphere has brought another form of multidisciplinary approach by the consultants. Organizations were required to quickly adapt to a highly changing environment, which has led to the golden age for the consulting industry, with an annual growth of 15 to 20% in the first decade of the 21st century (Poultfelt et al., 2010).



**Figure 1:** Market size of the management consulting industry worldwide from 2014 to 2023, with a forecast for 2024 (in billion U.S. dollars) (Statista, 2024)

Today the consulting industry is at its peak, but the dependence of clients on the expertise of external experts is expected to continue to grow. In the last decade the size of the consulting market at the global level was increasing almost constantly, and a particular jump occurred due to the economic consequences caused by the coronavirus pandemic. In 2022 the market size of the consulting industry was at its maximum, but it is estimated that in 2024 it will be even above that level (Statista, 2024).

### 3. THE IMPACT OF DIGITALIZATION ON MODERN CONSULTING

Although it certainly provides some new opportunities, the rise of digital technologies requires companies to redefine their approaches and organizational priorities. Traditional systems are becoming inadequate as the focus changes and shifts to concepts that were not thought of before, as shown in Table 1. Organizational

characteristics that were previously desirable are becoming inefficient, so organizations are forced to approach strategic and operational modifications in order to adapt to the trends of modern business, and the application of new technologies plays a key role in this. On the other hand, technology is developing much faster than the organizations, so the gap between the speed of technological evolution and the dynamics of organizational adaptation of new solutions is getting larger (Watson et al., 2023). That fact creates special challenges for the management of modern companies, so they often decide to seek help from consultants, from whom they expect recommendations regarding the modality of adaptation.

**Table 1:** Essential differences between traditional and contemporary organizations (Figueroa, 2017)

Characteristics of the model	Traditional (classical) model	Contemporary model
Organization	Centralization and concentration	Decentralization
Shaping	Deep organizational structure	Shallow organizational structure
Range of control	A narrow range of control	A wide range of control
Adaptation	Rigid (hard) structure	Flexible structure
Task (concept ion)	Static organization	Innovative organization
Organizational structure	Bureaucratic (mechanistic) structure	Organic (adaptive) structure
Communication (authorization)	Authority of individual	Teamwork
Relationships	Disrespect of people	Respect of people
Processes	Management with people	Management of processes
Culture	Inexistence of a corporate culture	Existence of a corporate culture
Changes	Unwillingness to organizational changes	Readiness for organizational changes
Regulation	Federal structure	Confederation of enterprise
Management	Functional decentralization	Federal decentralization

Having in mind these observations it can be said that the relationship between consultants and clients is evolving in accordance with the following factors and trends (Radov, 2022; Fokina & Barinov, 2019; Guandalini, 2022):

- *Continuous digitization* - clients' business increasingly relies on available technologies and their role and importance in redefining operations that are performed daily, so the consultants are expected to identify solutions and tools that are compatible with the clients' specifics needs.
- *Decision-making based on large amounts of data* - data and information represent key success factor in all spheres of business, and consultants should help the client in their collection, analysis and application in order to make decisions that will affect the achievement of desired business results.
- *Constant pressure to redefine knowledge and skills* - employees are expected to quickly and efficiently adopt new trends, so consultants are designing training programs that are supposed to provide new knowledge and skills that need to be successfully accepted and applied.
- *Focus on the customer experience* - customer satisfaction is the basis for stable business, and consultants are expected to help clients to develop processes and systems with the customers in the middle.
- *Growth of automation* - automation has a huge impact on modern business, especially in repetitive processes, so the consultants teach clients how to implement modern technologies and improve efficiency and productivity in everyday work.
- *Emphasis on sustainability* - due to local and international regulations organizations are expected to operate in accordance with the principles of sustainability, and consultants help them to reduce the negative impact of their practices on the environment in which they perform their activities.
- *Increasing demand for specific skills* - the consulting industry is becoming more and more specialized, so the consultants with expertise in a certain sphere become more popular, and that leads to the combination of different types of consultants in the client organization, which can have positive effects because each one of them is particularly competent in his field, but it also requires coordination and harmonization of proposed solutions.

- *Increase in remote work* - although there is generally resistance to the acceptance of modern technologies in daily work, in the last few years it has been shown that remote work in most cases does not lag behind the traditional "face-to-face" model of cooperation, and that flexibility and easier coordination of meetings between consultants and clients based on modern technologies are something that can be increasingly expected in the future.

It is obvious that modern consultants are faced with new or redefined requirements and this fact can become challenging on many levels when looking at the bigger picture - apart from them striving to perform their mission and help clients achieve benefits in the new business environment, at the same time they have to adapt themselves to market trends and align their business in accordance with available technologies, which indicates the specific relationship that exists between the digital transformation and the modern business consulting (Crişan & Stanca, 2021). Digital transformation allows consultants to simultaneously help clients to adopt new ways of working and organizing, but also to optimize the use of new technologies in order to improve their own business results. By adopting new digital tools and technologies, consultants can improve their speed, accuracy and applicability of their solutions, which gives them a competitive advantage in the consulting market.

Having all this in mind it can be said that the digital transformation has also caused significant changes in the design and implementation of consulting projects - not only in the described relationship between consultants and clients, but also internally, in the way that the consultants work. Modern technology irrevocably redefines the consulting industry, its projects and methods since it provides (Larsson et al., 2019; Nissen, 2018; Bayati, 2019; Tavoletti et al., 2022):

1. *Increased possibility to collect large amount of data* - the use of digital technologies makes it possible for consultants to collect a significantly larger amount of data that is (or relatively easily can become) structured in a form that is suitable for different types of analysis, and as such allows identification of different behaviour patterns, trends or potentials.
2. *Better support for problem analysis and the use of more complex analytical methods* - the phasis of processing collected data becomes easier and more accurate, and consultants who are trained to use advanced analysis methods can relatively easily come to the results and conclusions that are not achievable by the traditional analysis methods since they would require significantly more time and effort.
3. *New chance to ask the right questions* - given that the processes of problem analysis and solution design are interwoven and interdependent, previously described analysis allows consultants to go back if necessary, and to improve the diagnosis in the light of new discoveries and knowledge, so that they can provide better solutions for their clients with the right additional questions.
4. *The possibility of cooperation through virtual consulting teams* - modern communication platforms lead to the breaking down of barriers and enable cooperation that does not recognize physical or time boundaries, and thus promotes work in real time with the rational use of available resources.
5. *Conditions for the automation of activities and the use of artificial intelligence* - new technologies help consultants to identify and clearly separate simple from creative activities, to automate those that are repeated, and to shift their focus to complex ones that are crucial in order to create and maintain advantage on the market, while artificial intelligence can help, although still within limited frameworks, to improve support in business decision-making models.
6. *Cloud platforms that enable better organization and coordination of work* - Cloud platforms allow consultants to safely use, update and store large amounts of data at the same time, which contributes to a better and faster exchange of information and affects the quality of designed consulting solutions.

On the other hand, there are numerous challenges that can make consulting projects based on digital transformation difficult, and they are most often reflected in the necessity of constant learning and acquisition of new skills and knowledge, as well as in the pressure to develop high-quality solutions that will enable performance improvement. In addition, the successful application of consulting solutions based on digital technologies is complicated by the fact that, despite the attractiveness and increasing availability of new work methods, many client organizations still do not want to fully adapt to them, so consultants must constantly balance between the application of traditional and modern tools and technology (Tretyakov, 2022). Finally, the challenge lies in the reliability of using new tools in everyday business (Brunetti et al., 2020), because clients want to be sure that these new technologies are fully aligned with their needs, and that they will work as expected, which requires careful planning, critical analysis of own abilities and capacities and precise design of solutions that consider all the specifics of the company itself. Because of all this, digital transformation in consulting is a challenging venture, but inevitable for all those experts who seek

a way to survive in the modern business environment, to maintain competitiveness in their market and to improve business performance.

#### 4. CONCLUSION

Main findings presented in this paper are based on a review of relevant literature and thus can serve as a theoretical basis for future empirical and practical research on this important topic since the digital transformation has significantly influenced the development of business consulting as it has reshaped the consulting focus, the way in which the consultants cooperate with clients and the technological features of the solutions they provide. Advanced technologies and tools have brought new chances and challenges in this industry, which requires quick adaptation and development of special knowledge and skills from the consultants. Thanks to the new technology, their efficiency increases, since they have at their disposal better methods of collecting and processing a large number of data essential for analysing problems and designing consulting solutions. Interaction with the clients has also redefined its form, which has led to better time management, as well as to lower operating costs for consulting projects. In addition, digital transformation has enabled consultants to become more attractive to potential clients thanks to their own capability to adapt to the changing environment, their usage of modern digital tools and artificial intelligence, and thus their competitive advantage in comparison with other consultants. It can be concluded that digital transformation certainly represents one of the prerequisites for the consultants' further development since it helps them to improve their image on the consulting market, which continues to grow and change in accordance with economic, political and social trends both at the local and the global level.

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# PORTER'S DIGITAL VALUE CHAIN: A STRATEGIC ROADMAP FOR DIGITAL TRANSFORMATION

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**Abstract:** *Digital transformation is rapidly becoming a fundamental aspect for the growth and management of businesses across various sizes and sectors, offering numerous advantages. However, statistics indicate a high failure rate among these initiatives. In response to this challenge, this study conducted an extensive literature review and developed Porter's Digital Maturity Model based on Porter's Digital Value Chain. This model includes seven dimensions and six levels of digital maturity and was validated through interviews with experts across different industrial sectors. The model is detailed, comprehensive, suitable for various companies and industrial sectors, and adapts to different development stages across various company departments and matches the company's strategic goals. This model enables companies to accurately assess their digital maturity level, understand the digital landscape and contemporary requirements, and successfully execute digital transformation. It also enriches the available literature on digital transformation and digital maturity models.*

**Keywords:** *Digital Transformation, Digital Maturity Model, Porter's Digital Value Chain Model*

## 1. INTRODUCTION

Digital transformation has become crucial, especially as the COVID-19 pandemic forced increased online activities by limiting physical interactions. The economic crisis in May 2020 led to widespread business closures and about 200 million projected job losses (United Nations, 2020), accelerating digital transformation across industries as a key factor for sustainable economic growth (Shanti et al., 2023). This transformation brings numerous benefits, such as improved efficiency and higher profits, making it essential for business growth and management across all sectors.

Digital transformation refers to the incorporation of digital technology across every aspect of a business (Horlach et al., 2017). This transformation enhances or replaces traditional functions, leading to improvements in areas like productivity, sales growth, and customer collaboration.

A common method for evaluating a company's digitalization needs and capabilities for digital transformation is through maturity models. The purpose of a Digital Maturity Model (DMM), which is structured as a series of maturity levels, is to assess and compare an organization's current maturity against a desired level (Haryanti et al., 2023). According to Web of Science, there are 13,515 papers focused on DMM, with 81% of these papers published in the last five years. Despite the widespread availability of these models in the literature, Deloitte reports that 70% of digital transformation projects fail (Daskal, 2022). According to Senna et al. (2023) existing DMMs often face challenges in terms of their generalizability and theoretical foundations, so further research is needed.

Digital transformation reshapes how value is created and leads to new digital business models (Matt et al., 2015). Recognizing a need for empirical evidence, Holopainen et al. (2023) investigated how companies adapt their processes to benefit from these technologies, and Margiono (2020) studied changes in value creation methods. Given the lack of theoretical foundations in existing Digital Maturity Models (DMMs) and the emphasis on value creation, Porter's value chain model (Porter, 1985) is noted as both popular and effective (Nagy et al., 2018). However, out of 315 papers on Porter's value chain indexed by Web of Science, only 12 apply this model in the context of information technology, indicating a significant research gap and suggesting a direction for further research.

Therefore, this study contributes to overcoming previously mentioned challenges and addresses gaps in the literature in the following ways:

- (1) Developing a descriptive digital transformation maturity model based on digitalized Porter's Value Chain model, focusing on value creation.
- (2) Creating a theoretically founded model which assist organizations in successfully navigating digital transformation.
- (3) Creating a model which can easily adjust to specific industries and companies.

This paper is structured into five sections. Section two offers a literature review, covering digital transformation, organizational changes, digital maturity, and existing theories related to this topic. The methodology used in this study is detailed in the third section. The fourth section of the paper will introduce the model and its validation. Subsequent sections will analyze the model, discussing its theoretical and practical implications, suggesting directions for future research, and concluding the study.

## **2. LITERATURE REVIEW**

### **2.1. Digital Transformation**

In the era of the fourth industrial revolution, digital transformation (DT) significantly impacts both business and everyday life, highlighting the pervasive influence of digitalization across all aspects of society (Mitrovic et al., 2022). Traditional business processes and approaches are adapting to meet the demands of DT (Imran et al., 2021), integrating advanced technologies like artificial intelligence, the Internet of Things (IoT), blockchain and cloud computing. These technologies foster significant operational changes, enhancing customer experiences, streamlining operations, and fostering new business models (Shanti et al., 2023). Given these advantages, DT has emerged as a crucial strategic priority for industries.

Previous research suggests that for DT to be effective and fully realized, it should be evaluated from various angles: technology usage, organizational barriers, structural adjustments, and changes in value creation (Matt et al., 2015; Holopainen et al., 2023). DT fosters exceptional performance by influencing organizational elements both internally and externally (Shanti et al., 2023). This often involves major changes to key business functions, impacting products, processes, and organizational structures. Organizational structures should be adapted according to the scale of change. For minor transformations, new operations can be strategically integrated into existing frameworks (Holopainen et al., 2023).

### **2.2. Organizational changes driven by Digital Transformation**

Shifting towards digital activities allows organizations to diversify and enhance their offerings but also brings challenges. These challenges include the need for new technological skills and higher risks from inexperience in digital areas. Structural changes within the organization may be necessary to support these new digital initiatives, impacting the organizational setup, products, processes, and skill requirements (Matt et al., 2015). According to Matt et al. (2015), digital transformation is considered a strategic issue that significantly impacts various business areas, expanding beyond company borders to affect processes, products, production, supply chains, and sales channels.

The integration of modern technologies in business often leads to significant changes in value creation, impacting the traditional value chains. To stay competitive, organizations are updating their traditional ways of creating value by adopting various digital technologies (Imran et al., 2021). These changes underscore the broad and transformative effects of digital technology on businesses.

### **2.3. Theoretical Foundations of Digital Transformation's Impact on Organizational Change**

The link between technology implementation and organizational transformation is a well-established topic in the literature through several theories.

As Leonardi (2013) explains, sociomaterial theory argues that the material aspects of technology and social interactions are inseparable. This theory suggests that although society influences technology's design and function, once technology is created, it is treated as a fixed entity that people must adapt to in daily life (Leonardi, 2013). However, sociomaterial theory may not be entirely suitable for studying organizational changes influenced by digital transformation because it focuses on the interaction between technology and social practices only at a local level, making distinction between humans and technology unacceptable (Orlikowski & Scott, 2008).

Bruno Latour's actor-network theory (ANT) merges the social and material realms, seeing them as interconnected (Latour, 2005). However, Modell (2019) argues that ANT focuses too much on individual

actions and misses the broader social structures that shape organizational changes, like DT. This critique points out ANT's limitation in addressing the deeper complexities of structural dynamics.

According to structuration theory, social structures (like organizational structures) are both shaped by and shape human actions. However, Jones and Karsten (2008) argue that the theory doesn't sufficiently address how technology itself can influence social structures or lead to significant organizational transformations.

Sociotechnical systems (STS) theory highlights that organizational changes should account for both technical and social factors, recognizing the organization as an interconnected system where changes in one part can affect others. This comprehensive view includes the organization's structure, culture, and skills, aiding in managing the transformations triggered by technological progress (Imran et al., 2021), making STS theory an effective framework for this study.

2.4. Digital Maturity

In relation to the DT, digital maturity is essential. Digital maturity reflects an organization's current ability to effectively use digital technologies to boost innovation, efficiency, and competitiveness (Johnson & Uwaoma, 2023).

The terms “readiness” and “maturity” describe different stages in assessing an organization's progress towards digital transformation. “Readiness” is a preliminary check to determine if an organization is prepared to start development. It assesses the initial capability to engage in digital transformation processes. In contrast, “maturity” refers to evaluating the organization’s current state and its level of sophistication in digital capabilities. This helps in measuring how far an organization has come in integrating digital technologies into its operations (Haryanti et al., 2023).

Maturity models guide organizations through digital transformation by evaluating digital capabilities and identifying areas for improvement (Johnson & Uwaoma, 2023). As Johnson and Uwaoma (2023) explain, these models act as roadmaps for change and tools for assessing digital strengths and weaknesses, aiding in strategic planning and enhancing business agility. They also track progress across various maturity stages, ultimately improving business capabilities.

3. METHODOLOGY

The maturity models development method involves three stages (Figure 1).

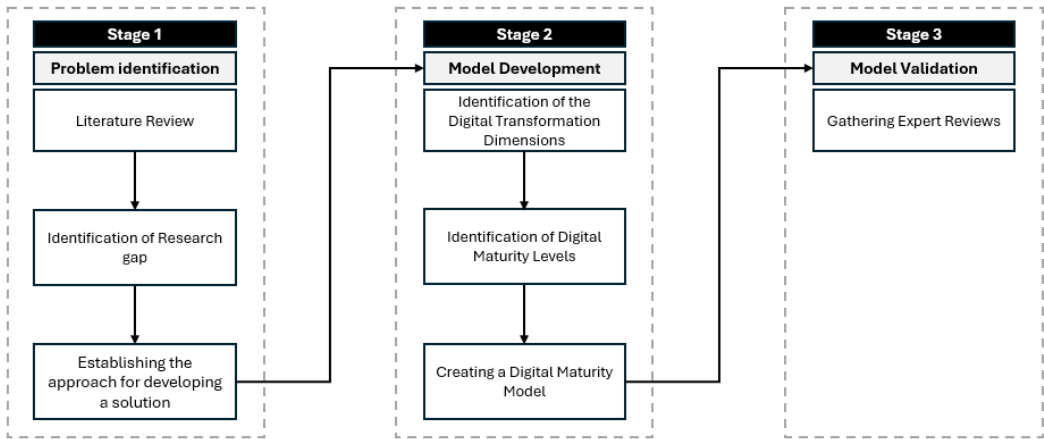
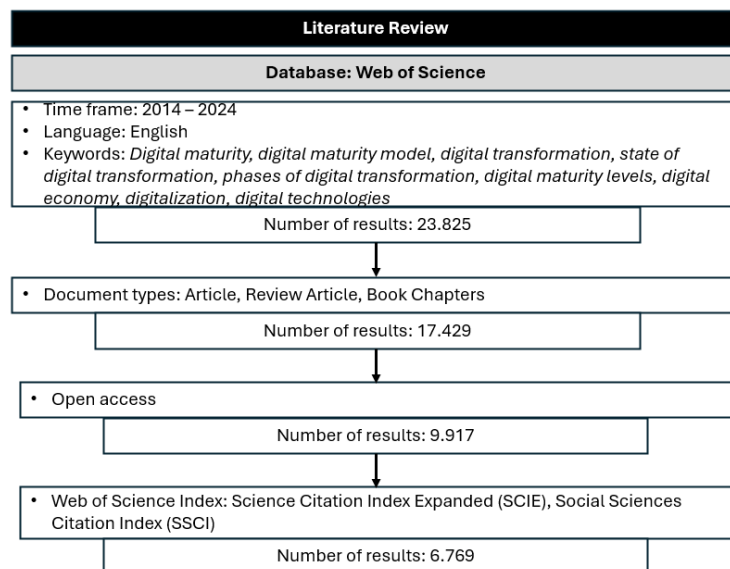


Figure 1: Model development process

The first stage involves identifying the problem, starting with a Literature Review conducted through the Web of Science, as illustrated in Figure 2.

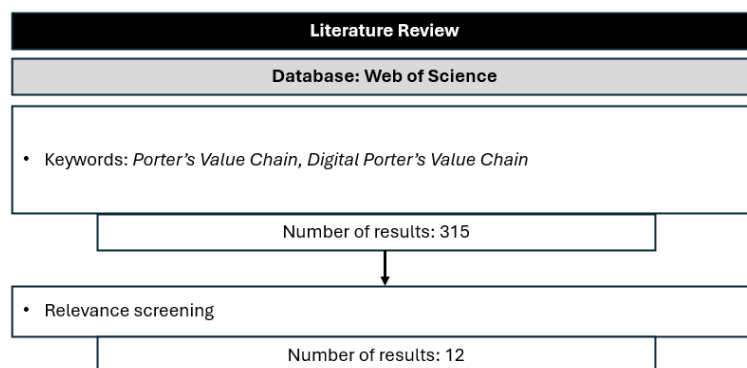




**Figure 2:** Literature Review process

The results were sorted by relevance, so the reading began from the start. The literature review highlights that existing DMMs often struggle with generalizability and theoretical foundations (Senna et al. 2023). These models typically evaluate digital maturity uniformly across the entire organization. This method may overlook variations between different organizational areas, where some might be more digitally advanced than others, thus highlighting the first research gap.

As discussed in the previous chapter, digital transformation necessitates organizational changes, particularly in how value is created and in modifying existing processes and procedures (Matt et al., 2015). This prompted further exploration of models focused on value creation, leading to the adoption of Porter's Value Chain model (Porter, 1985). Given the focus on digital transformation, the research examined how many studies incorporating Porter's Value Chain model applied it within the context of information technology (Figure 3) which led to the identification of the second research gap.



**Figure 3:** Literature Review process – Porter Value Chain Model

The final activity of the first phase is to determine the approach for developing a solution. After an extensive literature review, it was decided that the final model will be based on a Digitalized Porter's Value Chain Model. This model will feature multiple maturity levels, the significance of which was outlined in the previous chapter.

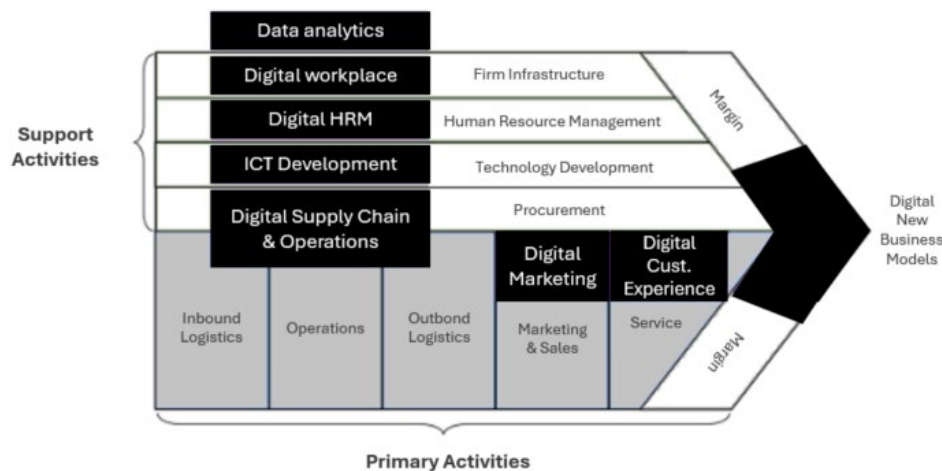
The second stage, Model Development, involved defining Digital Transformation Dimensions using Porter's Digital Value Chain Model and establishing suitable digital maturity levels to create the digital maturity model. These segments will be explained in detail in the next chapter.

The third stage, Model Validation, involved gathering assessments from three industry experts to obtain a comprehensive view of the model. After a 2–3-day review period, we conducted brief 30-45 minutes online interviews with each expert to gather their insights on the model's functionality, application, strengths, and weaknesses. The initial feedback from these interviews is summarized in the "Model Validation" chapter.

### 3.1. Porters' Digital Value Chain Model

The value chain model was first introduced in 1985 by Porter in his book, "Competitive Advantage: Creating and Sustaining Superior Performance" and since then has become one of the most widely used models when it comes to value creation and perception of different sectors and activities in companies. This model outlines the series of activities from pre-production to delivery that form the value chain. Organizational activities are categorized into primary and support activities, which together contribute to the organization's profit margin (Porter, 1985).

According to reports from consultancy firms and scientific literature, DT impacts all organizational activities, which are categorized as either primary or support activities by Porter's Value Chain Model. This perspective has led to the enhancement of Porter's framework into the "Digital Value Chain Model" (Figure 4) applicable across various industries. Key digital activities enhancing value and competitive advantage include digital customer experience, supply chain and operations, marketing, human resource management (HRM) and workplace, with information and communication technology (ICT) development and data analytics as crucial enablers (Türkmen & Soyer, 2019). These activities represent seven dimensions in our model (Figure 6 and 7).



**Figure 4:** Porter's Digital Value Chain Model

### 3.2. Maturity Levels

A maturity level is a classification within a maturity model that describes the degree to which an organization has refined and optimized its processes, behaviors, or capabilities. Each level typically represents a specific stage of an organization's development, where higher levels indicate more advanced and mature practices. Maturity models help organizations assess their current state, benchmark against best practices, and identify areas for improvement to achieve higher performance and efficiency. Over half of existing maturity models include maturity levels (Haryanti et al., 2023), so they will be included in our DMM as well.

Ilin et al. (2022) conducted extensive research on existing maturity models, including SW CMM, CMMI, ISO 15504, COBIT 4.1, SPICE PMMM, OPM3, and BPMM, identifying five maturity levels plus a level 0. Each level is detailed, covering aspects of processes, technologies, and employee characteristics. Due to its comprehensiveness and thoroughness in addressing these factors, this framework was selected for this research. Levels are shown in Figure 5.

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Basic infrastructure	Computerization	Connectivity	Transparency	Predictiveness	Adaptability
<b>Digital Integration:</b> None <b>Infrastructure:</b> Basic IT setup (industrial Wi-Fi, local networks). <b>Digital Skills:</b> Not required for employees. <b>Data Use:</b> No real-time; decisions rely on historical data.	<b>Process Digitalization:</b> Paper forms eliminated; processes executed via digital interfaces. <b>Data Automation:</b> Automated data transfer. <b>System Implementation:</b> Basic production and enterprise management systems in place. <b>System Integration:</b> Systems integrated for automatic data transfer. <b>Employee Training:</b> Employees trained on system use within their roles.	<b>Digital Factory Implementation:</b> Formalized approach to building the digital factory. <b>External Connectivity:</b> Processes to engage external actors for enhanced connectivity. <b>System Integration:</b> Strategic integration of current and future technologies. <b>Information Consolidation:</b> Unified information space and integrated data streams. <b>Employee Involvement:</b> Employees engaged in shaping the digital vision. <b>Role Definition:</b> Clear role separation and recruitment of skilled personnel in business, IT and production.	<b>Data Flow Management:</b> Formalized management processes for data flow. <b>Knowledge Exchange:</b> Established processes for active knowledge sharing <b>Data Mining:</b> Implemented data mining systems. <b>Systems Integration:</b> Integrated new systems for key business operations. <b>Employee Training:</b> Trained employees on system data handling and enhanced digital competencies.	<b>Audit Development:</b> Established audit processes. <b>Optimization Procedures:</b> Introduced regular optimization initiatives. <b>Activity Analysis Systems:</b> Implemented real-time systems for automated analytics, alerts, recommendations. <b>Digital Twins*:</b> Deployed digital twins for prototyping and optimization testing. <b>Cross-functional Collaboration:</b> Organized cross-functional sessions to address urgent issues and optimization. <b>Digital and Data Experts Recruitment:</b> Attracted additional digitally skilled employees.	<b>Autonomous Decision-Making:</b> Developed processes for systems to make autonomous decisions. <b>Forecasting and Planning:</b> Established regular processes for forecasting and production planning. <b>External Data Integration:</b> Integrated data from suppliers and buyers. <b>Artificial Intelligence Use:</b> Utilized artificial intelligence systems. <b>Culture of Innovation:</b> Fostered a culture of continuous improvement and innovation.

Figure 5: Digital Maturity levels

\*Digital twins are virtual models of physical entities, which allow real-time monitoring and optimization.

#### 4. PORTER'S DIGITAL MATURITY MODEL

Porter's Digital Maturity Model consists of seven dimensions and five levels of digital maturity, plus Level 0. The model is presented in Detail in Figure 6 and 7. In the model, explanations in squares represent DT implementation strategies which are programs or sequences of projects rolled out across the organization, enabling it to progress through various levels of digital maturity. Each iteration of DT will progressively reshape the business process by enhancing key business capabilities and gradually increasing digital maturity levels over time. The successful implementation of each strategy constitutes the transformation journey itself.

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
	Basic infrastructure	Computerization	Connectivity	Transparency	Predictiveness	Adaptability
Digital Supply Chain & Operations	<ul style="list-style-type: none"> <li>-Basic IT setup (industrial Wi-Fi, local networks)</li> <li>-No required additional digital skills for employees</li> <li>-No real-time data use; decisions based on historical data</li> </ul>	<ul style="list-style-type: none"> <li>-Electronic Document Management</li> <li>-Utilized digital interfaces to execute manufacturing operations</li> <li>-Installed and integrated basic production management systems</li> <li>-ERP Integration</li> <li>-Real-time inventory tracking systems</li> <li>-Automated supplier interactions</li> <li>-Introduced Cloud platforms</li> <li>-Employees are educated on new system functionalities.</li> </ul>	<ul style="list-style-type: none"> <li>-Secure and efficient communication channels with external partners and vendors</li> <li>-Secured compatibility between old and new systems and machinery</li> <li>-Created a uniform platform for all operational data</li> <li>-Easy data access across departments</li> <li>-Employees involved in digital strategy planning</li> <li>-Updated older machinery with new sensors, controllers, or interfaces</li> </ul>	<ul style="list-style-type: none"> <li>-Uniform standards (network) for data handling (exchange) throughout the supply chain</li> <li>-Systems for sharing insights and updates between departments and partners</li> <li>-Implemented real-time dashboards to monitor and manage manufacturing workflows</li> <li>-Staff trained on the latest digital tools and systems</li> <li>-Knowledge about supply chain innovations and production efficiency is actively managed and shared</li> </ul>	<ul style="list-style-type: none"> <li>-Introduced real-time monitoring systems that provide instant analytics, alerts, and actionable insights</li> <li>-Implemented rigorous audit processes</li> <li>-Utilized digital twins to simulate key business processes</li> <li>-Recruited digital and data experts</li> <li>-Conducted regular cross-functional meetings</li> </ul>	<ul style="list-style-type: none"> <li>-Implemented systems that autonomously manage inventory levels and order fulfillment</li> <li>-Data-driven forecasting processes for supply and demand planning</li> <li>-Real-time data exchanges with suppliers and buyers</li> <li>-Employed AI to enhance logistics planning, demand forecasting, and operational efficiency</li> </ul>
Digital Marketing	<ul style="list-style-type: none"> <li>-Basic IT setup (industrial Wi-Fi, local networks)</li> <li>-No required additional digital skills for employees</li> <li>-No real-time data use; decisions based on historical data</li> <li>-No active use of digital tools or platforms for marketing purposes</li> </ul>	<ul style="list-style-type: none"> <li>-Transitioned all marketing forms and processes to digital interfaces</li> <li>-Implemented essential marketing systems</li> <li>-Trained marketing staff on new digital marketing systems and tools</li> </ul>	<ul style="list-style-type: none"> <li>-Integrated marketing technologies</li> <li>-Centralized customer data from multiple channels</li> <li>-Defined and recruited roles for digital marketing, analytics and IT support</li> </ul>	<ul style="list-style-type: none"> <li>-Leveraged data mining to uncover customer patterns</li> <li>-Integrated network for cross-departmental marketing and sales data sharing</li> <li>-Upgraded the team's digital skills with a focus on data-driven marketing</li> </ul>	<ul style="list-style-type: none"> <li>-Implemented systems for instant marketing metrics</li> <li>-Collaborative sessions between departments</li> <li>-Recruited expert data analysts for advanced marketing data insights</li> </ul>	<ul style="list-style-type: none"> <li>-Adopted AI for customer segmentation and personalized marketing</li> <li>-Encouraged creative marketing approaches and experimentation</li> </ul>

Figure 6: Digital Maturity Model (part 1)

<b>Digital Customer Experience</b>	-Basic IT setup (industrial Wi-Fi, local networks) -No required additional digital skills for employees -No real-time data use; decisions based on historical data -No active use of digital tools or platforms for CRM	-Automated customer data collection and processing -Implemented CRM systems for customer insights -Integrated customer service platforms -Trained staff on digital tools for customer engagement	-Partner and platform integration -Employees involved in customer experience process innovation -Defined and filled specialized roles focused on digital customer experience	-Built a network for cross-departmental customer data exchange -Integrated customer experience platforms -Utilized data mining for customer behavior analysis -Enhanced quality of customer data	-Implemented systems for live customer experience analytics -Used digital twins to test and enhance customer journeys -Hired data specialists to deepen customer insights	-Integrated external data -Employed AI to personalize and enhance the customer journey
<b>ICT Development</b>	-Basic IT setup (industrial Wi-Fi, local networks) -No required additional digital skills for employees -No real-time data use; decisions based on historical data	-Streamlined data transfer across ICT systems -Ensured all ICT systems communicate seamlessly for data coherence -Educated employees on the functionalities and usage of new ICT systems	-Established processes to connect with technology partners and service providers -Actively involved ICT staff in developing and refining the technology roadmap -Defined and filled key ICT positions	-Set up active knowledge exchange among ICT team members -Ensured seamless integration of all ICT systems -Focused on upgrading the digital competencies of the ICT workforce -Deployed data mining systems	-Regularly launched initiatives to refine ICT processes -Facilitated cross-departmental discussions for ICT enhancements -Recruited expert data analysts for advanced ICT insight	-Implemented systems for independent ICT decision-making -Deployed AI to optimize network and data management -Promoted a culture of innovation within the ICT department
<b>Digital Human Resource Management</b>	-Basic IT setup (industrial Wi-Fi, local networks) -No required additional digital skills for employees -No real-time data use; decisions based on historical data -No active use of digital tools or platforms for HRM purposes	-Converted all HR documents to e-formats and implemented digital submission and processing -Linked payroll, benefits, and employee databases for automatic updates -Deployed a HRM System for centralized HR operations	-Merged all employee data into a single HR information system -Employees involved in developing and refining HR digital transformation strategies -Defined and filled roles for digital HR, data analysis, and HR IT support	-Established standardized data management procedures for HR -Set up systems for sharing HR insights and practices -Enhanced HR team's skills in digital system usage	-Regularly refined HR practices for enhanced efficiency -Applied real-time analytics for HR metrics -Organized joint sessions for collaborative HR strategy development and issue resolution	-Implemented tools for predictive workforce planning and talent needs forecasting -Merged external labor market data into HR planning strategies -Applied AI to improve recruitment, retention, and employee engagement
<b>Digital workplace</b>	-Basic IT setup (industrial Wi-Fi, local networks) -No required additional digital skills for employees -No real-time data use; decisions based on historical data	-Shifted all administrative and operational forms to digital formats -Utilized software that automatically updates records, processes requests, and manages document flow without manual input -Deployed central systems like Enterprise Resource Planning (ERP)	-Crafted a detailed plan to digitize workplace operations -Adopted collaboration tools like VPNs and cloud services to securely connect with external stakeholders -Merged various work systems (like Slack, Asana, Salesforce) -Created a central data storage system, like an intranet	-Built an interconnected system for seamless data sharing across departments -Deployed Business Intelligence tools for deep data analysis -Encouraged the creation and use of a centralized knowledge base	-Initiated systematic reviews and optimizations of digital processes to enhance workplace efficiency -Integrated systems that analyze workplace activities in real-time -Organized sessions using collaborative digital platforms	-Implemented systems which enable automatization of routine administrative tasks -Utilized advanced planning tools to predict future workload and resource requirements
<b>Data analytics</b>	-Basic IT setup (industrial Wi-Fi, local networks) -No required additional digital skills for employees -No real-time data use; decisions based on historical data	-Converted all manual data recording to digital interfaces -Automated the transfer of data between systems -Installed essential analytics and data management systems -Ensured all data systems are interconnected	-Built robust analytics infrastructure -Formed partnerships for direct access to external databases -Aggregated all organizational data into one platform -Recruited and clearly defined roles for data analysts, data scientists, and business intelligence specialists	-Constructed a central hub for secure data exchange among different business units -Implemented processes to cleanse data sets -Provided courses to improve skills in data analytics	-Initiated thorough checks on analytics processes and data integrity -Implemented systematic enhancements to analytical methods	-Instituted regular use of predictive models for accurate forecasting of business trends and resource needs -Fused external data sets, into internal analytics processes -Integrated AI algorithms to process large data sets

Figure 7: Digital Maturity Model (part 2)

#### 4.1. Model Validation

For the initial validation of the model, experts were interviewed, and their demographic characteristics and comments are presented in Table 1.

Table 1: Model Validation – Expert Interview Review

Expert	Education Level	Industry	Years of Experience	Strength/Weaknesses	Comments
1	PhD	Paper	15	<b>Strengths:</b> Applicable for all service industries that require a clear "guide" to digitalization to optimize/improve their processes and provide better service to their clients. <b>Weaknesses:</b> Needs more focus on traditional manufacturing activities, levels 4 and 5 are very challenging for manufacturing industries	<i>"The model has been meticulously prepared and thoroughly explained. The model is particularly suitable for the IT sector and similar service industries like online marketplaces."</i>
2	Master	Information Technology	7	<b>Strengths:</b> Well-detailed, strong emphasis on enhancing connections within and outside organizations, adaptable to different company types, emphasizes employee education <b>Weaknesses:</b> High implementation costs, challenging for small and medium-sized enterprises	<i>"The model is easily applicable and very detailed. When applying this model, both global and local specifics should be considered."</i>
3	Bachelor	Supply Chain & Logistics	12	<b>Strengths:</b> Very comprehensive model, it is clear what the next	<i>"The Model should include elements of sustainability"</i>

steps are in the progression process, transparency is often highlighted	<i>and scalability of implemented technologies. Anyhow it is very useful for high-level managers"</i>
<b>Weaknesses:</b> It is not always easy to determine the benefits or the return on investment	

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## 5. DISCUSSION

Assessing process maturity helps understand how well processes are managed and optimized. As companies evolve, they progress through stages with distinct management and strategic traits. Each maturity level prepares for effective process implementation at the next stage. Since not all companies fully grasp the digital landscape, a comprehensive assessment reveals potential growth. Understanding where the company stands helps in formulating a successful strategy (Ilin et al., 2022).

If an organization isn't willing to change its operations, DT will likely fail (Tabrizi et al., 2019). That is why Porter's Digital Maturity Model integrates several types of operations in the organization, categorizing as primary and support activities according to Porter (1985). Taking into consideration that the main topic of the research is DT, activities included in the model are based on Porter's Digital Value Chain Model developed by Türkmen and Soyer (2019).

The model provides general guidelines and is adaptable to various companies and industrial sectors, allowing companies to position themselves at a certain level depending on specific activities. Unlike previous models that require a company to position itself at one level (Johnson & Uwaoma, 2023; Kozina, 2019; Haryanti et al., 2023) based on overall digitalization, the advantage of this model is that it considers the varying degrees of development across different departments within the company and the company's strategic orientation as in research conducted by Kirmızı & Kocaoglu (2022). For example, a company operating in the paper industry may not have a strong need for marketing (or not at all), so it would position itself at level 0 or 1 for Digital Marketing activities, but at level 3 or 4 for Digital Supply Chain & Operations.

According to feedback from experts, the Porter's Digital Maturity Model effectively allows managers to accurately assess their company's digital maturity level. Using the model's detailed descriptions, they can formulate digital strategies and plan their next steps (Matt et al., 2015). Experts also note that the model is very adaptable to different industries and is not generalized, which is one of the shortcomings mentioned in the literature (Senna et al., 2023) that we aimed to overcome. According to expert opinions, the current version of the model is best suited for service industries, and future models could be redesigned to be more suitable for other industries. Certainly, the specificity of the model for each industry should be aimed for, as Expert 1 points out the fact that digital development in certain industries is more financially intensive than in others (Gandhi et al., 2016). Therefore, reducing the level of requirements due to the amount of money to be invested and the complexity of the process itself is necessary.

Digital transformation reshapes how value is created, leading to new digital business models (Matt et al., 2015). Recognizing a gap in literature, Holopainen et al. (2023) and Margiono (2020) have explored changes in value creation methods. Our work has addressed and bridged this gap by integrating the Digital Porter's Value Chain (Türkmen & Soyer, 2019), ensuring a concentrated focus on value creation within digital transformation.

In Sociotechnical Systems theory, both social and technical elements need to collaborate effectively to achieve organizational goals. Our findings show that employees, processes and technology are all crucial for achieving performance outcomes in digital transformation (Imran et al., 2021), incorporating them in every level and every dimension. This integration drives the organization toward common goals like adaptability and transparency.

## 6. LIMITATIONS AND FUTURE WORK

One of the biggest drawbacks of the new model lies in its complexity. It remains to be explored how applicable the proposed model is in practice and how understandable its application will be for practitioners. Furthermore, the complexity of the model reduces its flexibility.

Secondly, the model's evaluation was limited to only three experts, which may not provide a comprehensive assessment. Future research could involve further validation of the model by conducting additional interviews, enabling real-world use in various industries. Additionally, the model could be tailored specifically for all industries.

Lastly, the application of the proposed model should be linked to strategic analysis and organizational development directions in further research, in order to better determine priorities for organizational development and digital transformation.

## 7. CONCLUSION

The primary goal of this research was to develop a descriptive digital transformation maturity model that addresses identified research gaps: generalized models that lack theoretical grounding and the absence of models focused on value creation. Guided by Sociotechnical Systems theory and integrating the Digital Porter's Value Chain with a detailed description of six maturity levels across all activities of the value chain, Porter's Value Chain Model overcomes the gaps and provides a foundation for further developing of industry-specific models.

This model assists organizations in successfully navigating digital transformation, promoting excellent performance by offering guidelines to managers and employees for implementing digital transformation.

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# SPA RESORTS IN SERBIA: PLACES TO IMPROVE HEALTH AND WELL-BEING OF MODERN SOCIETY

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**Abstract:** *Due to the fast pace of life, sedentary work, unbalanced diet and little or no physical activity, modern man today faces significant challenges. In the long run, all of the above can even leave lasting consequences on their health. However, every individual wants good health and well-being, regardless of age or gender. If they cannot find health in their environment, they are ready to become tourists and travel. Spas in the Republic of Serbia have always attracted domestic tourists, primarily patients. Today, spas also offer services for healthy people who want to preserve their health. The aim of this review is to show that spas are also recognized as destinations for wellness tourism, which is becoming more and more popular in order to improve human health and well-being.*

**Keywords:** *health, well-being, wellness, spa, tourism*

## 1. INTRODUCTION

Every individual strives to improve their health. The well-known definition of health states that health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Driven by a desire for well-being, humans have always sought ways to improve their health. When unable to find it in their immediate surroundings, they have traveled, becoming tourists in search of better health. From the earliest health tourists—such as the Greek pilgrims who, even before the Common Era, journeyed from across the Mediterranean to Epidaurus on the sea coast, drawn not only by the ancient hospital but also by its various therapeutic methods, temples, and baths—to the American Indians who believed in the healing powers of hot and mineral springs over ten thousand years ago, there is evidence of spas being a significant part of people's lives, offering healing and improved health. In recent decades, spas have evolved to offer services not only for treating ailments but also for maintaining health, leading to the development of wellness centers. Velayuthan et al (Velayuthan et al, 2019, str. 598) wrote that the fact shows that the number of spa and wellness centre increases from year to year and the practice towards healthier lifestyle were accepted worldwide.

These centers have rapidly become havens of tranquility, where the modern individual can find and preserve their most precious possession – health. Wellness transcends mere good health, and wellness tourism, as a subsector of health tourism, is one of the fastest-growing segments of the tourism industry. This blend of health and leisure is recognized as a choice available to the modern individual, including in the Republic of Serbia, for preserving good health and well-being.

## 2. SPA TOURISM

Since ancient times, thermal-mineral waters have been recognized as places where rituals and ceremonies were performed, and later as sources for bathing and drinking. From the part of the Roman Empire known as "Spa," from which the acronym for the phrase "sanitas per aqua" meaning "health through water" was derived, spas emerged as centers where natural resources were applied for health and preventive purposes. Urbanization has somewhat disconnected humans from nature and its natural factors, but today, people are increasingly aware that natural elements such as thermal-mineral water, clean air, healthy diet, physical activity, and skincare are essential for good health. As Milićević (Milićević, 2015, str. 18) concludes: "spas are, therefore, resorts rich in healing waters, mud, pleasant climate, or other soothing factors. Through various therapeutic services, primarily based on the use



of water, administered by qualified personnel in a professional setting, spas help alleviate symptoms, accelerate healing or recovery, or in some other way aid the healing process.”

Furthermore, in relation to the way of meeting health-tourism needs, Živanović (Živanović, 2015, str. 18) defines two groups of health tourists created over time: “the first group comprises consumers of health tourism in a narrow sense, who utilize mineral waters and other healing factors for the purpose of prevention or treatment, within traditional thermal or spa tourism. Also, Živanović (Živanović, 2015, str. 18) notes that the second group includes consumers of health tourism in a broader sense, who, in addition to utilizing natural healing factors, also seek other types of activities. They seek interesting off-site offers, cultural and historical attractions, traditional or specific programs, and services. According to Živanović (Živanović, 2015, str. 18), for such consumers, “improving, preserving and promoting health is only one of many tourist needs.”

Observing the way individuals meet their health-related needs, Vujović & Vučinić (Vujović & Vučinić, 2022, str. 181) identify three groups of service users: consumers of traditional health tourism related to natural environmental factors, wellness tourism clients, and patients with serious health problems. The authors Pelegrín-Borondo, Araújo-Vila & Fraiz-Brea (2020, str. 1), note that spa resorts meet the demands of both medical and wellness tourists. Medical tourists are offered therapies, while wellness tourists use wellness services to maintain their health. Thus, spas are no longer just for rehabilitation. In fact, wellness centers are opening within them, often in hotels, attracting healthy individuals who seek to preserve their well-being. The Global Wellness Institute defines wellness as the active pursuit of activities, choices, and lifestyles that lead to a state of holistic health. In this paper, we will focus more on wellness tourists and the wellness services within spa hotels.

## **2.1. Contemporary wellness tourists and well-being**

Discussing health travel as a global tourism trend, Anufrijev & Dašić (2021, str. 2) state that: “that all tourism sectors will continue to add more wellness elements, and wellness tourism experiences will become more sophisticated.” It appears that the mentioned experiences relate to the enhancement of wellness and well-being. Many of them are based on relaxation and stress reduction. Podovac, Aklier, & Delić (Podovac, Aklier, & Delić, 2022, str. 456) note that in the defined 2025 Strategic Plan for Tourism Development, health tourism has been identified as one of the priority tourism products in the Republic of Serbia.

There is no doubt that people’s health is the greatest challenge and condition for the progress of every country. Health enables a person not only to show their own potential but also to be socially useful. However, health alone, if it pertains only to its physical aspect, appears insufficient for society itself. While it’s crucial for individuals to be physically healthy, it’s also important for them to be optimistic and not limit their care only to their immediate circle but also extend it to society as a whole.

Of course, no one enjoys absolute perfect health, but we expect individuals to prioritize their health with the means at their disposal. By investing in their well-being, individuals can achieve the desired state of health. This prompts the question of how individuals, especially those living in Serbia, can achieve this. This paper will explore some of the options for maintaining good health and enhancing well-being, particularly those offered by spas.

When it comes to wellness and well-being, Smith (2021, str. 2) points out that the terms are often mixed up, noting that the term “well-being” is an older and broader concept. As such, it encompasses health, social life, and the environment. Considering that humans are not just physical beings but also psychological and social beings, with a need for a healthy environment, achieving complete well-being is a significant challenge for people today.

Modern tourists, as noted by Lakićević, Pantović, & Fedajev (2021), choose tourism that will separate them from everyday life and provide them with new experiences and pleasures. In this way, spas have become some of the most attractive tourist destinations that are not exclusively tied to health tourism. In the context of demand and supply, research conducted by Dryglas (2020) has shown that the most important factors on the demand side are wellness-oriented activities, while the most important supply factors for the development of spa resorts are nature and spa/wellness services. Hashim et al. (2019) note that the Global Wellness Industry (GWI) also strongly promotes the spa industry, with individual health and well-being being central to its focus, which actually contributes to the triumph of this industry.

Dini and Pencareli (2022) believe that the entire paradigm of this sector has changed. Initially based on a perspective focused on physical health and well-being, a broader vision of holistic health has emerged.

Consequently, there has been a wider range of services and experiences that can contribute to people's well-being.

### **2.1.1. Wellness services for good health**

Among the services offered in wellness centers within hotels in spas, massage is the most common wellness service. Pecarski, Kiš, Ignjatović & Filipović (2023, str. 2015) emphasize "that people have always sought massage when they needed relaxation, well-being, and wellness." The series of movements used in massage (stroking, rubbing, kneading, etc.) not only activate skeletal muscles but also relax them, improve circulation, accelerate metabolism, and detoxification processes. As such, massage relieves stress and has a beneficial effect on both the mind and body, allowing for mental and physical relaxation. Considering that modern lifestyles often involve tension, massage therapy can be used to relieve tension and promote relaxation, which is undoubtedly very beneficial for modern individuals. In situations where an individual is responsible for the outcome, Trifunović (2023, str. 238) concluded that: "the tension that is always present in human relationships, as well as in all aspects of life, is a so-called modern "disease" or cause of stress, which prevents a healthy and happy life." Pointing out the importance of mental health, in his paper, Krstić (2023, str. 245) discusses the correlation between travel and inspiration for a person's future life. Kontić, Todosijević, & Kontić (2023, str.317) mentioned that optimal wellness enables us to achieve our goals and find meaning and purpose in life. Consequently, individuals can fully live up to their potential.

New trends and tendencies, which Smith and Puczkó describes, have appeared in the spa industry in recent years in their publication "Health, Tourism and Hospitality: Spas, wellness and medical travel", (2014). Alongside massage services, wellness offerings encompass a variety of body and face treatments. Among Serbia's most frequented spas, Vrnjačka Banja, Prolom Banja, Sokobanja, and Lukovska Banja are highlighted by Basarić, Milijić, & Bezbradica (2021). Later in the paper, we will discuss some of the spas that include wellness centers offering such services.

## **3. SWOT ANALYSIS OF SPAS WITH WELLNESS SERVICES WITHIN HOTELS/SPECIAL HOSPITALS**

Vukolić (Vukolić, 2022, str. 45) indicates that there is a global need for the establishment of numerous associations due to the rapid development of spa tourism, many of which aim to promote public welfare through improving physical fitness, medical care, and professional services, as well as encouraging educational programs related to healthy living, improving the quality, and increasing the availability of professional spa services (therapies, treatments, etc.). In Serbia, there are over 40 spa resorts that are part of the spa (and health) tourism offer, with various facilities that also include wellness services.

Table 1 presents a SWOT analysis of spa resorts in the Republic of Serbia that offer wellness services

**Table 1:** SWOT analysis of spa resorts that offer wellness services

Internal			
Pros	Strengths	Weakness	Cons
	Long-standing tradition Medicinal properties of thermo-mineral waters Existence of wellness and spa facilities Hospitality of the local population	Greater focus on the health benefits of spa resorts (for patients) Improvement of staff education regarding wellness services A variety of wellness tourism products for a longer stay at a spa destination (for healthy people) Lack of investment	
	Opportunities	Threats	
	Variety of local events Better development of local spa wellness tourism Promotion of local gastronomic offers Cultural and historical heritage of spa resorts Promotion at the tourism fair Creation of more favorable wellness service packages Creating a special tourist experience	Seasonality in the demand Lower purchasing power of potential domestic tourists Insufficient awareness of the importance of wellness tourism for maintaining good health and well-being Understanding the importance of wellness tourism for the development of the region as a whole Risk of mutual competition	
External			

## 4. DISCUSSION

We must not lose sight of the fact that the spa in Republika Serbia is characterized by a long tradition based on the healing properties of thermal mineral waters. Many spas have seen the importance of expanding their services related to the implementation of wellness and spa content in order to attract tourists who are healthy people without health problems. Such tourists are not bound only to hotel accommodation, they also meet the local population in their movements. The hospitality of the local population can influence, among other things, the repeat visit to the destination. Almost every spa, or its immediate surroundings, organizes at least one local event on an annual basis, which can influence the better development of domestic spa wellness tourism. Along with the promotion of local gastronomy, a special contribution is made to the promotion of the spa itself, while promotions at the tourism fair should also be used to create more favorable packages of wellness services. All together can present a special tourist experience, to which tourists will return again and again.

However, in addition to the introduction of services for healthy tourists, spas seem to be more focused on health services whose users are patients. However, in order to consider the promotion of wellness services, we must have quality staff who will perform such services, and staff education is very important. Moreover, it should be continuous. Also, the variety of tourist products should be increased in order to encourage tourists to stay longer at the destination. Of course, investing in investments is imperative. On the other hand, seasonality in demand among tourists is noticeable. The reason for this may be the lack of awareness among potential tourists about the importance of wellness tourism for the preservation of good health and well-being, and thus a misunderstanding of the importance of wellness tourism for the development of the region as a whole. Even in addition to the danger of mutual competition, spas in the Republic of Serbia have great potential to become one of the favorite destinations of wellness tourism, at least when it comes to domestic tourists.

## 5. CONCLUSION

The ongoing effort of individuals to enhance their health has prompted them to seek ways to achieve it. In response to this demand, spa resorts are increasingly incorporating wellness centers where guests can attain good health and well-being. The rising popularity of spa resorts can be attributed to their offerings, which now include wellness services. Recommendations for further development and enhancement of wellness tourism offerings can be derived from the SWOT analysis. Given that wellness and wellness tourism aim to enhance human health in a holistic manner, promoting spa resorts as wellness tourist destinations will attract more visitors, resulting in a positive impact on their overall health. Individuals satisfied with their health contribute to a healthy society, which, in turn, plays a role in maintaining the well-being of not just individuals but also the entire community.

Professional and efficient management of spa resorts and accompanying complexes, as well as entire destinations, with contents rich in the offer of health and spa services, is a prerequisite for increasing the competitiveness of the offer, in contrast to the traditional opinion that for a sustainable business model it is enough to offer access to healing water sources, forests, areas with a pleasant climate and quality therapeutic services.

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# PERCEPTIONS OF SCALING CHALLENGES IN DIGITAL INDUSTRIES – DIFFERENCES BY ORGANISATION SIZE

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**Abstract:** *Only 10% of organisations in the digital industry manage to scale successfully and build the ability to grow without being hindered by their structure. In this research, we wanted to understand better how the size of the organisation affects employees' perception of the severity of different scaling challenges so the results can be used to increase the percentage of successful scaling. By analysing different stages of organisational growth and a few specific organisations from this industry, we came up with a list of the scaling challenges, grouped them into five areas and used them to create the questionnaire. We had 120 respondents, 66 of them from small and medium-sized organisations and 54 from large organisations. Basic descriptive statistics and T-test showed that "Recruiting challenges", "Structure and process challenges", and "Leadership and management challenges" do not show statistical significance of difference that "Finance related challenges" are the only ones larger for small and medium organisations, while the "Organisational culture challenges" are the only ones significantly different for two groups of organisations. Bearing in mind these findings, the leaders in large organisations must have a greater focus on helping new employees adapt the organisational values, increasing employee engagement, making sure that employees understand organisational goals and standards, building a culture of high responsibility, learning to deal with constant changes and promoting internal innovations.*

**Keywords:** *scaling, challenge, organisation, culture*

## 1. INTRODUCTION

This article is focused on organisational scaling, defined by Belitski, Martin, Stettler & Wales (2023) as the process of "building and strengthening the internal capabilities, systems, and structures necessary to support and sustain growth". The digital industry is huge and constantly growing, but only a small percentage of organisations still manage to cope with scaling challenges. Regardless of the organisation's size, the challenges of further growth are always present. The goal of this research is to, through the analysis of data obtained from the industry employees, increase the understanding of how the size of the organisation affects employees' perception of the intensity of the scaling challenges. The research data could help the leaders of organisations in digital industries to have a better focus on the challenge they need to cope with in relation to the current size of their organisation.

## 2. METHODS

Our sample was based on the digital industries, companies were all from the information and communication industries. In total, we've had 120 respondents which were scaling up, either individually, or internally as a part of a huge corporation. In total 98 respondents were from Serbia, and 22 were from abroad. First part of the questionnaire collected general data about the company and the respondents entrepreneurial education, while the second part of the questionnaire gathered data on organisational scaling, based on the organizational lifecycle theory. The second part of the survey collected data on the challenges of organisational scaling, also taking background in the organisational lifecycle management which identifies specific struggles, difficulties and transitional problems for each specific stage of organisational growth (Adizes, Rodic & Cudanov, 2017). Organisational lifecycles that inspired this research as theoretical perspectives include ten stages of organisational lifecycle proposed by Adizes (1971) five stage model proposed by Greiner (1972), ; five stages of Churchill and Lewis (1983), the entrepreneurial process of growth presented by Hess (2012), entrepreneurial scale up presented by Harnish (2014) and growth stages of the entrepreneurial firm presented by Bell and Whittington (2018). Possible obstacles were identified as recruiting challenges, structure and process challenges, leadership and management challenges, organisational culture challenges and finance related challenges. Variables were tested for reliability, and according to Taber (2018), Cronbach's alpha coefficients are acceptable for all of them.

### 3. LITERATURE REVIEW

One of the important materials used for this research is the book *Scaling Up* by Verne Harnish, who has been actively involved in solving the issue of successfully scaling organisations through his career. Here he explains three organisational phases - "start up" in which 96% of established organisations remain, "scale up", in which few are found, and finally "stale out", huge "heavy" organisations that fail to scale further. Verne stands out four parameters as the key to successful scaling - bringing in and keeping in the right people, creating a differentiated strategy, executing the strategy flawlessly and having enough money when bad times hit (2014). He uses the same terminology as Greiner (1972), that the organisation goes through stages of evolution during growth, that these stages are predictable and require an adequate management method. Unlike Greiner, who defines challenges and potential solutions for each of the stages, Verne summarises and categorises the challenges into three groups that, according to him, are barriers to entering the next stage of growth, in whatever the current phases the organisation is:

- Leadership - inability to find/build enough capable leaders, those who can delegate and foresee,
- Scalable infrastructure - lack of systems and structures (physical and organisational) to handle the complexity of communication that comes with growth,
- Market dynamics - failure to address greater competitive pressure that creates and erodes margins.

Only when we solve these three things do we have the prerequisite to scale further - we increase the number of employees and systems that are needed to increase the organisation's offer.

Peter Cohan, also the founder of a consulting company and a lecturer at Babson College, researched the growth trajectories of successful and unsuccessful organisations and grouped the challenges for the growth based on two factors - the size of the organisation and its growth trajectories (2017).

Company Size	Growing	Declining
	Small	Big
	When will initial market be saturated? Should new growth opportunities be considered?	Can strengths be applied to another product or is it time to find an acquirer?
	What new source of growth is in the works? Is there room to grow in current markets?	Will an acquisition boost growth? Can we gain share in a new market? Is it time to sell?
	Growth Trajectory	

**Figure 1: Cohan - Growth challenges by company size and growth trajectory (Cohan, 2017)**

The novelty that Cohan's research brings is that some prerequisites for rapid growth are myths, and he uses cities as evidence of several organisations that have succeeded. However, that do not meet some conditions:

- In order to grow quickly, an organisation does not have to be small, not only startups grow (Google, Amazon, Netflix, Yahoo),
- In order to grow an organisation does not have to be in a fast-growing industry (Security Software, Soda Production, Credit Card Issuing, ..),
- You don't grow only through acquisitions.

Edward D. Hess summarised the research he did with 54 fast-growing organisations from 23 different countries (2012). He looks at growth from the perspective of organisational design, individual human behavior, strategy building and execution. Hess points out that growth is not always good because growth creates stress for people and can bring risks that can lead to the failure of organisation. He believes that an organisation must constantly improve the value proposition it brings to its users, and that it must do it better than competition. Hess identifies 10 challenges in the growth of organisations:

1. Determination and maintenance of strategic focus,
2. Learn delegation, management and leadership,
3. Installing and improving appropriate processes that will ensure quality and ensure financial control,
4. Daily cash management,
5. Make recruitment rigorous process,
6. Maintain the speed of growth so it does not burden the owner and the business,
7. Building a professional "family" culture of high responsibility,
8. Scaling sales and people,
9. Learning to live with changes, mistakes and the constant need to prioritise, to improve, to upgrade processes and people while growing,
10. Building a management team that works quite well together.

Since we researched the challenges in digital industries, we also had to refer to the specificity of the industry's products, which is primarily software, and to one of the most interesting studies on this topic which is described in the book "Accelerate" (Forsgren, Humble & Kim, 2018). This is a four-year research project whose goal was to use proven academic methods to find best practices for developing software in a way that brings value to organisations, profitability, productivity, and market share. In addition to the ones already mentioned, the research emphasises many other challenges, the most relevant of which are:

- Development of specific employee skills - product tools/processes, software development practices and technologies, soft skills,
- Choosing an appropriate software development methodology,
- Appropriate team structure,
- Continuous software delivery,
- Scalable infrastructure,
- Performance measurement - both software/products and teams and employees individually.

All the scaling challenges highlighted in the mentioned research are classified into five groups, according to which part of the organisation they refer to and which process they refer to. With the help of this categorisation, a survey for this research was conducted.

**Table 1. Scaling challenges in digital industries**

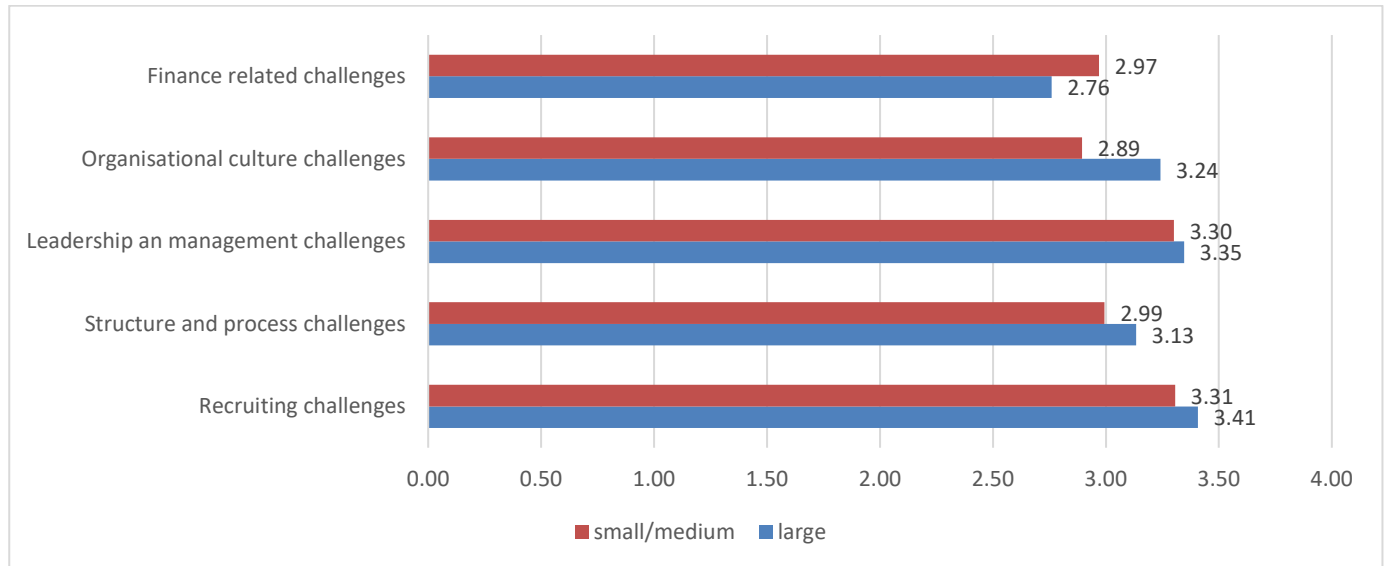
Finances	Achieving annual finances goals
	Creation of adequate procedures for financial control
	Provision of additional capital for growth
Recruiting and employee development	Hiring new people fast enough
	Creating a quality process for evaluating candidates
	Finding adequate new employees
	Loss of key talent of the organisation
	Building new abilities and skills of employees - product tools/processes, technologies and software development practices, soft skills, sales
Structure and processes	Choosing the appropriate product development methodology (Waterfall, Agile, Lean, ...)
	Choosing the appropriate team structure (Feature teams, Functional teams, Product teams, ...)
	Building and improving appropriate processes to ensure product quality
	Building and improving the system for monitoring the employees performance and promoting them
	Implementation of continuous delivery (automated delivery to production, test automation, ...)
Leadership and management	Creating a differentiated growth strategy (new markets, new products, acquisitions, ...)
	Maintaining a strategic focus at different levels of the organisation
	Transforming leaders - from executors through managers to coaches/mentors
	Finding and building sufficiently capable leaders who can anticipate, make decisions and delegate
	Management of the top leadership team itself and its dynamics
Organisational culture	Deciding what the organisation should do in-house and what to outsource
	New employees adapt the organisational values that were essential for the past success
	Maintaining of employee engagement
	Achieving an understanding of organisational goals and standards
	Building a culture of high responsibility
	Learning to live with changes, mistakes and the constant need for prioritisation, for improvements, for upgrading processes and people while growing
	Presence of innovations created by employees

To be reassured about the relevance of the selected challenges, we also researched a few organisations from digital industries, their perception of the scaling challenges, and how successfully they handled them. Google (Alphabet), with more than 150,000 employees, Google (Alphabet) is one of the most successful organisations in this industry, and the most material exists on scaling. The challenges that Google struggled with after 2009 are mostly related to organisational culture (maintain an entrepreneurial culture with a large number of employees), structure and processes (too much bureaucracy, people leaving due the lack of mentoring and formal career planning) and leadership and management (laying off the employees for the first time and shutting down non-profitable products) (Finkle, 2012). Supercell, the first European decacorn, with less than 400 employees, published some of their biggest challenges (Supercell, 2020). Even with this number of employees, they saw a challenge to maintain the great organisational culture and remaining small they struggled to survive in multiple markets and produce new functionalities quickly enough. Telltale games made a big success with a game made with 100 employees, then started hiring rapidly, tripled the number of

employees in less than four years which soon led to bankruptcy. Reasons for this can be summarised as not having leadership, management, structure, and processes ready to support this growth.

#### 4. RESULTS

A summary of results for our sample is given in the following graph – we can see a larger difference in the finance-related challenges for the small organisations, which is understandable because they have less accumulated resources and less access to funding. On the other hand, culture is hard to change, especially in larger organisations, which is presented in the graph below.



**Figure 1. Summary of organisational challenges**

Different values between groups and basic descriptive statistics are presented in the table below.

**Table 1. Analysis of different groups and basic descriptive statistics**

	Organisation's size measured in no. of employees	N	Mean	Std. Deviation	Std. Error Mean
Recruiting challenges	>= 250	54	3.407	.659	.090
	< 250	66	3.306	.601	.074
Structure and process challenges	>= 250	54	3.133	.812	.111
	< 250	66	2.994	.598	.074
Leadership and management challenges	>= 250	54	3.346	.604	.082
	< 250	66	3.301	.704	.087
Organisational culture challenges	>= 250	54	3.241	.636	.087
	< 250	66	2.894	.817	.101
Finance related challenges	>= 250	54	2.759	.762	.104
	< 250	66	2.970	.847	.104

**Table 4. T-test for observed variables difference of large vs medium and small organisations**

Variable / result	Levene's Test for Equality of Variances		t-test for Equality of Means				95% Conf. Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean diff.	Lower	Upper
Recruiting challenges (Equal variances assumed)	.800	.373	.880	118	.381	.101	-.127	.329
Structure and process challenges (Equal variances assumed)	1.992	.161	1.081	118	.282	.139	-.116	.395
Leadership and management challenges (Equal variances assumed)	3.265	.073	.373	118	.710	.045	-.195	.285
Organisational culture challenges (equal variances not assumed)	4.987	.027	2.614	117.7	.010	.347	.084	.609



Finance related challenges (Equal variances assumed)	1.907	.170	-1.416	118	.159	-.210	-.505	.084	
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According to our results, variables "Recruiting challenges", "Structure and process challenges", "Leadership and management challenges" do not show statistical significance of difference, "Finance related challenges" also has no significant differences, but is close (results might be 15.9% due to chance), and "Organisation culture challenges" are statistically significant. All values were self-reported during the survey. "Recruiting challenges" have mean value of 3.407 for large and 3.306 for small and medium organisations. The difference was not statistically significant, with by the .880 value of t-statistics with 118 degrees of freedom and a p-value of 0.381. "Structure and process challenges" have mean value of 3.133 for large and 2.994 for small and medium organisations. The difference was not statistically significant, with by the 1.081 value of t-statistics with 118 degrees of freedom and a p-value of 0.282. "Leadership and management challenges" have mean value of 3.346 for large and 3.301 for small and medium organisations. The difference was not statistically significant, with by the 0.373 value of t-statistics with 118 degrees of freedom and a p-value of 0.710. "Organisational culture challenges" have a mean value of 3.241 for large and 2.894 for small and medium organisations. The difference was statistically significant, with by the 2.614 value of t-statistics with 117.7 degrees of freedom and a p-value of 0.010. "Finance related challenges" have mean value of 2.759 for large and 2.970 for small and medium organisations. The difference was not statistically significant, with by the -1.416 value of t-statistics with 118 degrees of freedom and a p-value of 0.159. The results show that finance-related challenges are the only ones larger for small and medium organisations. In contrast, the organisational culture challenges are the only ones significantly different for the two groups of organisations.

#### 4. CONCLUSION

Survey data confirmed that the challenges identified through literature research are relevant, but none were assessed as not existing in the surveyed organisations, regardless of their size. Small and medium organisations mostly struggle to find adequate new employees, provide additional capital for growth, and create a differentiated growth strategy. In contrast, large organisations are "heavy" and do not have enough innovations and leaders to move the organisation faster. "Recruiting challenges", "Structure and process challenges" and "Leadership and management challenges" are pretty big in both small/medium and large organisations and do not show statistical significance of difference, which can indicate to leaders that even with a different number of employees and with a need for different approaches to handle these challenges, their employee's perception of the intensity of these challenges are not so different. On the other hand, "finance-related challenges" are larger for small and medium organisations, which confirms the need for the leaders of these organisations to focus on different strategies for obtaining capital, as can be found in the literature in this work. The findings show that the only ones significantly different for small/medium and large organisations are organisational culture challenges - new employees adapting the organisational values, employee engagement, understanding of organisational goals and standards, building a culture of high responsibility, learning to deal with constant changes and having internal innovations. These are the areas where all the leaders in larger organisations, regardless of their place in the organisational hierarchy, must educate and put in more effort. As the data of this research show, these are the areas where they can potentially learn from smaller organisations.

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# DESIGN PARAMETERS ADJUSTMENT TO ERP SOLUTION IN POST-IMPLEMENTATION PERIOD: A CASE STUDY FROM SERBIA

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**Abstract:** *In the literature, there are many statements that during or after the implementation of an ERP system, it is necessary to harmonize the ERP system with certain parameters of the organization, such as the organizational structure and processes. However, there is not much information available in the literature on how this is achieved. This paper is written in the form of a case study and was created as a result of a project in a public company whose core is passenger transportation. The project goal was to change the organizational structure of the maintenance department and reengineer a part of the maintenance process in order to harmonize it with the implemented ERP solution in the post-implementation period. The paper presents some of the problems that were present during the realization of the project, as well as proposed solutions for solving them.*

**Keywords:** *ERP, organizational structure, process reengineering, post-implementation*

## 1. INTRODUCTION

In the modern business world, computerization, automation, and ERP systems have become the backbone of both public and private sector organizations (Mahar, Ali, Jumani, & Khan, 2020). ERP systems are standardized, integrated software solutions based on “best practices” from different industries (Nwankpa, 2015) that integrate and streamline various business processes within an organization (Olaoye & Potter, 2024). Organizations adopt ERP systems to maintain daily operations, procedures, and other functions so that activities can be done more effectively and proficiently (Mahar, Ali, Jumani, & Khan, 2020). ERP systems have predefined business rules and require firm procedures that determine how business processes will be carried out (Hustad & Stensholt, 2023). However, these predefined rules will never completely correspond to the implementing organization's existing processes and practices (Hustad & Olsen, 2011) (Hsu, 2020). ERP system implementation is considered, among other things, mostly as a process of checking current business flows and operations methods, data management, change management, user training, post-maintenance support, etc (Kenge & Khan, 2020). Still, after the implementation is over, it can't be said that the effort is over. Organizations need to align their processes with the standard functionality of the ERP system or customize the system to meet specific business requirements (Olaoye & Potter, 2024). If that isn't done during the implementation period, it certainly needs to be done in the post-implementation period, with probably greater effort. That's why ERP failure rates appear to be at a significantly high level (Coşkun, Gezici, Aydos, Tarhan, & Garousi, 2022). ERP systems cannot improve productivity and efficiency without the organization adapting their business processes to the ERP system's rules (Hustad & Stensholt, 2023). These solutions force changes in business processes, employees' roles, and organizational structure (Hustad & Stensholt, 2023) (Olaoye & Potter, 2024) and their inadequate implementation can negatively affect the organization's performance. Unfortunately, some mistakes made during the implementation phase can be exposed only in the post-implementation phase (Singh, 2022). However, it is not clear from the literature how companies should decide whether to customize an ERP system to their needs or whether they should instead change their business processes to fit the standard ERP system (Hustad & Stensholt, 2023).

This paper will present the main activities and findings of the project of adapting the organizational structure and processes to the implemented ERP solution in the post-implementation period. The project was conducted in a public company whose main activity is passenger transport, specifically for the maintenance department and its ERP module. It will briefly explain the organization of the maintenance department and flaws regarding the semi-digitalized process of issuing and entering work orders for maintenance into the

ERP system, proposed solutions following organizational design, and potential benefits of such a newly designed system.

## 2. SITUATIONAL ANALYSIS

The maintenance sector of the observed company is organized according to the territorial principle of departmentalization (Ugoani, 2021) (Nguyen, 2019). Departments are divided by regions in which the vehicles that operate in those regions are maintained, but also according to the type of vehicles they maintain. There are Section A, Section B, Section C, Section D, and Section E. On taking a deeper look into the organizational structure of each of the sections, both similarities and differences between individual sections can be seen. The most significant difference can be observed in Section A, which at the lower level is divided into four organizational units, each having its own head. Other sections are seemingly identical at the level of organizational units, where there is only one organizational unit at a subordinate level, having its own head. This paper emphasizes the important difference between departments' job systematization, job descriptions, and the actual tasks and responsibilities performed by employees.

In the current organizational structure, there are no systematized positions whose main job is issuing and entering the realization of work orders into the system. Besides that, in job descriptions of existing positions, there are no tasks related to the mentioned job, as if that job is not performed anywhere at all. However, this is not the case in reality. During interviews with employees, it was established that issuing work order tasks are performed in each section, but without formal responsibility in the form of a job description task, but rather as an informal task assigned to specific people as executors. This means that the job is not assigned to the same position in each section or even to the same position type. Interviews helped determine, for each section, which employees perform tasks of issuing and entering work orders into the system.

In Section A, an employee at the position of Coordinator, located in one of the subordinated organizational units, is responsible for issuing and entering the realization of work orders into the system. Besides the fact that there are two more executors at the same position, he is the only one that performs these tasks for all organizational units in Section A, and that is his only assignment, practically *de facto* job description. In Section B, work orders are also entered by the Coordinator, who also has this as his only job. In Section C, the work is performed by the Head of the Section and the Deputy Head of the Section, alternately, in Section D, the employee in the position of Head of the subordinated organizational unit, and in Section E, the employee in the position of Assistant Head of the Section, all in addition to the other tasks they have on a daily basis, which are mostly managerial and somewhat engineering in nature. This kind of work organization in each section can in some way tell about the workload of employees in mentioned positions, but on the other hand, the volume of the specific task of issuing work orders is limited by various factors, like the number of vehicles that are maintained, the type and age of the vehicles, work shifts, etc. There was a question why exactly these employees were assigned to this task, and the answer is that they were chosen people who have a degree in engineering, are sufficiently computer literate, and their participation in operational maintenance work is not necessary on a daily basis. It is important that there is a person who is an engineer and knows most of the malfunctions, as well as being able to independently evaluate the components and operations that need to be performed to bring the vehicle into working condition.

The appearance of the organizational structure is greatly influenced by the processes taking place in the organization (Jaško, Čudanov, Jevtić, & Krivokapić, 2017). In the current system, the process of issuing and entering the realization of work orders is set as secondary, employees see it as burdensome, a kind of technicality that just needs to be completed, without investing more effort and attention than is necessary to complete the process. No attention is paid to the orderliness or timeliness of recording and data entry (Todorović, et al., 2024). This is because the employees do not understand the operational or strategic importance of this subprocess. Such behavior is additionally stimulated by the fact that this job does not officially appear in anyone's job description. Due to the lack of a procedure for issuing and realization of work orders, this process is carried out in different ways in sections. Where the volume of work is larger, work orders are opened and closed retroactively, nearly always after all maintenance activities on the vehicle have already been performed. What is common to all sections in this process is the entry of inaccurate data into the system. Namely, when issuing a work order, ERP should withdraw all planned operations and norms set in the system for the execution of operations by order type. Norms represent working hours necessary to complete a task (Jaško, Čudanov, Jevtić, & Krivokapić, 2014). After the realization of operations according to the work order, the actual working hours of the operations should be entered on the same, precisely recorded by the Supervisor of the group during or after the realization of maintenance activities. The reality is that rarely any work order is executed in the prescribed manner (Todorović, et al., 2024). Supervisors usually, under excuses that they don't have time to deal with administrative tasks, don't fill in the rubric realized time of operations on the work order or fill it in using the approximate method, estimating the

working time at the very end of maintenance activities completion. If the supervisor hasn't entered the time realization of maintenance activities, this leaves the employee who enters the data into the system with a small choice of options: to chase the supervisor to enter the right data; to try to estimate the real duration of activities themselves; or to enter the norm as realized time for each activity. The first option is difficult to implement because firstly, they don't have line authority over the supervisor, while expert authority in the company is not highly valued. The second option would involve additional effort by the engineer, which almost certainly results in equally wrong data. That is why the engineer decides on the third option, where they rewrite norms of operations in the rubric realized time and close the order as such.

Entering incorrect data on the execution of work orders leads to the fact that there are incorrect data in the system that can lead to wrong conclusions and potentially poor decisions with bad consequences (Gessa, Jiménez, & Sancha, 2023). It is impossible to determine the exact (or even close) maintenance costs in such a system, with this way of recording data. Considering that for most work orders, in the system, the recorded realization time is equal to norms, real labor costs are calculated according to work norms, so that all those deviations where workers worked more or less than norms are not visible. In addition, the norms are set to take the average hourly cost of the maintenance sector, rather than the hourly cost of the specific position performing the activities. Variation in these prices is not insignificant and can make a big difference when multiplied by the hours of work on the work order. In order to solve this problem in the future, it is necessary to record, in addition to the time worked on each activity, the specific employee who performed the activity, which is hard to imagine in the current system setup (Todorović, et al., 2024).

### **3. RESULTS AND DISCUSSION**

ERP implementations often require changes in organizational structure (Olaoye & Potter, 2024) and business process reengineering (Kraljić & Kraljić, 2019) so it was crucial to map existing business processes and workflows (Hustad & Stensholt, 2023). As the first step in the solution, a new design of the organizational structure was presented, which implied introduction of additional level in the middle line of management and lowering the level of sections to a subordinate level in the organizational hierarchy. This changed predominantly territorial departmentalization (Jaško, Čudanov, Jevtić, & Krivokapić, 2017) of the maintenance department so that at a higher level activities were grouped by subject, which was then divided territorially where justified.

Further development of the solution involved a complete revision of all jobs in the sector, formal descriptions and informal tasks. Following mapped maintenance process and auxiliary processes, a revision of jobs was carried out, where unnecessary jobs were terminated, new required jobs were created and some were changed in accordance with real responsibilities. For each position, job descriptions have been created that describe exactly what is done at the position. All territorial units were mirrored symmetrically, in terms of structure, positions, job description, with certain exceptions dictated by the specifics of the units.

The biggest change was the revision and systematization of engineer jobs. In the existing structure, engineers were employees who spent most of their time in the workshop, working as better executors, with enriched knowledge, where they solved more complex problems. In the previous part of the paper, it was explained who in the sections dealt with work orders and how – de facto one of the engineers; de jure that job did not even exist. One of dilemmas during establishment of new structure was the question of whether to formalize the position of an engineer in each of the sections, whose exclusive job would be issuing and entry of work orders, or whether that job, as before, should be assigned to one of the engineers, according to competences and managerial decision, as addition to regular engineering tasks. By analyzing the volume of work and workload of the executors, it was established that the systematization of a separate positions for issuing work orders would not be justified in any of the sections, except maybe Section A, due to small volume of work that this job entail. It was decided that better alternative would be to add tasks related to work orders issuing to the engineers in sections, where they would perform the tasks of the engineer in the workshop in addition to the work order issuing tasks. On the other hand, since it would be written in the job description of the engineer's position, it would mean that every potential executor who finds himself in that position should know how to perform that job, thus acquiring the necessary interchangeability in terms of performing those tasks in periods when an executor who mainly deals with it is off work.

In addition to position of an engineer who deal with issuance and entry of work orders into system, certain tasks related to control and revision of work orders entered, review of norms and lists of operations, distribution to executors, etc., were added to the Head of the section, as potentially the most experienced engineer in the section. He would handle the improvement of defined norms and operations in system. Each Head of section should perform this job for his organizational unit and it is in his job description. The work related to the continuous improvement and structure of ERP system is formalized in the form of separate

workplace located at the sector level, directly subordinated to the sector director and which collects and consolidates all information related to ERP in the maintenance sector. This position, called SAP Coordinator, does not have to be among the best engineers in the company, but it is necessary to understand certain concepts from an engineer's point of view, but also has some business analytics skills. That position grew out of the role of lead engineer in the ERP implementation project, who was the main link between the provider and the company throughout the implementation period and will continue to be so in the post-implementation period, as it involves further work on improving and adapting the system to the company.

In many cases, ERP systems cannot improve corporate productivity and efficiency without the organization adapting their business processes to the ERP system's rules (Hustad & Stensholt, 2023). ERP system implementation implies radical and complex process changes, so called business process reengineering (Kraljić & Kraljić, 2019). Regarding that, further improvement went in the direction of reengineering the process of issuing and realizing work orders and its formalization. As it was already said, the procedure for this process did not exist, and therefore it was carried out in different ways in each section. It was necessary to standardize the process and perceive system's ability to adequately follow that flow. In certain segments, it was necessary to make certain adjustments, process to system and system to process, depending on the limitations (Luo & Strong, 2004). When the appropriate flow of the process has been set, with recognized changes and limitations, the roles in the process have been defined and formalization in the form of a procedure has been carried out. In every version of existing process flow, there were quite a few irrationalities and gaps that needed filling. Some things were removed from the process, some new things were added, and some were changed to fit the new process (Todorović, et al., 2024). This procedure obliges all organizational units that carry out maintenance to act in the manner defined in it. This achieved the unification of the process, the precise definition of responsibility in the process, the exact sequence of steps that are performed in order to properly ensure the entry of work orders, with a minimum of errors, which will ensure the validity of the data at the very end of the process. What is newly added to the process is the tendency towards increasing digitalization. The existing process flow involved a bunch of paperwork and manual filling, and then typing the filled papers into the system. Such a way of work was conditioned by two things. First, the engineers and supervisor who are located directly in the workshop did not have a computer, nor their own account in the ERP system, so they could not enter the realization of work orders. The only computers were in the administrative building, next to the workshop. The second, more difficult variable was the reluctance of the supervisor to introduce digital aids into the workshop. Therefore, the new solution of the process implied the continuation of the process with the use of the current work technology, with the minimum necessary use of paper, but without instantly breaking the supervisor's resistance to changes and introducing digital aids into the workshop. On the other hand, certain modifications have been made in the system, which support the change of working methods and the introduction of digitalization into the workshop, when the opportunity arises. The process supports such a way of working.

It is very important to understand why organizational structure redesign and process reengineering following digitalization described in this paper is significant for company to realize its full potential (Kraljić & Kraljić, 2019). Only by correctly executing an optimally set process, respecting the defined procedures and roles in the process, can reliable factors for business management be created. When the system will be stored with valid data about the real norms in the plan, real execution times, exact executors and their prices per hour of work, only then will a basis for decision-making based on the data be created. Data handling process have to be more sophisticated (Kapoor, Singh, & Rawat, 2022). Until then, it is a mere assessment of the management regarding maintenance costs, employee performance and general performance of the maintenance sector.

#### **4. CONCLUSION**

With an ERP system, businesses can optimize their processes, eliminate redundancies, automate routine tasks, and improve overall efficiency (Olaoye & Potter, 2024). Of course, if the organization is ready for such a thing. Although the company entered the restructuring process independently of the ERP system implementation process, it was certainly an important factor when defining individual jobs and process reengineering, as presented in the paper. It was a unique opportunity to align the structure and the system after the implementation of the ERP system, with some mutual adjustment. Although this paper describes a greater adjustment of the structure to the system, it is clear that to a certain extent there was also a need to adjust the system to the structure, and that there will only be a need for it in the later period when the conditions for further optimization of the process through greater digitalization are met. If this happens, it can be assumed that there will be no obstacles for the centralization of the process of issuing and entering the realization of work orders within only one workplace at the sector level. If the new process setting takes effect, employees will have much less manual activity regarding data processing (Lavinia Barna & Stefan Ionescu, 2023) compared to the previous state. In case digitalization is fully adopted in the workshops and

managers accept/learn to use tablets or some other devices for electronic data recording, papers, and the need for the physical presence of employees dealing with the administration of work orders in the workshop will be completely eliminated. The next investment in information technology can provide more opportunities to increase productivity and even more improve business processes (Putra & Rahayu, 2021).

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# **DIGITAL OPERATIONS AND LOGISTICS MANAGEMENT**



# DIGITAL TRANSFORMATION AND KEY PERFORMANCE INDICATORS IN MANUFACTURING: A COMPREHENSIVE LITERATURE REVIEW

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**Abstract:** Digitalization presents a revolution in the manufacturing sector that refers to the transition from traditional to digital technologies forming an integral part of Industry 4.0. The purpose of the article is to present the relevant literature dealing with Digital Key Performance Indicators and Digital Transformation Key Performance Indicators and their application in the manufacturing industry. The aim of the article is to improve the comprehension of digitalization in production processes and their optimization, where these key performance indicators are of high importance. The intention of the article is to highlight the importance of the application of digitalization in manufacturing companies, identifying key challenges, by presenting the results of the literature review using the bibliographic databases Scopus and Web of Science. The results presented in this article can help manufacturing companies improve the planning of their resources and direct them towards digital transformation, tending to gain a competitive advantage in the market.

**Keywords:** digitalization, Industry 4.0, manufacturing, digital KPIs, digital transformation KPIs

## 1. INTRODUCTION

Digitalization presents a key process of transition from traditional work methods to digital technologies. In modern business, huge progress has been made in the fields of information technology, automation and robotics. All these technological achievements are a prerequisite for the development of Industry 4.0, that presents “the current trend of digitalization, automation and data exchange in production” (Thun et al., 2019). Industry 4.0 is a new industrial era that digitally transforms all processes across industries, from manufacturing to logistics, through innovative technologies (Rajković et al., 2023). The first step in digital transformation is “to assess the digital maturity and readiness of the company” (Machado et al., 2019). In practice, companies often encounter challenges in the process of digitalization, such as lack of skills and employees, finding the appropriate technology, balance between strategic, operational and financial KPIs, and others (Kane et al., 2018). Concerning all mentioned, digitalization has transformed the way companies do business, communicate and manage resources and processes. It has profound implications for every industrial branch, especially manufacturing. To achieve company objectives, it is essential to continuously monitor and measure performance, making adjustments as needed to align with desired outcomes (Radjenović et al. 2023). To measure performance effectively, it is crucial to establish specific performance indicators, along with the methods and benchmark values needed for comparing the results of these indicators (Lečić-Cvetković et al., 2024). With the emergence of digitalization, the need to monitor and measure performance through Digital Key Performance Indicators (DKPIs) and Digital Transformation Key Performance Indicators (DTKPIs) has appeared. “Digital transformation is characterized by the fusion of advanced technologies and the integration of physical and digital systems, enabling innovative business models and new production processes to prevail” (Almeida et al., 2020). Digitalization has impacted DKPIs and digital transformation in several ways. It enabled companies the need for KPIs measurement and analysis to collect a greater amount of data using technologies such as the Internet of Things (IoT), Data Analytics (DA) and Artificial Intelligence (AI), to extend the set of KPIs that companies use and measure, as well as to provide a deeper understanding of the company's processes (Siedler et al., 2020). It has also empowered incremental innovations in the way how companies operate, requiring new KPIs to measure the efficiency of business models and processes. This provides a reduction in production costs and increase flexibility. Digitalization presents a key driver of changes enabling performance measurement in the fast and more dynamic business environment. This article introduces the concepts of DKPIs and DTKPIs in the manufacturing industry by reviewing the relevant literature in this field.

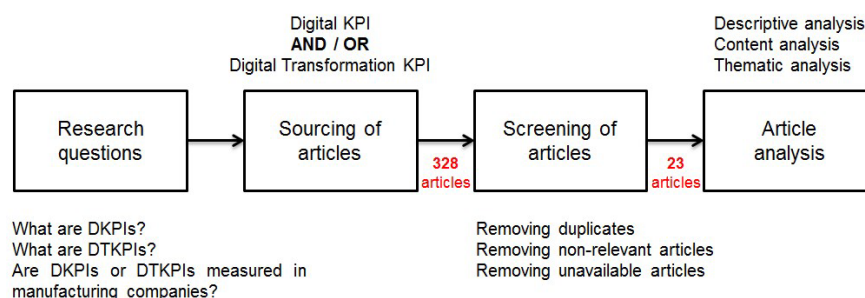
This article consists of five chapters. The first chapter is the introductory chapter. The second chapter presents theoretical concepts of digitalization in the manufacturing industry. The third chapter presents the research methodology and summarized results of the literature review of articles from the Scopus and the Web of Science (WoS) bibliographic databases. The fourth chapter presents the findings from the literature review pointing out the significance of DKPIs and DTKPIs in assessing digital performance and transformation strategies. The conclusion of the article is presented in the fifth chapter.

## 2. DIGITALIZATION IN PRODUCTION MANAGEMENT

In 2011, when the term Industry 4.0 was introduced, digitalization has received increasing attention, aiming at a digitalized industry that has become more dynamic. In this regard, digitalization affects not only production processes, but also business models, and for this reason in practice is also referred to as digital transformation (Jeske et al., 2021). The main goal of digitalization in the manufacturing industry is primarily to increase productivity, efficiency and support human-robot cooperation. Digitalization in the manufacturing industry provides new opportunities for process optimization that can directly affect the improvement of product quality and cost reduction. Digital transformation is defined as “the use of new digital technologies (devices, social media) to enable major business improvements, such as improving user experience, simplifying manufacturing operations or even creating new business models” (Liere-Netheler et al., 2018). In this regard, it encompasses the change of business model, monitoring and processes in production using digital technologies such as IoT, AI, DA, robots and others. It presents “one of the most important keys to competitiveness in the era of Industry 4.0, guaranteeing high performance in production indicators through linking productivity and flexibility, eliminating costs and improving product quality” (Bitsanis & Ponis, 2022). “The ultimate goal of digital transformation is to increase sales, sustainability and customer satisfaction” (Libert et al., 2016). DTKPIs are used to determine how far a company has progressed in its digital strategy and in improving its results in the digital market, while DKPIs present measurable indicators that are necessary to manage and monitor the production process performances, enabling companies to analyze the impact of the digitalization process in all business processes. DKPIs should support operational objectives and include parameters such as production efficiency, overall equipment effectiveness (OEE), downtime, product quality and other indicators to assess the success of the application of digital technologies (Miqueo et al., 2020). The DTKPIs and the DKPIs present an important part of the management strategy, as they allow companies to quantitatively analyze what impact digitalization has on the business. Understanding the process of digitalization and its benefits in manufacturing environments, both theoretically and practically, it allows companies to better plan and strategically direct their resources towards digital transformation, indicating the great importance of this topic for the manufacturing industry.

## 3. RESEARCH METHODOLOGY

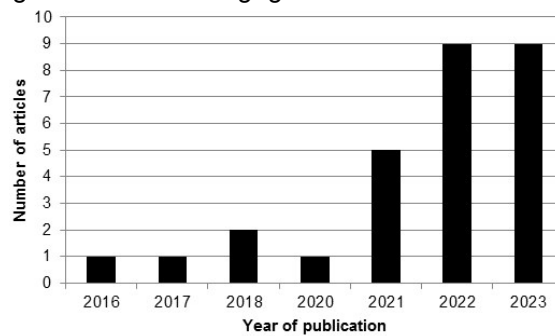
The aim of this article is to explore the utilization of DKPIs and DTKPIs within the manufacturing industry. Specifically, this research endeavours to analyze the implementation and efficacy of these KPIs in optimizing various facets of manufacturing processes. For this research, a systematic literature review of articles based on the application of DKPIs and DTKPIs in companies was done. The authors of this article have applied the following research methodology (Tomašević & Slović, 2022; Tranfield et al., 2003): formulation of research questions, sourcing of articles, screening of articles and analysis of articles, as presented in Figure 1.



**Figure 1: Research methodology**

The first phase of the research methodology was to define three research questions that reflected the purpose of this article: What are DKPIs?; What are DTKPIs? and Are DKPIs or DTKPIs measured in manufacturing companies? The second phase of the research methodology was the sourcing of articles. To comprehensively explore the landscape of DKPIs and DTKPIs and their role in digital transformation, a systematic research strategy was utilized. Two keywords were selected to search bibliographic databases: “digital kpi” and “digital transformation kpi”. These terms were chosen to encompass various aspects of performance measurement in the context of digital initiatives. These terms were combined using the “AND” association to refine the search results (e.g. “digital kpi” AND “digital transformation kpi”). The search was confined to article titles, abstracts and keywords, focusing on peer-reviewed journals and articles written in

the English language from 2014 to 2024. The search was conducted using bibliographic databases such as Scopus and WoS. Using both databases ensures comprehensive coverage across publishers without excluding any, with Scopus offering wider coverage and WoS providing access to older sources, aiding thorough research (Thürer et al., 2019). Authors chose to search only journals as Source type to ensure the inclusion of peer-reviewed literature and reviews, prioritizing recent and scholarly information pertinent to their research. The search resulted in a total of 328 articles, all included in the original sample. The third phase of the research methodology was a screening of articles. By removing duplicates, the original sample was reduced to 325 articles. By reviewing the references cited in the selected article, the authors have discovered an additional 8 articles that aligned with search terms and research questions. Despite not being retrieved from the Scopus and WoS databases, these articles were deemed relevant and were included in the analysis. Upon examining the titles, abstracts and keywords of the articles identified in the search results, six out of eight articles from the WoS database, 293 out of 317 articles from the Scopus database and six out of eight additionally included articles were excluded. This resulted in a total of 28 articles remaining for the subsequent stage of analysis. Figure 2 and Table 1 summarize the basic characteristics of the 28 articles sample. Figure 2 illustrates a progressive increase in published articles over the years, particularly notable in 2022 and 2023, indicating a heightened level of engagement or focus within the field during those two years.



**Figure 2:** Distribution of articles per publication year

Table 1 presents the most common journals that have published selected articles.

**Table 1:** Journals where selected articles were published

Journal	No. of articles
International Journal of Computer Integrated Manufacturing	3 (10,71%)
IEEE Access	3 (10,71%)
Sustainability	3 (10,71%)
Applied Sciences	2 (7,14%)
Machines	2 (7,14%)
Other (one article per journal)	15 (53,57%)

For five out of 28 articles, authors did not have access, so the original sample was finally reduced to 23 articles. The remaining 23 articles underwent a detailed analysis, as presented in the fourth chapter.

## 4. RESEARCH FINDINGS

To facilitate analysis, an Microsoft Excel spreadsheet was created as a two-dimensional matrix to collect relevant research information. During the detailed literature review analysis, six out of 23 articles did not provide essential information regarding the results of DKPIs and DTKPIs application and KPIs, so they were excluded from the detailed analysis, leaving 17 articles to be in detail analyzed. The following details were extracted from each article and presented in Table 2: identification of the industry sector where the company from the analyzed article operates; identification of DKPIs or DTKPIs in the article; concise clarification of how and why the specified KPIs are employed within the observed industry; enumeration of the KPIs specified per article, with a focus on the most significant ones; specification of the outcomes ensuing from the implementation and measurement of the identified KPIs. The noticeable focus on DKPIs and DTKPIs within manufacturing is exemplified by the nine articles, highlighting their critical role in directly evaluating digital strategies associated with manufacturing, five articles demonstrate indirect connections, while three show no connections. Various definitions are available to address the initial research question. The response to the first research question (*What are DKPIs?*) is presented in the following. DKPIs are essential metrics used to evaluate various aspects of a company's performance in the digital era, providing quantitative insights into the company's digital activities, such as online presence, customer engagement, operational efficiency and sustainability efforts (Engel et al., 2022; Joo et al., 2022). These KPIs are quantifiable metrics derived from real-time data processing, essential for evaluating and optimizing industrial performance across various levels, particularly within the context of Industry 4.0 (Ferrer et al., 2018). Within the specific industry, DKPIs are strategically used for different purposes. These include enhancing workplace design to foster

productivity and employee satisfaction, tackling environmental concerns by reducing carbon emissions and optimizing production processes to improve cycle time (Joo et al., 2022; Kanan et al., 2023). The response on the second research question (*What are DTKPIs?*) is that DTKPIs are quantifiable parameters used to evaluate the progress and success of a company's efforts to adapt, innovate and leverage digital technologies across its operations, processes and strategies (Sanchez-Gonzalez et al., 2022). These KPIs have a crucial role in facilitating a company's improvement and innovation across various sectors, including minimizing customer complaints, optimizing operational efficiency and enhancing product quality (Ng Corrales et al., 2022; Salwin et al., 2023). By tracking DTKPIs related to minimizing customer complaints, companies can assess the effectiveness of their digital initiatives in addressing customer needs and resolving issues promptly, leading to higher satisfaction and loyalty (Salwin et al., 2023). DTKPIs focus on optimizing operational efficiency and product quality, enabling organizations to identify areas for improvement, streamline processes and deliver better products and services to customers (Fortoul-Diaz et al., 2023; Sarabia-Jácome et al., 2020). Additionally, by developing evaluation systems encompassing financial, logistics, customer and improvement perspectives, companies can assess the holistic impact of digital transformation efforts, guiding strategic decision-making and ensuring alignment with overall business objectives (Xiao-Ping et al., 2021). The answer to the third research question (*Are DKPIs or DTKPIs measured in manufacturing companies?*) is that DKPIs and DTKPIs are certainly measured in manufacturing companies. Based on the results presented in Table 2, it can be concluded that DKPIs focus on measuring the performance of specific digital activities or channels, while DTKPIs assess the broader impact of digital initiatives on the company's overall transformation path and strategic objectives.

**Table 2.** DKPIs and DTKPIs in different industry branches

Article	Industry	DKPIs / DTKPIs	Application	KPIs	Results
(Aiello et al., 2020)	Manufacturing	DTKPIs	Assisting decision makers in decision-making; KPIs for monitoring preventive maintenance effectiveness	Component efficiency; Equipment reliability; Number of interventions; Number of alarms	A secure maintenance management approach using blockchain and mathematical models showcased through pump monitoring
(Demko-Rihter et al., 2023)	Manufacturing	DKPIs	Improving ability for material reusability; Decreasing material losses; Increasing the share of recycled materials in new products	Proportion of material losses; Quantity of production material compared to GDP; Recycling rates for wastes	Not stated
(Engel et al., 2022)	Service	DKPIs	Formalizing customer expectations; Ensure accountability for service quality	Service availability; Service up-time; Incident resolution time;	Not stated
(Facchinetti & Citterio, 2022)	Telecom	DKPIs	Monitoring performance and resource optimization	Overall equipment productivity	Defined measures of the service-providing efficiency factors
(Ferrer et al., 2018)	Manufacturing	DKPIs	Illustrating and implementing a set of KPIs as outlined in the ISO 22400 standard	Allocation efficiency; Utilization efficiency; Availability; Quality ratio; Scrap ratio	Defined KPIs improved monitoring performance and enhanced the management of production activities (scheduling, resource allocation...)
(Fortoul-Diaz et al., 2023)	Manufacturing	DTKPIs	Improving the efficiency of the asset in performing repetitive tasks	On-time delivery; Average task completion time; Time activity	Achieved on-time delivery; More precise architecture in competition time; Assets perform a task close to half of the total time
(Joo et al., 2022)	Manufacturing	DKPIs	Improving the effectiveness of energy-intensive manufacturing methods to attain carbon neutrality	Specific energy consumption; Total production; Pouring temperature (quality facet)	Reducing process loss without altering product quality or existing facilities resulted in a 12.6% decrease in energy consumption
(Kanan et al., 2023)	Manufacturing	DKPIs	Improving workplace design; Reducing carbon emissions produced from direct use of electricity; Improving cycle time	Job satisfaction; Carbon emission by material wastage; Cycle time; Lead time	Improvements in work design reduced stress; Carbon emissions reduced by 19.2%; Reduction in cycle time by 15.5%
(Lange et al., 2021)	Service	DTKPIs	Maximize aerodynamic performance, resource efficiency and competitiveness in Formula Student racing projects	Drag; Downforce	Major design improvements led to performance upgrade
(Marziala et al., 2022)	Transportation	DKPIs	Problems with the outsourced logistic systems; Trucks failed to provide services on time; Order fulfillment issues	Punctuality of trucks; Order picking errors	Developed KPIs enhance operational oversight and foster real-time decision-making
(NG Corrales et al., 2022)	Logistics	DTKPIs	Increasing the overall efficiency in the production support activities	Availability; Performance; Quality; Punctuality	Guiding framework, enhanced data collection; Data-driven management transition; Optimized truck arrival planning
(Salwin et al., 2023)	Manufacturing	DTKPIs	Minimizing customer complaints; Optimizing operational efficiency and product quality	Employee performance; Quantitative production indicator; Level of complaints; Level of scrap	Employee performance and production performance nearly 10% higher; Scrap level decreased by 47% (plastic) and 22.6% (steel)
(Sanchez-Gonzalez et al., 2022)	Transportation	DTKPIs	Aiming to facilitate the industry's digital transformation	Improvement on ratio cost using old process; Decrease in human errors; Decrease in annual maintenance hours	Implementing given KPIs allows maritime container shipping companies to identify quick wins, optimize processes, align strategies, mitigate risks and measure success

**Table 3. (continued)**

Article	Industry	DKPIs / DTKPIs	Application	KPI	Results
(Sarabia-Jácome et al., 2020)	Transportation	DTKPIs	Monitoring and enhancing the efficiency of the operation leveraging Industry 4.0 technologies	Vessels average time occupancy; Container terminal occupancy weekly; Average time waiting for a free terminal	Streamlined seaport systems through integrated Big Data architecture, enhancing operations planning, decision-making and coordination
(Verhaelen et al., 2021)	Manufacturing	DKPIs	Defining indicators from three dimensions (costs, flexibility, innovations) and two levels (site and supply network)	Material stock; On-time delivery date; Throughput time; Batch size	Performance improvement, in supply network (access to new customers and markets) and site level (efficiency, quality, flexibility)
(Watanabe et al., 2018)	Manufacturing	DKPIs	Evaluating the performance indicators for dispersed productive systems related to sustainability	Wastewater discharged; Packaging materials reused; Energy costs; Labor accident rate	The framework tracks sustainability in developing countries but may need adjustments for cases where sustainability is a top priority
(Xiao-Ping et al., 2021)	Logistics	DTKPIs	Developing evaluation system through financial, logistics, customer and improvement perspective	Sales revenue; Warehouse cost; Average delivery time interval; IT penetration	The utilization of IT and digitalization significantly enhances the efficiency, accuracy and coverage of information transfer

## 5. CONCLUSION

Digitalization in industry, including the manufacturing industry, is changing the company's environment by enabling companies to face challenges in the environment and make better progress. It also enables changing the way performance is measured, that allows improving the efficiency of production processes, productivity and product quality. Digitalization is related to Industry 4.0 and its technologies. It often happens that technologies are implemented, but the company is not ready to fully exploit their potential, that depends on the degree of the company's development. This article identifies important aspects of the application of DKPIs and DTKPIs in production through systematic research of the relevant literature. Their importance in production was highlighted, allowing for quantitative analysis of the impact of digitalization on processes and business as a whole. DKPIs provide measurable indicators for evaluating manufacturing processes, such as equipment efficiency, downtime, product quality, and others, while DTKPIs present indicators of the success of the business model transformation. Together, they give an overall picture of the company's business performance, enabling the company's management to make timely and adequate decisions, following a strategy with predefined digitalization goals. The direction of future research of the authors of this article is to examine the effectiveness of applying the DKPIs and DTKPIs in companies around the world from various industries and to identify opportunities for further improvement of business processes.

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# THE USE OF INTERNET OF THINGS AND ROBOTICS IN SUPPLY CHAINS

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**Abstract:** *In recent years, there has been an increasing number of supply chains that have integrated new advanced technologies and have gone through digital transformation. The aim of this paper is to examine the possibilities and benefits of using Internet of Things (IoT) technology and robotics within the supply chain processes. The research methods include desk analysis, comparative analysis of literature and analysis of relevant case studies. The results reveal different ways in which IoT can be utilized within supply chains and how it can be used in integration with robotics to improve the performances of supply chains. Examples of supply chains that use robotics with IoT enhancement are also given. The paper can serve as a piece of basis for the digital transformation of supply chains in Industry 4.0.*

**Keywords:** *Supply Chain, Supply Chain Processes, Internet of Things, Robotics, Industry 4.0.*

## 1. INTRODUCTION

The development of the Internet catalyzed a chain reaction for the 4.0 industrial revolution which greatly impacted how supply chains (SC) operate. One of the key factors that leads the digital transformation of the supply chain in industry 4.0 is a growth of customer expectations. E-commerce and online shopping rapidly increased which resulted in new bonds flowing into different supply chains making them more entangled, as well as adding a new layer into consideration when managing a company's supply chain network. This new global market space isn't bound by a physical shop location or the location of the customer, in this market the whole world is available via a digital device. The new digital market space wasn't the only new expectation of customers, but also the need for more variety in individualization of products and the need for customization. The combined effect of all the new demands resulted in the expansion of the market gap, as well as the need for the supply chain to be faster, resilient and more flexible. The transformation required the integration of new advanced technologies, as well as a more interconnected relationship between different entities in a SC. The supply chain of Industry 4.0 embraces advanced technologies to meet modern challenges and gain and keep a competitive advantage. Some of the advanced technologies that revolutionized the supply chain are Internet of Things (IoT), robotics, blockchain, big data analytics, artificial intelligence (AI), cloud computing, etc. The focus of this paper is the use of the Internet of Things (IoT) in different processes in the supply chain, as well as how IoT integrate and enhances robotics that are used in supply chain processes. The motivation behind this paper stemmed from a desire to delve into the impact of IoT and robotics on the supply chains. The aim is to analyze the extent to which these technologies have been considered in the context of supply chains and to showcase their practical applications.

The remainder of the paper is organised into four sections. Section 2 is designated for the theoretical background, while the possibilities and benefits of using IoT and robotics within the supply chain processes are analyzed in Section 3. The examples of supply chains that use integrated IoT and robotics solutions are presented in Section 4. Finally, the conclusions and directions for further research are given in Section 5.

## 2. THEORETICAL BACKGROUND

Every company is a participant in one or more supply chains. A supply chain is a network of interlinked organizations that encompasses the procurement of materials and parts, transformation of these materials into products and services, and delivery of products and/or services to end customers. The aims of supply chain are to satisfy customer needs and to maximize supply chain profitability. Nowadays, development of industry 4.0 technologies brings new challenges and opportunities for supply chains. Thus, a new question arises: How to transform traditional supply chain into smart supply chain?

The term smart supply chain refers to the integration of advanced technologies such as various IoT devices and infrastructures, the use of robotics, artificial intelligence and data analytics, into supply chain processes to optimize decision-making, forecasting and automation capabilities (Wu et al., 2016). Smart supply chains



are interconnected systems that are instrumented, intelligent, automated, integrated and innovative, which result in real-time data circulation and the creation of value. These SCs integrate IoT, AI and automation in a harmonious way making them more efficient, agile and competitive in comparison to the traditional SC (Chaopaisarn & Woschank, 2019). The most prominent characteristics of smart supply chains are that they are intelligent, integrated, adaptive, flexible, innovative and have self-optimizing procedures (Zhang et al., 2023). One of the main objectives of SC digitization is the successful transformation of traditional SC into smart SC. Amongst the vast majority of technologies, the focus here will be placed on IoT and robotics, how they can be used and what benefits they can provide to the SCs.

The digital transformation of the supply chain is a complex, long-term process that necessitates a high level of expertise not only within individual companies but also across the entire supply chain (Li & Zhang, 2023). Strategically, this transformation unfolds in several stages, commencing with thorough analysis and process reengineering, followed by the implementation of advanced and emerging technologies and systems (Preindl et al., 2020). A prerequisite for digital transformation of supply chain is a comprehensive analysis and optimization of processes—essentially, a deep understanding of the processes and the elimination of inefficiencies. Among the various technologies, the IoT and robotics are essential components for digital transformation of supply chain (Hartley & Sawaya, 2019; Gezgin et al., 2017).

The term IoT was first used by Kevin Ashton, co-founder of the Auto-ID Laboratory at MIT, in 1999. He used this term during his presentation at Procter and Gamble (P&G) about how their supply chain can be connected to the Internet using Radio Frequency Identification (RFID). Ashton used the term IoT to give the new concept of having data collected automatically and stored in a system by using the Internet as the vessel of transportation and the key factor of communication between different parts of the supply chain (RAIN RFID, 2015). IoT is “an open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in the face of situations and changes in the environment” (Madakam et al., 2015). IoT is “an area of cutting edge development that combines such paradigms as cloud and mobile computing with physical objects that are capable of both network communication and interaction with the physical world” (Ryan & Rozier 2024). A broader definition of IoT gives emphasis on “a global network which allows the communication between human-to-human, human-to-things and things-to-things, which is anything in the world by providing a unique identity to every object” (Aggarwal & Das, 2012). The IoT consists of various devices. Goumagias et al. (2021) suggested a branching grouping system based on their functionalities. Thus, the following seven main branches which represent the key functionality of the IoT are: computation, actuation, sensing, services, identification, connecting and semantics. Each of the main branches is decomposed into smaller branches that either directly highlight one specific IoT device/ technology or are decomposed into groups of technology. Further, groups are decamped into specific IoT devices or technologies. For example, the computation branch is decomposed into branches for operating systems, software and hardware, then each of them has specific technologies listed. The branch for sensing directly decomposes into IoT devices such as RFID tags, QR codes, GPS, Barcodes and many more. This classification system covers the evolution of IoT over the past 15 years (Goumagias et al., 2021). The adoption of the IoT in supply chains offers significant benefits, including real-time supply chain management, improved performance management, increased transparency in logistics operations, and enhanced operational efficiency (Haddud et al., 2017). Additionally, IoT integration enables improved track and trace capabilities, simplification of return material authorization operations, and enhanced supply chain efficiency through features like scanning without a line of sight and reading multiple RFID-tagged items at once (Tu, 2018).

The era of industrial robots was begun in 1961. A clear definition of industrial robot from 1979 is well-known and broadly accepted - “a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of task” (Groover et al., 2008). Further in the paper when comparing and analyzing robotics and its use in various parts of the supply chain this definition will be used as the criteria and reference for what a robot is. The most commonly used robotics types in supply chains are (*A Guide to Robotics in Supply Chain* | ASCM Houston, 2022): Autonomous Mobile Robots (AMR) and Labour Reduction Technology (LRT). One of the major effects of Industry 4.0 was the exponential increase of robotics used in different processes. The need for a more advanced automation system has also arisen. Robotics have a crucial role when it comes to process automation within a supply chain. The use of AMR and LRT robotics enhances operational efficiency by replacing labour-intensive tasks, which results in process output being more productive, as well as cheaper and more resource efficient. One of the more prominent results and reasons for using robotics in supply chain processes is the enhanced reliability of the SC as a whole (Wu et al., 2016). The use of robotics isn't confined to just manufacturing, robotics is used in warehousing, delivering, packaging, order fulfillment, sourcing, retailing and many more processes outside the manufacturing plant. While there is a misconception that robotics is only used in manufacturing, the research and industrial use show that the most dominant area of use is in warehousing and distribution (Yong et al 2018).

In order to pinpoint where there is a possibility and what are the potential benefits of integrating IoT with robotics in a supply chain, the first step is to break down the supply chain into core processes. According to the Supply Chain Council (2010), the supply chain encompasses the following main processes: plan, source, make, delivery and return. Sallam, Mohamed & Wagdy (2023) propose the detail division of supply chain processes into demand forecasting, inventory planning, procurement and sourcing, manufacturing, warehousing and distribution, order management, transportation and logistics, demand management, supplier relationship management, quality control and assurance, information and data management, continuous improvement and customer service and satisfaction. An interesting view point on supply chain processes was given by Basodan (2016), who analyses the SC processes from a perspective of having four main process cycles. These cycles are customer order cycle, replenishment cycle, procurement cycle and manufacturing cycle. Each cycle consists of key processes for that cycle, for example, the customer order cycle consists of processes regarding arrival of customer, customer order entry, customer order fulfillment and customer order receiving. The key supply chain processes according to The Global Supply Chain Forum (GSCF) are (Table 1): customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, supplier relationship management, product development and commercialization, and returns management (Lambert, 2005). This division of supply chain processes is frequently used in literature.

**Table 1.** Description of supply chain processes by GSCF(Lambert, 2005)

Process of the supply chain	Description of the process
Customer relationship management (CRM)	CRM refers to the process of establishing, developing, and maintaining positive relationships with customers. This includes customer segmentation activities for targeted marketing.
Customer service management (CSM)	CSM involves arranging the sales of products and services to customers, monitoring sales performance, and resolving potential issues before they affect customers. CSM provides customers with real-time information regarding delivery dates and product availability to better enhance their experience.
Demand management	Demand management involves forecasting demand, synchronizing supply and demand, as well as increasing flexibility and reducing demand variability. Gathering data on key customers and from Point-Of-Sales (POS) endpoints is crucial for effective demand management.
Order fulfillment	Order fulfillment processes are used for identifying customer needs and creating conditions to meet their requirements with minimal delivery costs. This ensures that customers receive their orders on time and in good condition.
Manufacturing flow management	This type of management supports the transformation of raw materials into finished products and reaching the desired level of production flexibility. Production flexibility refers to the ability to manufacture a large number of different products timely and at the lowest possible costs.
Supplier relationship management (SRM)	SRM refers to establishing, developing, and maintaining positive business relationships with suppliers. This process supports supplier segmentation and long-term cooperation with key suppliers.
Product development and commercialization	Product development and commercialization refers to the development and introduction of new products to the market. This process is essential for staying competitive and meeting the changing and growing demands of customers.
Returns management	Returns management refers to the management of product, packaging, and reusable resource returns, as well as the implementation of specific activities aimed at reducing unwanted returns within the company and between key supply chain participants.

The well-known division of supply chain processes from GSCF is used here as the baseline to determine where an integrated approach of using IoT and robotics can be implemented within a supply chain. Further, the study is guided by the following research questions:

1. In which supply chain processes is IoT used and how?
2. In which supply chain processes robotics are used and why?
3. Is there a possibility of integrating IoT and robotics?
4. Where and what combination of IoT and what type of robots can be integrated?
5. What are the benefits of investing in this type of integration?

### 3. USE OF IOT AND ROBOTICS IN SUPPLY CHAIN

For companies to keep up with the rapidly changing and growing customer demands and expectations, the supply chain has to be improved. This improvement can be achieved with the integration of new advanced technologies such as IoT and robotics. IoT is used for real-time data collecting, and optimizing data collection, which results in more effective monitoring and control, as well as better decision-making. Robotics is used for labour-intensive tasks, tasks that can be dangerous for human workers, actions that have a pattern of movements and many more uses (Chen & Papazafeiropoulou, 2013; Giourouki, 2024). Using the GSCF division of supply chain process as the baseline of the analysis, a comparison of the use of IoT is presented in Table 2. The use of IoT is collected from various authors, to give a representative view of the practical use of IoT in supply chain, as well as the benefits of use for each supply chain process.

Robotics can be mostly found in use in the processes that are labor intensive, repetitive and/or have a distinct pattern of movements. Robotics use can be found in many of the SC processes. Using the supply chain process division given by GSCF, the most common areas of use of robotics can be found in processes regarding demand management, order management, manufacturing flow management, product development and returns management (Giourouki, 2024; Nee, 2023). Robotics are used in the majority of supply chain processes and the reason why is to either automate manufacturing processes or warehouse activities, used for the transportation of goods and around-the-clock works making it easier to have shorter response times (Nee, 2023). The use of robotics in SC has a lot of benefits even though the initial investment comes to about 2 million dollars. Some of the reasons to use robotics in supply chain processes are (Rennie, 2023): create competitive advantages, reduce the overall operational cost, cut labor needs in half, eliminate human-prone errors, improve the safety of staff, optimize activities and boost efficiency and productivity. A pattern that can be detected in major supply chains is the trend of combining and integrating technologies, such as the integration of IoT and robotics to keep up with the rise of the complexity of managing a supply chain network, predicting demand and synchronizing processes within the supply chain (Chen & Papazafeiropoulou., 2013).

**Table 2.** Use of IoT in supply chain processes

SC process	IoT used	How is IoT used	Benefits of use	Authors
Customer relationship management	Sensors and data collection devices	IoT is used for gathering and analysing data collected from customers. This data is then used to create customer personas and better marketing campaigns. Using IoT marketers can track customer interactions, preferences, and behaviors to tailor their strategies effectively. This data-driven approach helps businesses enhance customer relationships, increase customer loyalty, and drive sales growth.	Better understanding of customer needs. IoT gets crucial data that is used for enhancing customer engagement and interaction.	(Hashem , 2021)
Customer service management	Sensors, telematics and diagnostic tools	Collecting real-time data, which gives a more accurate forecasting of customer needs. By transferring data to a central system, an automated decision-making is made possible, which as a result has improvement of service quality that directly increases customer satisfaction.	Enhanced forecasting results, faster response to customer needs.	(Yerpud e & Singhal, 2018)
Demand management	RFID, sensors	IoT is used to enhance demand management, with more accurate data collection and gives more visibility of in stock and out of stock inventory. An example of use is in retail stores where the use of IoT helps organize offers of limited-time discounts to clear out left over stock in order to make room for new arrivals. Sensors are placed in data collection points with unique identifications, the data is transmitted via Internet in real-time.	Using IoT organisations can set up automated purchases based on real-time stock-level data.	(Caro & Sadr, 2019) (Yerpud e & Singhal, 2017)
Order fulfilment	RFID, WSN	Using the signals sent and received by IoT devices, improved the efficiency of ordering, lowers costs and improves delivery time. IoT in order management automates data collection and updates data for, various information collection points, making the process of controlling incoming parts and activities faster and easier than before. Some of the main uses are the handling of inconsistencies and delays in real-time, streamlining the process and improving efficiency.	Customers receive timely updates on order status, which has resulted in enhanced customer satisfaction due to faster order processing time and more accurate deliveries.	(Varriale et al., 2021) (Lee et al., 2018)
Manufacturing flow management	RFID, Wireless Sensor Network (WSN)	Monitoring, to optimize operating hours, detect errors, as well as quality and administrative control. Controlling and monitoring the manufacturing flow using IoT devices improves visibility of products, reduces holding inventory costs.	Use of IoT made the visibility of the whole manufacturing process flow easier and more transparent.	(Yang et al., 2019) (Hamdy et al., 2022)
Supplier relationship management	Sensors	Integrated in the VMI (Vendor Managed Inventory) system, where its main use is real-time data collection and transferring data. Using IoT helps improve response time and better communication with suppliers.	Using IoT gives real-time data which is used to improve supplier relationships.	(Yerpud e & Singhal, 2018)
Product development and commercialization	Sensors	IoT sensors collect data that is then utilized for predictive analytics to forecast future outcomes, detect failure patterns, as well as reduce development time and costs. IoT facilitates the base for the creation of smart connected products that generate valuable data for insights, leading to improved decision-making, faster development cycles, and cost reduction.	Use of IoT minimizes the chance of significant hardware development errors, and improves data interoperability in development processes	(Mahmu d, 2018)
Returns management	RFID, PAID	IoT is used for tracking and analyzing product life cycle data, allowing for the prediction of quality and value of returned products. Enables real-time data collection on product status, aiding manufacturers in the return acquisition process.	IoT collected data is used to predicting the remaining value of returned products, reducing recovery costs, and saving time.	(Fang et al., 2016)

#### 4. INTEGRATION OF IOT AND ROBOTICS

As the complexity of modern supply chains increases the need to implement advanced technologies as well as combine existing technologies into a symbiotic system arises. Most manufacturing and warehousing facilities have implemented some sort of AMR to improve efficiency and productivity. Integrating IoT with this type of robotics is possible and it is used in some of the larger supply chain networks in the world (Jain, 2019). For example, Automated Guided Vehicles (AGV) are enhanced with sensors for navigation, as well as barcode and QR code readers, which means that they can send data to a router that can distribute that data in real-time (Nee, 2023). A leading example of computer and robot-integrated technology is Automated Storage and Retrieval System (AS/RS) solutions, which use coordinates to find and retrieve/store products in their dedicated spots, connecting them to a unique system where IoT devices collect and store data (Pingale & Kulkarni, 2019). Enhancing robots with IoT leads to a quicker return on investment (ROI) than buying IoT technology all on its own (Watson, 2024). A list of companies that use robotic enhanced with IoT is shown in Table 3.

**Table 3.** Companies using IoT enhanced robotics

Company	Robotics & IoT solutions	Where it is used	How it works / For what is used	Reference
DHL	Autonomous Security Robot (ASR).	Warehouse	ASRS operates by using thermal imaging for safety and security, their main purpose is monitoring and surveillance.	( <i>Warehouse Robotics: Is This the Moment of Truth?</i> , 2023).
Amazon	Kiva Robots types "G" and "S"	Warehouse	Kiva Robots are connected to a centralised system, using hundreds of sensors located in the warehouse as well as sensors located on the robots; the robots navigate and collect orders by priority. Amazon Prime order has to be filled first no matter the order of transactions, that's where IoT has the major effect.	(Valerio, 2015)
FANCU	FANCU Robots	Manufacturing	FANCU Robots are designed with sensors in them, they are called intelligent robots because of their ability to work with IoT, the company offers their IoT software solutions as well.	( <i>ROBOT - PRODUCT - FANUC GLOBAL</i> , 2024)
Red Stag Fulfillment	Advanced warehousing drones (aerial robots)	Warehouse	These drones fulfil a crucial role when it comes to process optimisation in the warehouse. They do inventory tracking and management, quicker order fulfilment and are used as a monitoring tool for safety and security.	(Selwitz, 2023)

#### 5. CONCLUSION

The aim of this paper was to give a unified piece of study about the individual as well as the combined use of IoT and robotics in the supply chains. The paper highlights the various ways that IoT and robotics are used in different parts of the SC and presents real cases from practice that use the integration of these two technologies. This study is limited by the use of only a fraction of all the available materials that tackled the use of these technologies in the supply chain. Advanced technologies are growing at a rapid pace, and in the last decade, there have been more innovations discovered than in the previous two decades combined. Due to this, many companies are wary of using new unexplored technology and prefer to use technologies that they have reliable and industry-tested data and results on. The use of sensors and RFIDs is a common and well-loved practice amongst many SCs. At the same time the use of robotics to automate processes and reduce labour and operational costs is a trend. There is little evidence about supply chains that take a challenge of integrating robotics with IoT. Most of the authors who analyses the effects of utilizing IoT as is or with robotics have concluded that these technological advancements are the fundamental tools in transitioning the supply chain into Industry 4.0. Further research is needed to see what digital, social, mobile, and emerging technologies or what combination of technologies can push the supply chain into the industrial 5.0 revolution and what benefits and challenges lie ahead of that transition.

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# ATTITUDE TOWARD DIGITALIZATION AND APPLICATION OF DIGITAL TOOLS AMONG JUNIOR AND SENIOR TEACHING STAFF

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**Abstract:** *In this study, we analyzed the variables “Application of digital tools” and “Digitalization attitudes” among teachers in an academic environment. Our analysis focused on 43 senior and 25 junior teachers, excluding non-teaching staff. In order to ensure a relatively equal group size, the groups were divided according to hierarchy level 4, more precisely the assistant professor level. The mean for “Application of digital tools” was 3.82 (SD = 0.66) for senior faculty members and 4.16 (SD = 0.59) for junior faculty members. This difference was statistically significant ( $t = -2.114$ ,  $df = 66$ ,  $p = 0.038$ ) and supported our hypothesis H1. For the variable “Digitalization attitudes,” the mean was 4.08 (SD = 0.58) for senior faculty members and 4.39 (SD = 0.61) for junior faculty members. This difference was also statistically significant ( $t = -2.071$ ,  $df = 66$ ,  $p = 0.042$ ) and confirmed our hypothesis H2. These results illustrate how important it is to take into account both the use of digital tools and the attitude of teachers in academic environments towards digitalization.*

**Keywords:** *Application of digital tools, attitudes towards digitalization, teaching staff*

## 1. INTRODUCTION

Information and communication technologies dynamically influence the world and all ongoing processes. Introducing ICT into the teaching process can significantly enhance the quality of educational work. The digitization of the education system encompasses not only the integration of digital technology into the teaching process but also the digitization of all processes within the education system, including the development of various portals and services for students, teachers, and parents, as well as services facilitating data exchange with other stakeholders.

It is undeniable that COVID-19 has had a significant impact on integrating innovative digital technologies into the learning and teaching process. However, the digitalization of the education system is not an easily achievable goal and is not a one-way process. Some of the platforms commonly used in the teaching process include Moodle, Cisco Webex, Microsoft Teams, Google Classroom, among others.

Nevertheless, it is crucial to underline that the significance lies not solely in the technology employed, but rather in the methodologies and competencies of the teachers. Moreover, substantial investment in teachers, who play a pivotal role throughout the entire educational system, is paramount. When considering countries that have incorporated digital literacy into their national curriculum, it is worth noting that Norway, for instance, implemented this as early as 2006. When comparing education systems across different countries based on students' knowledge, the PISA tests provide insights into the quality of educational systems. Unfortunately, Serbia does not excel in student performance on these tests. Whether the issue lies within the fundamental system itself or if students lack motivation to participate in these assessments is a recurring question each time the results are published. What's certain is that PISA tests don't evaluate students' knowledge acquired through the curriculum but rather focus on functional knowledge relevant to today's digital world. Education's focus is on guiding students to comprehend the essence of knowledge, to reason, to draw conclusions, and to apply knowledge. Yet, it's crucial not to overlook the fundamentals. Hence, the challenge lies in striking a balance between these two aspects, achieving harmony between traditional and digital learning methods. This approach ensures the utilization of digitalization's benefits while preserving the importance of classical education.

In relation to that, we propose two hypotheses:

H1: Application of digital tools is higher among junior teaching staff, compared to the senior teaching staff

H2: Positive attitudes towards digitalization are higher among junior teaching staff, compared to the senior teaching staff

## 2. LITERATURE REVIEW

The differences that exist between the concept of digitalization and digital transformation is certainly one of the key concepts in the domain of strategies related to digitalization itself. The difference between the concepts of digitalization and digitization should also be considered. Digitization represents the conversion of analog information into digital form, while digitalization refers to the use of digital technologies to transform business processes and create new values (Fatras, 2020).

The modern world could not be imagined without digital transformation, because currently it represents a concept without which no business can be imagined. With the advent of digitalization itself in the educational sphere, there are various changes in the structure of the institutions themselves, the way teaching and non-teaching staff work, as well as the evolution of various pedagogical strategies in order to accompany the development of digitalization itself. Rozensher (2011) and Carpenter (2019) also emphasize the need for the faculty to adapt to digital tools and methods, which agree with our views. Lupton (2012) further emphasizes the importance of digital literacy for faculty, which is one of the prerequisites for using the very products of digital transformation, while Biggane (2019) discusses the evolving role of faculty in digital teaching and learning, as well as the need for effective approaches to improve student engagement.

Looking at the current picture in the world, universities, no matter how hard they try to keep up with the digitization process itself, lag behind in that sphere compared to other industries, which agrees with the research of Rodríguez-Abitija (2021). The introduction of digitization is certainly a complex and painstaking process that is influenced by many factors, which agrees with the research conducted by Alenzi (2023) and Bond et al (2018). Of course, to implement all this, in addition to the desire, a lot of things are necessary, from the infrastructure itself, then the absence of resistance to changes and, of course, the desire for training.

By introducing digitization itself, students are encouraged to follow the developing trends, thus creating better results. The convergence of digital tools and methodologies in higher education is not only a technological shift, but also a pedagogical one, requiring teachers to adapt their teaching approaches to meet the needs of modern learners. This change is indeed essential for universities to remain competitive and relevant in the digital age. Through digitization, universities can improve efficiency related to administration, facilitate access to various necessary information and improve communication within the institution. Digital transformation is not only a way to acquire new knowledge, it is a step towards a safe and bright future created by us.

## 3. METHODS

The data was gathered from 74 employees of University of Belgrade, Faculty of Organizational sciences. Most of the employees were teaching staff, with only 6 employees in support and research. Employees were asked to identify their positions in organizations, and then a battery of questions regarding their awareness, knowledge, attitudes, application of tools and requirements for training in the field of digitalization. This paper focuses on three-item variables "Application of digital tools" and "Digitalization attitudes." Variables were checked for normal distribution. While the graphs presented below show resemblance with a normal distribution, with strong skewness to the left for the application of digital tools and outliers in high values for digitalization attitudes, values of Kolmogorov-Smirnov test reject the hypothesis of normality. Having in mind relatively large sample, since t-test becomes increasingly robust to violation of normality assumptions with increase in sample size (Heeren & d'Agostino 1978; Sawilowsky & Blair 1992), we have used the t-test to check our assumptions.



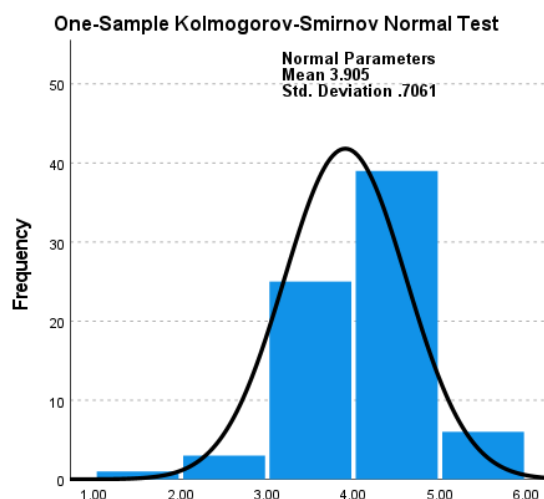


Figure 1: Distribution of variable application of digital tools

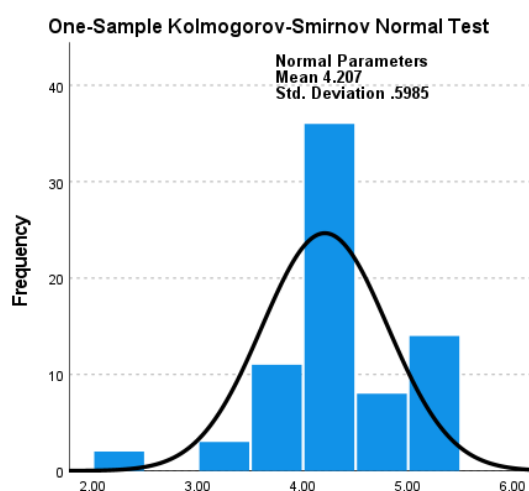


Figure 2: Distribution of variable digitalization attitudes

Scales were checked for reliability using the Crombach Alpha, which returned 0.660 for digitalization attitudes and 0.785 for application of digital tools. Taber (2018) systemizes Crombach Alpha reporting of the first value in different research as acceptable, adequate, satisfactory and sufficient, while the second value is also reported as high, reasonable and good. Both values are adequate for further analysis, according to Hair et al. (2003). Data was analyzed using the SPSS package for descriptive statistics analysis and t-test.

#### 4. RESULTS

In our analysis we have focused on the variables “Application of digital tools” and “Digitalization attitudes”. Overall results show higher values of both constructs, with descriptive statistics presented in the Table 1. Out of the whole sample, six rows were eliminated as the non-teaching personal and total of 43 senior teaching staff and 25 junior teaching staff employees were analyzed. These groups were chosen by split on hierarchical level 4, an assistant professor level, because it is a major event in the development of academic staff, and because it splits the sample on relatively similarly sized groups.

Table 1: Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Application of digital tools	74	1.33	5.00	3.9050	.70607	.499
Digitalization attitudes	74	2.00	5.00	4.2072	.59853	.358
Valid N (listwise)	74					

Analysis of our variable values for two different groups is given in the table below.

**Table 2: Group statistics**

	Hierarchy	N	Mean	Std. Deviation	Std. Error Mean
Application of digital tools	>= 4 (senior)	43	3.8216	.66067	.10075
	< 4 (junior)	25	4.1592	.58705	.11741
Digitalization attitudes	>= 4 (senior)	43	4.0774	.58073	.08856
	< 4 (junior)	25	4.3864	.61429	.12286

**Table 3.** T-test for the analysis of "Application of digital tools" difference between junior and senior teaching staff

Levene's Test for Equality of Variances		t-test for Equality of Means				95% Conf. Interval of the Difference	
F	Sig.	t	df	Sig. (2-tailed)	Mean diff.	Lower	Upper
.399	.530	-2.114	66	.038	-.33757	-.65638	-.01876

Our first variable "Application of digital tools", as self-reported by our respondents, have a mean value of 3.82, and a standard deviation of 0.66 for senior teaching staff, an higher mean of 4.16 and standard deviation of .59 for junior teaching staff. The difference was statistically significant, confirmed by the -2.114 value of t-statistics with 66 degrees of freedom and a p-value of 0.038, as presented in our table 3.

**Table 4.** T-test for the analysis of "Digitalization attitudes" difference between junior and senior teaching staff

Levene's Test for Equality of Variances		t-test for Equality of Means				95% Conf. Interval of the Difference	
F	Sig.	t	df	Sig. (2-tailed)	Mean diff.	Lower	Upper
.122	.728	-2.071	66	.042	-.30896	-.60681	-.01111

According to our results, variable "Digitalization attitudes", as self-reported by our respondents, have mean value of 4.08, and a standard deviation of 0.58 for senior teaching staff, an higher mean of 4.39 and standard deviation of .61 for junior teaching staff. The difference was statistically significant, confirmed by the -2.071 value of t-statistics with 66 degrees of freedom and a p-value of 0.042, as presented in our table 4. These results confirm both our hypothesis.

## 4. CONCLUSION

The use of digital tools and instructors' attitudes towards digitization were the main topics of our study on digitization in higher education. The findings offer a summary of the state of affairs as well as insights on potential future advancements in the field of education. The findings demonstrate the critical need for colleges to make digital transformation a top strategic priority. The notions of "Use of digital tools" and "attitudes towards digitization" have higher mean scores among novice teachers than among senior teachers. This suggests a generational shift towards the adoption of digital technologies and a growing understanding of the significance of digital skills in modern education. Our research shows that digitization is universally present in the modern world, and that the need for it is therefore too great. Although many believe that digitization can cause the traditional way of working to break down, one must be aware that if it is not implemented, there will be an excessive digital gap. By introducing digitization, work and access to information can certainly be facilitated for students and professors. Looking at these facts, we believe that educational institutions must enter the digital infrastructure itself and, in addition, try to train the people who make up that institution as efficiently as possible. Universities, as places where knowledge from various fields is acquired, should take a leading role in use of digital technology, and provide students with the best possible digital tools in order to follow all the trends in the world.

Studies that will continue to deal with this topic should investigate which digital tools are, as well as the approach to education itself, which will give the most advantages to students. We should also consider the problem of how to solve all digital obstacles in the best possible way. With these proposals, we get the possibility that faculties, despite all the problems they encounter, remain a safe path to success and a place

where the most relevant knowledge from various fields is acquired, all with the help of digitalization. With this research, the idea was to emphasize the importance of digitization, as well as the fact that it is a phenomenon that is increasingly present between people and as a tool that will certainly be a daily part of normal life and functioning in general. This research represents the beginning of examining employees' attitudes about digitalization, and the main idea when creating the paper is that, in addition to examining attitudes, on the other hand, they should also encourage the students in the survey to think more about it. In addition to this research, as a result of the comprehensive survey, it is planned to do more research, which would complete the research and raise the field of digitization to a higher level. Also, this research confirmed both hypotheses that younger teaching staff trust and use digitization more, but on the other hand, a great desire and need was expressed for older teaching staff to also apply and use all the possibilities offered by digitalization. A phenomenon such as digitization should certainly become an everyday thing and a thing that will make everyday life easier for people all over the world, and for the teaching staff, which is the subject of this research, in the best way possible to transfer knowledge gained from various fields to students and improve themselves.

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# FOSTERING ENTREPRENEURIAL MINDSETS: GENDER AND ORGANIZATIONAL PERSPECTIVES

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**Abstract:** *This research investigates the influence of gender dynamics and organizational contexts on entrepreneurial intentions among employees within diverse organizational settings. Employing a survey-based approach, data were collected from 122 participants in Serbia and various European countries, focusing on socio-demographic characteristics and organizational conditions. Nonparametric tests, including the Mann-Whitney and Kruskal-Wallis tests, were utilized for analysis. The findings reveal significant disparities between men and women regarding entrepreneurial consideration, with men exhibiting a stronger inclination towards entrepreneurship. Moreover, employees in mid-level positions show the highest propensity for entrepreneurial aspirations. Managerial support for empowerment and autonomy in daily tasks positively correlates with increased entrepreneurial consideration among employees. These results underscore the importance of addressing gender biases and fostering supportive organizational cultures to promote entrepreneurship within organizations.*

**Keywords:** *Entrepreneurial intentions, Organizational context, Gender dynamics, Survey, European Countries*

## 1. INTRODUCTION

Entrepreneurship, the driving force of innovation and economic growth (Kacperczyk & Younkin, 2021), is consistently capturing the attention of researchers. As societies evolve, so too do the factors that influence individuals' aspirations towards entrepreneurial pursuits. Central to this research are the roles played by gender dynamics and organizational settings in shaping entrepreneurial intentions and behaviours.

Gender, a fundamental aspect of individual identity, has long been recognized as a determinant of entrepreneurial engagement. While strides have been made towards gender equality in entrepreneurship, disparities persist, with men historically outnumbering women in entrepreneurial ventures (Rocha & Van Praag, 2020; Zelekha, 2021). The reasons behind these disparities are multifaceted, reflecting societal norms, cultural expectations, access to resources, and perceptions of risk and opportunity (Guzman & Kacperczyk, 2019). Moreover, the organizational context in which individuals operate plays a pivotal role in influencing entrepreneurial aspirations. Organizational culture, leadership practices, and structural arrangements shape the attitudes, behaviours, and opportunities available to employees regarding entrepreneurship (Dobni, 2012). Empirical evidence suggests that organizational support for innovation, autonomy, and risk-taking fosters an entrepreneurial mindset among employees (Michael Msawenkosi Thabethe et al., 2024).

Against this backdrop, this study aims to unravel the relationship between gender dynamics, organizational contexts, and entrepreneurial aspirations. By examining how gender influences entrepreneurial considerations within diverse organizational settings, the goal is to delineate effective strategies for gender support within organizations. Additionally, the study delves into how organizational factors such as seniority level, managerial support, and autonomy impact individuals' entrepreneurial intentions and behaviours, with the aim of identifying key determinants that organizations can leverage to foster a conducive environment for entrepreneurship among their workforce. The research methodology employs a survey-based approach, utilizing a questionnaire to collect data. Nonparametric tests are then utilized for analysis, providing a systematic exploration of the identified variables. Through this approach, the study aims to shed light on the dynamics of entrepreneurial intentions within organizational contexts.

Following the introduction, the subsequent section is dedicated to reviewing relevant literature. The third section highlights the research methodology and details the data collection process, while the fourth section

presents the research findings. Focusing on these results, the final segment engages in a discussion to draw conclusions from the study.

## 2. LITERATURE REVIEW

The literature on entrepreneurship presents a rich and evolving landscape of research, highlighting the multifaceted factors influencing individuals' entrepreneurial intentions and behaviours (Rakićević et al., 2022; Maheshwari et al, 2023; Do Nguyen & Nguyen, 2023; Batista-Canino et al., 2023). The study by Thurik et al. (2023) explores how entrepreneurship research is impacting other academic disciplines. Over the past four decades, entrepreneurship has evolved into a robust scientific discipline by integrating theories, paradigms, and methodologies from various domains such as business, economics, psychology, sociology, geography, biology and engineering. This interdisciplinary approach has elevated the status of entrepreneurship as an academic field, leading to other disciplines borrowing from its perspectives (Thurik et al. 2023). The article presents seven examples of this phenomenon, highlighting how entrepreneurship research challenges the fundamental presumptions of other academic domains and offers fresh insights into their core principles. Furthermore, entrepreneurship research plays a role in validating other disciplines both in practical application and academic context.

Study by Kirkley (2016) explores how personal values shape entrepreneurial behavior, finding that independence, creativity, ambition, and daring are key motivators. It emphasizes the influence of deep-seated beliefs on decision-making and highlights cultural and contextual differences in entrepreneurial activity. Crecente et al. (2021) explore the relationship between the value of entrepreneurship in relation to gender and regional behavior. Traditionally, entrepreneurial organization has been viewed separately from gender and economic growth. Leveraging data sourced from the Global Entrepreneurship Monitor (GEM) spanning 50 nations, the research conducted by Crecente et al. (2021) delves into factors like total early-stage entrepreneurial activity (TEA) and opportunity-driven entrepreneurial activity (OPP). The methodology entails a thorough examination of regional convergence, scrutinizing the trajectory of entrepreneurial activity rates across time while differentiating between genders. The discoveries by Crecente et al. (2021) indicate that the role of gender in entrepreneurship significantly influences the delineation of distinct clusters of countries, delineating how male and female entrepreneurs contribute to the creation of new economic prospects. Furthermore Gruber and MacMillan (2017) propose a perspective rooted in identity theory, which acknowledges entrepreneurs' varied meanings attached to entrepreneurship. It identifies three types of entrepreneurs: those driven by economic gain, those concerned with community welfare, and those aiming for societal impact. This reconceptualization offers insights into the complex nature of entrepreneurship and its broader social implications.

Ahmetoglu et al. (2019) delve into the impact of organizational factors on entrepreneurial inclinations and effectiveness within organizational settings. Their inquiry scrutinizes the influence of organizational structure and autonomy on entrepreneurial tendencies, locus of control, and performance. The research uncovers that although aspects of organizational structure correlate with work autonomy and performance, they do not directly associate with individual-level variables. Nonetheless, work autonomy demonstrates a correlation with entrepreneurial tendencies and locus of control, implying possible indirect ramifications of organizational structure on individual-level variables through work autonomy. This study illuminates the potential influence of organizational factors on entrepreneurial inclinations and underscores the importance of fostering entrepreneurial inclinations among employees for enhancing corporate entrepreneurship and overall performance. Moreover, Urban and Gamata (2020) elucidated the connection between organizational dynamics such as support from management, incentives, and allocation of time, and their impact on academic entrepreneurship. Their survey of academics revealed that rewards notably influence the outcomes of academic entrepreneurship, underscoring the necessity for tailored support structures emphasizing organizational rewards and incentives. In addition, Otache and Mahmood (2015) have developed a framework that investigates the interplay between corporate entrepreneurship, external context, company culture, and business outcomes. Their work underscores the significance of understanding how external factors and internal culture molds the connection among entrepreneurial initiatives within organizations and their overall performance. By reviewing existing literature, their framework suggests that the effectiveness of corporate entrepreneurship in enhancing business performance hinges on the compatibility between organizational initiatives and the surrounding environment.

The compiled research underscores the imperative of exploring the multifaceted determinants influencing entrepreneurship, given its pivotal role as a cornerstone of economic vitality and catalyst for innovation.

## 3. CASE STUDY SETTING

The survey design aimed to comprehensively investigate the factors influencing individuals' contemplation of transitioning into entrepreneurship. It was meticulously crafted to gather insights from participants on both socio-demographic characteristics and organizational conditions. The socio-demographic section of the survey sought to capture key information such as gender, age, nationality, education level, and employment position. These demographic variables were chosen to provide a holistic understanding of the survey respondents and to assess any potential correlations between these factors and entrepreneurial considerations. Furthermore, the survey delved into organizational dynamics by querying participants about various aspects of organizational culture, employee empowerment, autonomy, and entrepreneurial thinking. Respondents were asked to rate statements related to these themes on a 1-5 Likert scale, allowing for nuanced insights into their perceptions and attitudes towards these organizational factors. By incorporating both socio-demographic questions and organizational assessments, the survey aimed to uncover multifaceted insights into the drivers of entrepreneurial consideration. This comprehensive approach enabled investigation of the interplay between individual characteristics, organizational contexts, and entrepreneurial aspirations. The following table presents the survey questions alongside the corresponding variables utilized in the research. These variables were specifically chosen for inclusion in the study based on their demonstrated efficacy in capturing relevant insights and contributing to the research outcomes.

**Table 1:** Survey questions and corresponding variables in the research

Question	Variable
How do you identify your gender?	Gender
What is your current position level within the organization?	PositionLevel
My immediate supervisor or manager is supportive in empowering me to make decisions. (1-5)	ManagerialSupport
I have a high level of autonomy in managing my daily tasks and projects. (1-5)	DailyAutonomy
I am very open to taking risks in my personal and professional life. (1-5)	RiskTolerance
I am likely to consider starting my own business in the next 2-3 years. (1-5)	ConsiderEntrepreneurship

The selection of the Mann-Whitney and Kruskal-Wallis tests as analytical methods for this study stems from their appropriateness in analyzing non-parametric data and conducting comparisons between groups. In exploring entrepreneurial considerations within organizational contexts, where data distribution diverges from normality, these tests offer reliable and robust results. The Mann-Whitney test is adept at comparing two independent groups, as demonstrated by Lovric (2011). This makes it well-suited for evaluating variations in entrepreneurial consideration across different gender categories. Conversely, the Kruskal-Wallis test expands upon this functionality to encompass multiple groups, as demonstrated by Ostertagová et al. (2014). This allows for the exploration of variations in entrepreneurship consideration across various position levels and organizational attributes. The analysis was conducted using version 23 of IBM SPSS Statistics.

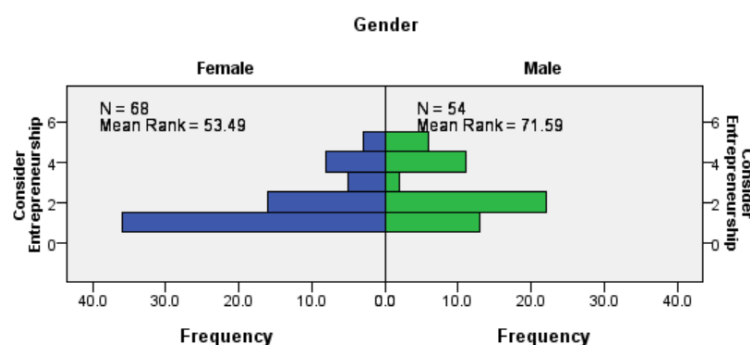
### 3. RESULTS

#### 3.1 Sample description

The study engaged 122 participants, employed within organizational settings, from various European countries, such as Germany, Belgium, Scotland and Serbia. Regarding gender distribution, 55.7% identified as women, while 44.3% identified as men. This pattern corresponds with the observations made by Smith (2008), indicating a tendency for women to emerge as the predominant participants in survey-based research. This phenomenon may stem from factors such as their increased involvement or enthusiasm for engaging in such studies. In the study, the age variable displayed a mean value of 32.32 years, with a standard deviation of 9.51, illustrating considerable variability among individuals' ages within the research cohort. Age-wise, the participant distribution is as follows: 25.4% of respondents were under 26 years old, 30.3% were aged between 26-29 years, 21.4% fell within the 30-39 age range, and those over 40 constituted 22.9% of the sample. Regarding professional experience, participants were categorized as follows: 22.9% had less than 2 years of experience, 34.4% had 2-5 years of experience, 14.7% had 6-10 years of experience, and 28% possessed over 10 years of experience. This diverse range of experience levels within the sample provides a broad spectrum of perspectives, enriching the depth of insights that can be gleaned from the research findings. In terms of professional roles, the distribution was as follows: 44.3% occupied entry-level positions, 33.6% held mid-level roles, and 22.1% were in senior-level or leadership positions. This distribution reflects a varied representation across organizational hierarchies, offering the opportunity to explore how perspectives and experiences differ among individuals with varying levels of authority and responsibility within their respective workplaces.

#### 3.2 Result analysis

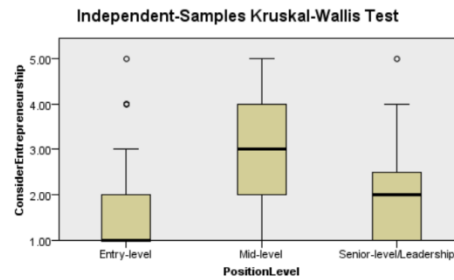
To assess the influence of gender on the likelihood of considering starting a business within the next 2-3 years, the Mann-Whitney test (Mann-Whitney U: 1291,  $p < 0.005$ ) was applied due to the non-normal distribution of this variable. The results unveiled a significant disparity between men and women regarding their contemplation of entrepreneurship, with men exhibiting a notably higher mean rank of 71.59 compared to 53.49 for women. This suggests a stronger inclination among male employees in organizations towards exploring the possibility of initiating their own ventures. Further examination of the Mann-Whitney frequency graph, presented in figure 1, reveals interesting insights. A substantial portion of women, comprising 52.9% of the female cohort, strongly disagreed with the notion of pursuing entrepreneurship, as indicated by their responses on the Likert scale. In contrast, a considerably smaller proportion of men, representing 24.1% of the male cohort, expressed strong disagreement. This discrepancy underscores the differing attitudes towards entrepreneurial pursuits between genders within organizational contexts. Moreover, when considering future aspirations, a noteworthy finding emerges. A notable 31.5% of men, equivalent to 17 individuals employed in organizations, conveyed agreement or strong agreement on the Likert scale regarding their intention to embark on entrepreneurship within the next 2-3 years. In contrast, this figure drops substantially to 16.2% among women, with 11 individuals expressing similar aspirations. This discrepancy highlights potential disparities in perceived opportunities or readiness to venture into entrepreneurship between male and female employees.



**Figure 1:** Independent samples Mann-Whitney U test for entrepreneurship consideration in next 2-3 years based on gender (Source: Authors' work)

Following the identified impact of gender on entrepreneurial consideration, the study aims to investigate potential differences between men and women concerning risk tolerance. This inquiry is prompted by the hypothesis that women may exhibit lower levels of risk tolerance, potentially contributing to their lesser inclination towards entrepreneurship. For this analysis, the Mann-Whitney test (Mann-Whitney U: 1327,  $p < 0.01$ ) was employed, revealing a statistically significant distinction between men and women in terms of risk tolerance. The mean rank for men stands at 70.93, contrasted with 54.01 for women, indicating a notably higher level of risk tolerance among men compared to women. The significant difference in risk tolerance between men and women, alongside the previously noted gender influence on entrepreneurial consideration, suggests a potential relationship. Men's higher risk tolerance may contribute to their greater inclination towards entrepreneurship, highlighting the need for initiatives addressing risk perception to support female entrepreneurship.

The subsequent investigation aims to explore the impact of organizational seniority on the intention to pursue entrepreneurship within the next 2-3 years, and to ascertain any potential correlation between seniority levels and entrepreneurial consideration. To achieve this objective, the Kruskal-Wallis test (Chi-Square: 34.366,  $p < 0.001$ ) was utilized, revealing a statistically significant disparity between organizational seniority and entrepreneurial consideration. Upon comparing the mean ranks obtained, a distinct pattern emerges. Entry-level employees exhibit the lowest mean rank of 43.80, suggesting they are the least inclined towards entrepreneurial pursuits. In contrast, senior-level employees display a higher mean rank of 61.76, indicating a greater propensity for entrepreneurial consideration. Notably, employees in mid-level positions attain the highest mean rank of 84.65, signifying the strongest inclination towards entrepreneurship. This interesting finding suggests that individuals at this career stage may harbor greater entrepreneurial aspirations, perhaps driven by a desire for autonomy, leadership opportunities, or the potential for greater financial rewards. These results are visually depicted in Figure 2.



**Figure 2:** Independent samples Kruskal-Wallis test for entrepreneurship consideration based on position level (Source: Authors' work)

With three independent Mann-Whitney tests, seniority levels were compared regarding their consideration of entrepreneurship. The results indicate a statistically significant difference between each pair of seniority groups: entry-level and mid-level (Mann-Whitney U: 387.00,  $p < 0.001$ ), entry-level and senior-level (Mann-Whitney U: 493.00,  $p < 0.01$ ) and mid-level and senior-level (Mann-Whitney U: 324.500,  $p < 0.01$ ). This sheds light on the distinct patterns of entrepreneurial inclination among different seniority levels within the organization.

This research also delves into the influence of perceived managerial support for empowerment in decision-making on the consideration of entrepreneurship. By examining this variable, the study aims to provide a comprehensive understanding of the factors shaping individuals' entrepreneurial aspirations within organizational settings. The Kruskal-Wallis test (Chi-Square: 51.569,  $p < 0.001$ ) revealed a statistically significant difference in the consideration of entrepreneurship within the next 2-3 years among groups categorized by perceived managerial support for empowerment in decision-making. Individuals who strongly disagree that their manager empowers them to make decisions exhibited the lowest mean rank of 25, followed by those who disagree with a mean rank of 32.39. This suggests that individuals who perceive a lack of managerial empowerment demonstrate a decreased tendency to consider entrepreneurship. Conversely, individuals who are neutral about their manager's support display a mean rank of 42.78, while those who agree with managerial support show a mean rank of 74.58, and those who strongly agree have a mean rank of 84.38. These results can be seen in table 1 and indicate that greater managerial support in decision-making correlates with an increased consideration of entrepreneurial ideas among employees.

**Table 2:** Kruskal-Wallis test ranks for entrepreneurship consideration based on managerial support

	ManagerialSupport	N	Mean Rank
ConsiderEntrepreneurship	"Strongly Disagree"	7	25.00
	"Disagree"	23	32.39
	"Neither agree nor disagree"	18	42.78
	"Agree"	44	74.58
	"Strongly Agree"	30	84.38
	Total	122	

When conducting two independent Mann-Whitney tests - one between the groups that strongly disagree or disagree that the manager encourages them to make decisions (Mann-Whitney U: 66.500,  $p > 0.50$ ), and another between the groups that strongly agree or agree that the manager encourages them to make decisions (Mann-Whitney U: 520.000,  $p > 0.1$ ). The findings from both independent Mann-Whitney tests indicate no statistically significant differences between the groups who either strongly disagree or disagree that the manager encourages decision-making, and those who strongly agree or agree with managerial encouragement. These results emphasize the crucial influence of managerial support on employees' entrepreneurial aspirations. Regardless of the extent of support provided, whether it is high or moderate, the presence of managerial encouragement for independent decision-making positively correlates with a greater inclination towards entrepreneurship among employees. Conversely, the absence of managerial support, regardless of its degree, diminishes employees' propensity to consider entrepreneurship. This underscores the significance of fostering supportive leadership within organizations to cultivate an environment conducive to entrepreneurial thinking and innovation.



The research also explored how the level of autonomy in managing daily tasks and projects within the organization influences the consideration of entrepreneurship. The Kruskal-Wallis test (Chi-Square: 49.338,  $p < 0.001$ ) revealed a statistically significant difference in the consideration of entrepreneurship among different groups based on their level of autonomy in managing daily tasks at work. Individuals who strongly disagree or disagree that they have autonomy at work, with mean ranks of 25 and 37.40 respectively, demonstrate a lower likelihood of considering entrepreneurship. Conversely, those who are neutral, agree, and strongly agree that they have daily autonomy at work, with mean ranks of 62.39, 78.91, and 80.11 respectively, show an increase in entrepreneurial consideration with higher levels of daily autonomy. These findings underscore the importance of autonomy in the workplace as a driver of entrepreneurial consideration among employees. The significant difference observed across groups highlights the pivotal role of autonomy in shaping individuals' entrepreneurial aspirations.

**Table 3:** Kruskal-Wallis test ranks for entrepreneurship consideration based on daily autonomy

DailyAutonomy		N	Mean Rank
ConsiderEntrepreneurship	"Strongly Disagree"	16	25.00
	"Disagree"	24	37.40
	"Neither agree nor disagree"	18	62.39
	"Agree"	37	78.91
	"Strongly Agree"	27	80.11
	Total	122	

#### 4. CONCLUSION

In conclusion, the findings of this study highlight the critical role of gender dynamics and organizational contexts in shaping entrepreneurial aspirations within organizational settings. The results underscore the importance of addressing barriers and biases that may hinder women's participation in entrepreneurial activities to foster a more inclusive and diverse entrepreneurial culture within organizations. Furthermore, the interesting finding regarding employees in mid-level positions exhibiting the highest mean rank for entrepreneurial consideration suggests a nuanced relationship between organizational seniority and entrepreneurial inclination. This underscores the need for organizations to recognize and support the entrepreneurial aspirations of individuals at different career stages, particularly those in mid-level positions who may harbour untapped potential for innovation and leadership. Moreover, the results emphasize the crucial influence of managerial support on employees' entrepreneurial aspirations. The presence of supportive leadership that empowers employees with autonomy in decision-making positively correlates with a greater inclination towards entrepreneurship. Conversely, the absence of managerial support diminishes employees' propensity to consider entrepreneurship, highlighting the importance of fostering a supportive organizational culture that encourages risk-taking and innovation. Additionally, the significance of autonomy in the workplace as a driver of entrepreneurial consideration underscores the importance of empowering employees with autonomy in daily tasks. Autonomy fosters a sense of ownership and empowerment conducive to entrepreneurial thinking, promoting innovation, creativity, and employee engagement. Overall, these findings provide valuable insights for organizations seeking to cultivate an entrepreneurial culture and drive innovation within their workforce. By addressing gender disparities, fostering supportive leadership, and empowering employees with autonomy, organizations can create a conducive environment for entrepreneurial thinking and promote the growth and success of entrepreneurial ventures within their midset. Moving forward, future research should continue to explore the complex interplay between gender dynamics, organizational contexts, and entrepreneurial aspirations, considering additional factors such as cultural norms, educational backgrounds, and industry-specific contexts. Longitudinal studies tracking individuals' entrepreneurial journeys over time could provide further insights into the long-term impact of organizational interventions on entrepreneurial outcomes. To conclude, by unravelling the intricate relationship between gender, organizational contexts, and entrepreneurial aspirations, this study offers valuable insights to organizations, policymakers, and researchers seeking to promote gender equality, foster entrepreneurial talent, and drive innovation within organizational settings and beyond.

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# APPLICATION OF SAP Ariba SOFTWARE AS Web EDI SOLUTION IN THE AUTOMOTIVE INDUSTRY

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**Abstract:** *Electronic Data Interchange (EDI) presents a necessity for successful communication between stakeholders, enabling fast data interchange without human intervention. However, the Internet-based version of EDI, Web EDI, provides new business opportunities, especially for small and medium-sized companies. This paper presents the application of SAP Ariba software as a Web EDI solution in the company from the automotive industry from the Republic of Serbia. The aim of this paper is to emphasize the advantages of the application of Web EDI, as well as to present the importance and implementation process of SAP Ariba software as a Web EDI solution in the observed company. The intention of this paper is to present the significance of SAP Ariba software for small and medium-sized companies that are cooperating with companies from the automotive industry, in terms of acceptance and follow-up of automotive standards and requirements. This paper explains the connection and main cooperation process between two companies in the automotive industry with the usage of SAP Ariba software as a Web EDI solution. This paper is valuable for all companies that are considering the implementation of Web EDI, especially for ones that are cooperating with companies from the automotive industry.*

**Keywords:** *Automotive industry, EDI, Web EDI, SAP Ariba*

## 1. INTRODUCTION

In today's turbulent business conditions, many companies cannot do business without appropriate information systems (IS). To manage business, the most applied is Enterprise Resource Planning (ERP). ERP presents "an IS with a centralized database that can be used to manage a company's entire business" (Bourgeois et al., 2019). It consists of separate modules for different operations (finance and accounting, costs management, procurement, manufacturing, customer relationship management, human resources, warehouse and logistics, planning, quality and others) and enables complete integration of data and operations of one company. Initially, ERP systems were primarily intended for use in big companies. With the expansion of IS and the development of cloud solutions, small and medium-sized companies started implementing ERP systems. One of the global market leaders in the ERP software industry is the German company SAP (System Analysis Program Development) (SAP, 2024). SAP offers various modularity of ERP systems. One of the latest released, in 2015, is SAP S/4 HANA (Prasetyo & Solidman, 2021) that presents a "next-generation SAP Business Suite application created exclusively for the SAP HANA Platform" (Pattanayak, 2017). In this paper observed ERP system is SAP S/4 HANA.

Once the company is enabled to integrate all information with the appropriate ERP system, the next step is connection with external stakeholders via Electronic Data Interchange (EDI), defined as "the computer-to-computer exchange of business information electronically, in a structured format, between business trading partners" (Goksoy, Vayvay & Karabulut, 2012). Data exchange is faster and leaner, bringing the opportunity for the company to improve internal processes and take maximum advantage of EDI systems applications (Janssens & Cuyvers, 2023). For the implemented EDI connection, companies must implement ERP software, that is usually the main obstacle for small and medium size companies, since ERP software requires significant financial and human investments. However, the implementation of Web EDI systems presents a solution for these companies since it can work completely independently from ERP software and enables successful data interchange.

The paper is organized as follows. After the introduction chapter, the terms EDI and Web EDI and their application for data interchange are presented in the second chapter. The third chapter emphasizes the importance of EDI application in the automotive industry. The fourth chapter presents SAP Ariba software, while the fifth chapter presents the application of SAP Ariba software as a Web EDI tool in the automotive industry. The sixth chapter presents the conclusion of this paper.

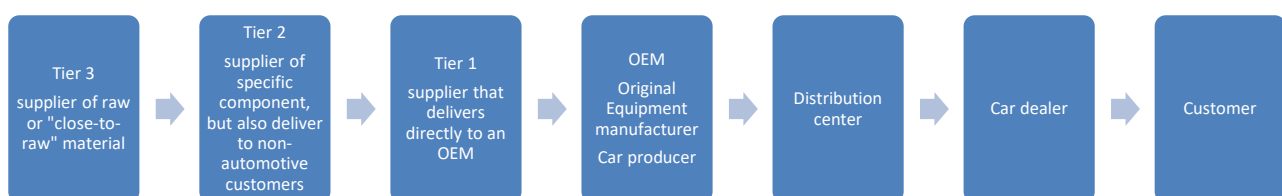
## 2. APPLICATION OF EDI AND WEB EDI FOR DATA INTERCHANGE

Adequate IS is one of the most important existence factors of many companies, while EDI connection is one of the competitive advantages for many companies, mainly in the manufacturing, trading, and logistics sectors (Goksoy, Vayvay & Karabulut, 2012). The importance of EDI is visible in today's fast-changing business conditions, where the main focus is on the fast response to any change, without loss in data and processing steps. When it comes to establishing EDI connection, companies first adopt EDI technology and then increase its use to improve competitive and financial advantages (Iacovou et al., 1995; Kumar & Crook, 1996). The second phase in this process is often integrating EDI with other applications, driven by the company itself or by customers (Goksoy, Vayvay & Karabulut, 2012). The main benefits that the company have from the EDI implementation are (Downing, 2002): reduction of paperwork and improvement of transaction efficiency, improvement of inventories/suppliers control, strengthened channel control and improvement of customer relationships. One growing trend in the business world is the formation of electronic partnerships with customers and/or suppliers. This aims to decrease time and distance obstacles, that affect the development of EDI.

For the majority of big companies, EDI presents a necessity that is usually integrated into the company's ERP system package. "Opposite to large companies, small and medium-sized companies often demonstrate a reluctance to invest in EDI mostly based on excessive investment costs when compared to the perceived benefits" (Mira da Silva, 2003). In this situation, "when a smaller stakeholder does not have sufficient resources to implement EDI, Web EDI presents a solution" (Bujak, Gurak & Jagodziński, 2018). For usage of the Web EDI company needs to have Internet access and Internet browser, decreasing investments in implementation. The basic functionalities of Web EDI are the same as that of the EDI. The Web EDI connection enabled completely new opportunities for small and medium-sized companies to become stakeholders with big companies, with the option to completely fulfil their requests (sending/receiving orders automatically in real-time, sending Advanced Shipping Notifications (ASNs), invoices and others) at reasonable costs. However, disadvantages of Web EDI implementation in companies are limited possibilities to integrate Web EDI with software of one's own (Bujak, Gurak & Jagodziński, 2018), repeated manual entry process into web forms and an increased risk of errors (Beck, Weitzel & König, 2003), increased security risk of illegal entry into software comparing to ones installed in local drive on computer (Zilbert, 2000) and others.

## 3. IMPORTANCE OF EDI APPLICATION IN THE AUTOMOTIVE INDUSTRY

The automotive industry "is one of the most influential industries in the world and involves a wide variety of companies that design, develop, manufacture and sell automobiles and their spare parts" (Masoumi, Kazemi & Hanim Abdul-Rashid, 2019). According to the same authors, the automotive industry presents "important economic sectors by revenue, since its turnover is equivalent to the sixth largest economy in the world". One of the most important requirements of the automotive industry is to have all processes strictly defined and followed by proper software solutions with a final target of creating continuous information and material flow (Stojković, Rajković & Lečić-Cvetković, 2018). Quality is imperative in the automotive industry, while standardization is the main tool for its achievement. The production process in the automotive industry is complex and knowing that most Original Equipment Manufacturers (OEMs) in the automotive industry make 30 to 35 [%] of value internally and delegate the rest to their supplier (Ambe & Badenhorst-Weiss, 2010), OEMs can forcefully demand from their suppliers to adhere to their specific standards (Großmann & von Gruben, 2014). Components of the supply chain in the automotive industry are presented in Figure 1.



**Figure 1:** Components of the supply chain in the automotive industry (Ambe & Badenhorst-Weiss, 2010)

One of the required standards throughout the whole supply chain in the automotive industry is EDI connection. As previously explained, it is led by OEMs, and other levels (Tier 1 to Tier 3) has to accept it, where Tier 1 presents suppliers that deliver directly to an OEM (exclusively produces parts for the automotive industry), Tier 2 presents suppliers of specific component, who delivers to non-automotive customers and Tier 3 presents suppliers of raw materials.

The main focus of this paper is the importance of the EDI connection between Tier 1 (in this case customer) and Tier 2 (in this case supplier). Suppliers of Tier 1 are big companies that produce components built in

vehicles. Therefore, the majority of Tier 1 presents the most successful companies in the automotive industry with strict standards and requests to ensure quality and optimize their processes. For them, EDI connection is the standard that their suppliers (Tier 2) must implement. With an EDI connection, the main transactions that can be done between these two companies are:

- Automatic transmission and update of orders – lowers the risk of losing data in an exchange via E-mail or paper form or to miss to inform the supplier about changes in the orders;
- *Just-in-Time* creation of ASNs - enables customers to get real-time information about goods in transit and to reduce effort in tracking goods;
- Creation of labels according to defined standard – to optimize internal processes such as goods receipt and to reduce the need for re-labeling;
- Creation of other documents important for the delivery, and others.

As already mentioned, one of the main reasons why small and medium-sized companies decide to implement EDI lies in external pressure, from their customers. Two-thirds of respondent suppliers indicated they adopted EDI only because they were told by their, usually, important and big customers (Tuunainen, 1998).

#### **4. SOFTWARE SAP ARIBA**

Software SAP Ariba was founded in 1996 and purchased in 2021 by the German software company SAP for \$4.3 billion (Wang et al, 2022). According to the same author, through the use of the Internet and Business-to-Business (B2B) e-commerce, SAP Ariba automatize the purchase of commonly used supplies and services. The SAP Ariba “is a cloud-based innovative software that remodeled the process of buying, selling, and managing cash, while it can also be considered a strategic product that helps in the integration of Procurement & Vendor/Supplier collaboration” (Wang et al, 2022). SAP Ariba as a Web EDI tool is used in many companies, offering many solutions such as (SAP Ariba, 2024; Yarramalli et al, 2020):

- SAP Ariba SLP & Risk - enables supplier risk evaluation;
- SAP Ariba Spend Analysis – supports sourcing process with information about purchases, suppliers and –costs;
- SAP Ariba Sourcing – ensures achievement of savings by selecting qualified suppliers from a broad supplier network;
- SAP Ariba contract management – enables paperless contract management;
- SAP Ariba buying and Invoice management – automatize procure-to-pay processes;
- SAP Ariba commerce automation & Supply Chain Collaboration – enables “collaboration with trading stakeholders on a single networked platform to ensure the supply of direct materials through better planning, inventory visibility and automation” (SAP Ariba, 2024).

#### **5. APPLICATION OF SAP ARIBA AS WEB EDI TOOL IN THE AUTOMOTIVE INDUSTRY**

This chapter will present the application of SAP Ariba commerce automation & Supply chain collaboration in one of the leading companies from the automotive industry in the Republic of Serbia (Tier 1), where EDI functionalities are part of this solution. The observed company (Tier 1) uses SAP Ariba to connect with its suppliers (Tier 2) who doesn't have an ERP system that allows direct EDI connection. This software enables suppliers to use SAP Ariba as a Web EDI tool to see orders from their customers, create ASNs, labels, track stock on the customer side, do invoicing process directly from SAP Ariba and generate useful reports.

With the implementation of SAP S/4 HANA, the observed company set two standard requests towards their suppliers of direct materials: the creation of ASNs for every shipment and the creation of the Global Transport Label (GTL). GTL presents a label format which complies with different label standards in the automotive industry and can be used in both national and international transport processes along the supply chain. An important characteristic of GTL is the existence of a unique Handling Unit (HU) number that allows the company the full traceability of goods since HU numbers are also part of data in EDI. Having pallets with unique HU numbers in the company reduces the need for re-labelling since these goods are then distributed directly to the warehouse and later production, without additional manipulation activities.

Not all the suppliers have an ERP system that can support these requests. Therefore, the observed company decided to implement SAP Ariba as a Web EDI option for the ones (Tier 2) that are not capable of creating ASNs and labels according to GTL standards. In this case, costs for implementation of SAP Ariba are covered by the customer (observed company), so that suppliers do not have additional costs for usage of SAP Ariba. One important premise here is that SAP Ariba is integrated with ERP software SAP from the observed company via Cloud Integrated Gateway (CIG), that presents a middleware solution for the connection of SAP Ariba with ERP software SAP S/4 HANA. In the following subchapters, the structure of connection, supplier connection process and daily usage of SAP Ariba are presented.

5.1. Structure of connection

Message flow between ERP (SAP) software and SAP Ariba is presented in Figure 2. From ERP, the information goes to CIG via a Cloud connector that has a role in ensuring a secure connection to SAP “Cloud”. CIG add-on presents an extension of ERP that was developed in the observed company to enable additional functionalities of SAP software required for the implementation of specific operations in SAP Ariba. SAP Ariba Buyer account presents account which is used by the customer (Tier 1), while SAP Ariba Supplier account presents account used by supplier (Tier 2). If there are some discrepancies in data, messages sent from/to ERP software remain in CIG and require manual intervention to arrive at the final destination, that is SAP Ariba Supplier account/ERP software.

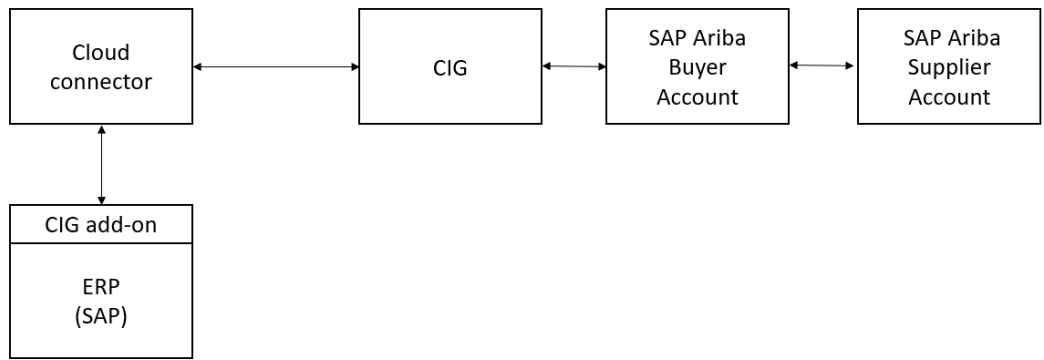


Figure 2: Message flow between ERP (SAP) software and SAP Ariba in the observed company from the automotive industry (Internal material from the company from the automotive industry, 2024)

Figure 3 presents the information exchange direction between ERP (SAP) and SAP Ariba for basic message types. Each message has a path flow presented in Figure 2.

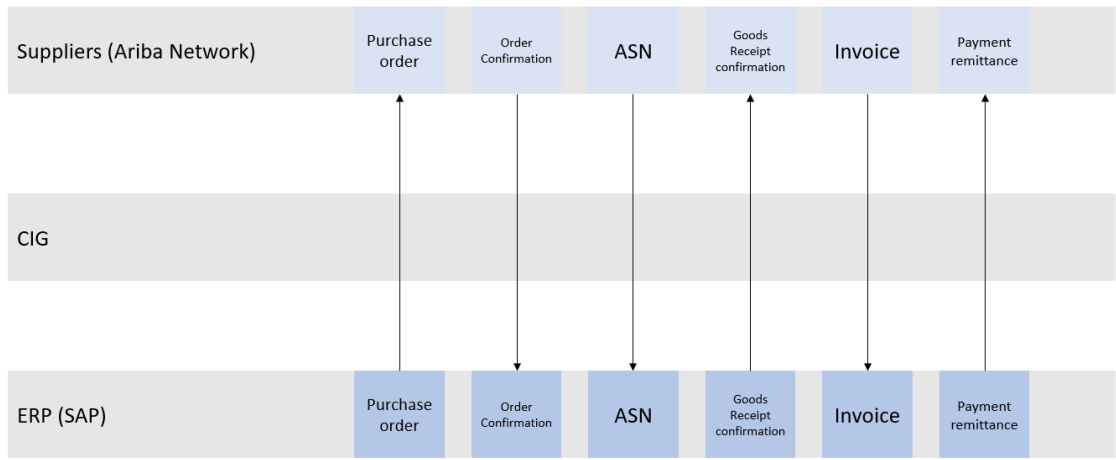


Figure 3: Direction of information exchange between ERP software to SAP Ariba in the observed company from the automotive industry (Internal material from the company from the automotive industry, 2024)

Communication between the observed company (Tier 1) and supplier (Tier 2) starts when Tier 1 sends orders from SAP ERP software to SAP Ariba. Once the supplier (Tier 2) receives the order, he has the opportunity to confirm the order in SAP Ariba. Confirmation is then sent back to Tier’s 1 SAP ERP software. In the company observed in this paper, order confirmation is not mandatory, so suppliers can skip this step. Once a shipment is ready, suppliers create ASN in SAP Ariba and this information is transferred to SAP ERP software of Tier 1. The next step is the goods receipt. After it is done, a receipt message is sent to the Tier 2 with information about the received delivery note number. Suppliers have the option to create an invoice in SAP Ariba and send it to SAP ERP. After paying the invoice, the payment remittance is sent from SAP ERP to SAP Ariba where suppliers can see it.

5.2. Supplier connection process

The beginning of the supplier connection process is starting the cooperation with the supplier. Suppliers are asked for their technical capabilities and can choose the type of connection – classical EDI or connection via

SAP Ariba (Web EDI). If the supplier chooses SAP Ariba, SAP Ariba enrollment team, provided with the supplier name and in the name of the customer (Tier 1) contacts the supplier and supports the supplier in acceptance of training relationship terms as well as in the creation of supplier profile in SAP Ariba. Once this part is done, responsible counterparts on the Tier 1 side are doing the necessary settings in SAP S/4 HANA to enable message exchange between customer and supplier. Additionally, maintenance of the HU configuration setup needs to be done by the customer, on the supplier level, to ensure a unique HU number for each pallet/box. After the process is finished, the supplier is provided with training and information on how to use basic functionalities of SAP Ariba – order checking, order confirmation, ASN & Labels creation and report generating. If the supplier is enrolled in a consignment or vendor-managed inventory process, additional training on these functionalities is provided.

### 5.3. Day-to-day business with SAP Ariba

Once the connection is established, SAP Ariba can be used for daily operations. Suppliers have the task of logging in to the SAP Ariba portal and checking whether new or updated orders exist. In supplier profile settings, they can also choose to get email notifications when updates are there so that they do not have to check and log in to SAP Ariba on a daily level. Before shipment, the supplier must start the creation of ASN to ensure the generation of labels. Once labels are available, suppliers are obliged to print them and put them on the pallets prepared for shipment. When labelling is done and goods are physically shipped, the supplier finishes the creation of ASN that is transmitted directly to the ERP software of the customer. Although this kind of connection simplifies day-to-day business and creates opportunities for small and medium-sized companies to become stakeholders with leading companies in the automotive industry, some of the obstacles are:

- This kind of connection brings additional tasks to the supplier's company because they are obliged to check orders and create ASNs outside of their system, manually, as well as to do re-labelling of pallets;
- Data interchange between ERP and SAP Ariba can show discrepancies, that require manual intervention from the customer side;
- Reaction time of SAP Ariba software is slower compared with the "classic" EDI, mostly depending on Internet connection;
- From time to time some issues appear, influencing SAP Ariba to stop working or having "bugs". It requires solving by the SAP Ariba support team, disabling suppliers to use the software until the issue is solved.

## 6. CONCLUSION

EDI brought meaningful business improvements to companies in all industries. The main advantage of Web EDI implementation is the enabled connection and cooperation between smaller companies, suppliers and leading companies from the automotive industry. In this paper, the application of SAP Ariba as a Web EDI solution in the company from the automotive industry of the Republic of Serbia is presented. Within the application of SAP Ariba, the company enabled its suppliers to perform transactions according to defined standards in the automotive industry. Additionally, the main improvements in the observed company were: decreased workload on a daily level – orders are automatically sent to SAP Ariba, abolishing orders sent via e-mail or fax, shipment information can be followed in real-time with ASNs, no need for additional tracking of the goods and contact with supplier, goods receipt process is simplified with usage of GTLs, and others. Application of SAP Ariba software as Web EDI simplified day-to-day business.

The first direction of further research of the authors of this paper would be the implementation of the additional functionalities of SAP Ariba software, such as consignment and vendor-managed inventory, in the observed company. The second direction of further research would be a comparison of functionalities of different Web EDI solutions used in the automotive industry, such as a comparison of SupplyOn and SAP Ariba software.

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# **E-BUSINESS ECOSYSTEMS AND TECHNOLOGIES**

# DIGITAL TRENDS RESHAPING B2B BUSINESSES - IDENTIFYING RESEARCH GAPS

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**Abstract:** *In the fast-paced realm of contemporary business, digital transformation is no longer just a choice; it's a necessity for organizations to thrive in the competitive landscape, especially within the B2B sector. This paper identifies and analyzes key digital trends such as e-commerce, social media analytics, IoT, blockchain, and AI, demonstrating their transformative potential in enhancing operational efficiency, global competitiveness, and strategic decision-making in business. Each trend discussed is deeply rooted in empirical evidence and scholarly discourse, offering a cohesive insight into their profound impact on enterprises. The goal is to provide a comprehensive understanding of these trends, highlighting the challenges and opportunities they present. By emphasizing the necessity of mastering these trends for sustainable growth and competitiveness, this study underscores the importance of interdisciplinary research to fully harness digital transformation in B2B contexts.*

**Keywords:** E-commerce, B2B, Digitalization, IoT, Digital Marketing  
Digital Transformation

## 1. INTRODUCTION

In today's rapidly evolving business landscape, digital transformation has become imperative for the sustained growth and competitiveness of organizations, particularly within business-to-business (B2B) operations. As technological advancements continue to reshape industries and consumer behaviors, businesses must skillfully adapt and leverage emerging digital trends.

Through an extensive literature review drawing insights from diverse academic works and research studies, this article aims to explore key digital trends impacting businesses. Each trend examined in this review is supported by factual evidence and Intellectual discourse, providing a nuanced perspective of its organizational impact.

The evolution of digital technologies such as e-commerce, social media analytics, Internet of Things (IoT), blockchain, and artificial intelligence (AI) presents both opportunities and challenges for B2B enterprises. Embracing e-commerce not only has expanded global reach but also enhanced customer service, while digital marketing simultaneously boosts brand visibility and enables direct communication. Social media analytics, informing strategic decisions by understanding consumer behavior, play a pivotal role. Additionally, IoT enhances supply chain efficiency and traceability, whereas blockchain fosters collaboration and value creation in exchange mechanisms. Big data and AI, driving data-driven insights, revolutionize business operations.

The objective of this article is to offer a comprehensive analysis of these trends in the dynamic terrain of modern business. In an era where digital transformation is crucial for maintaining a competitive edge and fostering growth, comprehending and leveraging these emerging trends are paramount.

## 2. REVIEWING DIGITAL TRENDS

### 2.1. E-COMMERCE AND DIGITAL MARKETING ADOPTION

The fusion of e-commerce and digital marketing has redefined business dynamics and customer interactions. E-commerce optimizes operations, fosters sustainability also empowers global competitiveness (Appel et al., 2020; Grewal et al., 2020). Serving both as an operational streamliner and a sustainability driver, e-commerce reduces transaction fees, enhances customer satisfaction, and sustains an eco-conscious marketplace. Notably, during crises like the COVID-19 pandemic, it becomes a lifeline for businesses, ensuring survival and facilitating growth in financial metrics and production value. E-commerce benefits businesses of all sizes, including Micro, Small, and Medium Enterprises (MSMEs), by enhancing global visibility, attracting new customers, and providing efficient services. Its accessibility enables engagement anytime and anywhere,

thereby facilitating global trade. Overall, e-commerce significantly improves business efficiency, reduces costs, increases revenues, and enhances customer satisfaction (Gao et al., 2023).

B2B marketing strategies traditionally differ from those in B2C, emphasizing sales and in-person relationship cultivation. The procurement journey is more complex, involving fewer but deeper customer connections marked by collaboration and personalized sales efforts (Setkute & Dibb, 2022). Embracing e-commerce would enhance economic and environmental performance and drive long-term sustainability (Gao et al., 2023). Digital marketing, especially in omnichannel sales and distribution logistics management, plays a pivotal role in shaping market dynamics (Parfenov et al., 2021). Crafting polished websites, addressing inquiries in diverse languages, and exploring international markets enhance B2B companies' reputation. Digital marketing ensures sustainable competitive advantage by swiftly branding products, delivering information, and connecting directly with consumers online (Gao et al., 2023).

However, the digital frontier presents formidable challenges such as technical issues, resource constraints, and cybersecurity concerns (Annosi et al., 2021). Navigating this landscape demands businesses to remain agile, adaptable, and committed to maximizing digital tools' potential. Differences in marketing approaches between small and large corporations stem from contextual factors in B2B and SME environments. SMEs, constrained by resources, employ more informal marketing tactics, requiring tailored digital marketing methods aligned with their unique traits and operations (Setkute & Dibb, 2022).

## **2.2. SOCIAL MEDIA ANALYTICS IN MARKETING**

Social media analytics is crucial for understanding consumer behavior and guiding digital strategy. Despite challenges like managerial resistance and technical limitations, social platforms offer communication avenues, reshaping engagement. B2B SMEs struggle to leverage it due to traditional preferences, technical constraints, and management resistance (Setkute & Dibb, 2022). The shift to remote work has accelerated collaboration tool adoption in the business environment. Social media platforms evolve, providing communication and data exchange opportunities (Daniel Zeng et al., 2010).

They serve as hubs for computational social science research and big data analytics (Batrinca & Treleaven, 2015). In business, they catalyze support, publicity, and feedback, aiding product development and market analysis (Batrinca & Treleaven, 2015; Dwivedi et al., 2018; Grewal et al., 2020). Retail and finance sectors leverage it for brand building and consumer insights (Batrinca & Treleaven, 2015). Marketers view it as a digital frontier, using influencers and chatbots for engagement (Appel et al., 2020; Grewal et al., 2020). While emerging technologies like AR and VR reshape interaction paradigms (Grewal et al., 2020) IDC forecasts \$72.8 billion in AR and VR expenditure by 2024 (IDC, 2020).

Ethical practices and consumer trust building are key therefore, social media data privacy attitudes influence marketing strategies (Appel et al., 2020). Despite challenges like uncertain value hindering analytics adoption (Setkute & Dibb, 2022) social media impacts online retail behavior, unlocking strategic insights (Hänninen et al., 2018). Digital marketing adoption in B2B SMEs lacks comprehensive analysis (Setkute & Dibb, 2022) and firms need to embrace digital channels to meet customer communication needs (Ritter & Pedersen, 2020).

## **2.3. INTERNET OF THINGS (IoT) IN SUPPLY CHAIN MANAGEMENT**

The integration of IoT technology into supply chain management has represented a revolutionary shift towards efficiency and transparency. By leveraging interconnected devices and real-time data analytics, now businesses are able to optimize performance, mitigate risks, and enhance visibility across sectors like transportation, logistics, and agriculture, fostering data-driven decision-making and sustainability.

Since its inception in the late 1990s, IoT has evolved alongside Internet technologies, sensor networks, and RFID tags, transforming everyday objects into intelligent assets and empowering seamless communication over the Internet. RFID and sensor technologies revamp logistics, aviation, food safety, and retailing, bolstering supply chain resilience and enhancing operational efficiency (Whitmore et al., 2015). Digital solutions foster collaboration and efficiency within food supply chains, reducing waste and enhancing energy efficiency (Annosi et al., 2021).

In manufacturing, IoT facilitates initiatives such as smart manufacturing, quality control, and sustainability through real-time data utilization (Ben-Daya et al., 2019). IoT's impact extends beyond supply chain domains,

permeating sectors like transportation, logistics, and agriculture, where it enhances operational visibility and fosters data-driven decision-making (Xu et al., 2014).

In retail, IoT technologies are driving innovation and enhancing customer experiences, they have redefined business logic and fostered collaboration among stakeholders (Hänninen et al., 2018). B2B buyers expect the same level of convenience, personalization, and responsiveness as their consumer interactions. Prioritizing customer experience (CX) would enable organizations to build stronger relationships and drive repeat business (Salesforce, 2020). Advancements in sensor technologies also offer insights into consumer behavior during online shopping, optimizing the online shopping experience through refined webpage design and marketing strategies (Fu et al., 2020).

The digitalization of logistics operations involves specialized IT platforms, driving operational optimization in distribution logistics management (Parfenov et al., 2021). As global consumers increasingly demand sustainable products and services, B2B organizations need to implement sustainability initiatives to meet expectations and regulatory requirements (Nielsen, 2018).

The transition from competition between distribution channels to economic competition between digital trading platforms signifies a structural shift in global economic communication systems, necessitating strategic negotiations and operational recalibration (Parfenov et al., 2021). Ultimately, IoT integration and digitalization pave the way for a greener, more sustainable future, optimizing supply chain performance and enhancing operational efficiency across industries.

## **2.4. BUSINESS MODEL INNOVATION**

Blockchain technology and digital platforms can also navigate business model innovation, and create new avenues for value and alignment across industries. In supply chain management, studies have shown that it enables companies to real-time tracking of goods, reduce fraud, and streamline transaction processes (Krichen et al., 2022). As blockchain adoption is growing, B2B organizations are exploring its potential in finance, healthcare, and logistics (Taherdoost & Madanchian, 2023; Tonelli & Association for Computing Machinery, 2017). Deloitte reports that 40% of executives plan significant investments in blockchain technology (Deloitte, 2020).

Digital transformation compels businesses to adapt and innovate, fostering collaborative ecosystems where stakeholders coalesce to drive value creation (Paulus-Rohmer et al., 2016). The emergence of novel business models spurred by blockchain technology would drive competitiveness and value creation (Ritter & Pedersen, 2020). In sectors like digital retail, blockchain ensures data security, fostering consumer confidence in digital marketplaces (Hänninen et al., 2018). As digitization permeates industries, businesses transition to digital formats, highlighting ongoing discussions in modern business (Ritter & Pedersen, 2020).

Multi-sided digital platforms transform the retail landscape by offering vast selection and convenience to consumers while providing suppliers access to a global marketplace (Hänninen et al., 2018). Software-as-a-service (SaaS) and cloud computing have reformed B2B software delivery, offering scalability, flexibility, and accessibility while reducing IT infrastructure costs. As businesses have embraced digital transformation, SaaS and cloud computing have become essential IT strategies, driving innovation and agility (Gartner, 2021). In international trade, blockchain and digital platforms can enhance collaboration and resilience, optimizing supply chain performance and fostering sustainability (Annosi et al., 2021; Parfenov et al., 2021). Mastering and leveraging innovative business models are imperative for success in the data-driven economy, where agility and innovation steer competitiveness and value creation (Hänninen et al., 2018; Ritter & Pedersen, 2020).

## **2.5. BIG DATA AND ARTIFICIAL INTELLIGENCE (AI) IN BUSINESS OPERATIONS**

In the realm of business, the synergy of Big Data and AI reshapes industries, driving efficiency and competitiveness. The digital supply chain's promise hinges on effective data management amidst raw inputs as big data analysis offers benefits like accurate sales projections and efficient promotions.

Retail leaders leverage data for optimal pricing and product assortments, enhancing sustainability efforts by optimizing shipping and curbing fuel use (Annosi et al., 2021). The convergence of big data and Artificial Intelligence (AI) redesigns business operations, driving efficiency and competitiveness. AI-driven insights, spanning predictive analytics to supply chain optimization, unlock growth avenues and transform industries. Effective data utilization and robust cybersecurity are vital for maximizing AI and big data analytics potential and understanding inter-firm network connections is crucial for creating competitive advantages (Paulus-Rohmer et al., 2016).

AI, tracing its roots to the 1950s, is projected to contribute trillions to global GDP by 2030, spanning natural language processing, speech recognition, and decision-making across supply chain operations (Pournader et al., 2021). AI and machine learning transform B2B operations, automating tasks and optimizing processes. According to (McKinsey & Company, 2018) AI adoption in B2B sales and marketing could generate up to \$1.1 trillion in economic value annually. With AI, managers anticipate disruptions, preempt system failures and refine recovery tactics.

The fusion of big data and AI, tracing back to early computing applications, underscores its pivotal role in digital transformation. Addressing compliance, cybersecurity, and fostering digital synergy are crucial for navigating this landscape. Data, empowering organizations to enhance efficiency and foresight, stands as the linchpin of digitization. Businesses must adeptly wield data assets to drive innovation and competitiveness while fortifying cybersecurity measures against potential threats (Ritter & Pedersen, 2020).

AI and big data analytics catalyze innovation, revolutionizing the shopping experience and enhancing efficiency. Studies indicate that large successful companies leverage algorithms and consumer data to unlock growth opportunities and propel industry transformation in the digital age (Hänninen et al., 2018).

### **3. ANALYSIS OF RESEARCH GAPS**

The research gaps identified in this literature review underscore the multifaceted nature of this evolving landscape and highlight the need for comprehensive, interdisciplinary research. This analysis reveals several key areas where further investigation is warranted, ranging from broader perspectives to more focused inquiries into specific applications and domains. Identified research gaps stress broader, interdisciplinary perspectives. For example, (Grewal et al., 2020) urge integrating diverse disciplines for technology and marketing exploration, though (Batinca & Treleaven, 2015) emphasize ethical considerations in social media analytics. Multidisciplinary approaches are vital for tackling B2B digitalization challenges effectively.

Emerging technology coverage gaps in specific domains are apparent. (Ben-Daya et al., 2019) stress comprehensive literature reviews on IoT in supply chain management, and (Fu et al., 2020) advocate for exploring IoT-enabled personalized recommendation systems in online shopping. Staying updated on tech advancements is crucial for B2B operations and customer experiences.

Some research gaps emphasize the necessity for focused investigations into specific applications or domains. (Annosi et al., 2021) pinpoint a gap in studying digitalization within food supply chains to prevent food waste, whilst (Gao et al., 2023) highlight the absence of research on e-commerce and digital marketing adoption's impact on the financial and sustainability performance of MSMEs.

Many research gaps indicate the necessity for more empirical studies and case analyses to validate theoretical frameworks and explore practical implications. (Dwivedi et al., 2018) advocate for longitudinal studies on social media's long-term effects on mental health, while (Hänninen et al., 2018) stress conducting case studies on multi-sided platforms' role in industry transformation. These findings underscore evidence-based research's significance in informing decision-making and strategy development in B2B settings.

Additionally, gaps exist in comprehensive coverage of emerging technologies and their impacts across diverse domains. For example, the survey of emerging threats in cybersecurity by (Jang-Jaccard & Nepal, 2014) may overlook vulnerabilities in specific sectors or emerging attack vectors relevant to niche industries. This suggests the necessity for research considering the unique challenges and requirements of different B2B sectors when addressing cybersecurity concerns.

Furthermore, gaps persist in understanding the practical aspects of technology adoption and implementation challenges. While (Krichen et al., 2022) and (Taherdoost & Madanchian, 2023) highlight the need for more research on the real-world applications and adoption barriers of blockchain technology in various contexts, (Ritter & Pedersen, 2020) discuss digitization capabilities but lack concrete guidance on aligning business models with digitalization trends. Similarly, (Schiff et al., 2020) stress the need for a comprehensive analysis of ethical implications in AI governance.

Moreover, gaps in understanding industry-specific challenges and adoption barriers are evident. Articles by (Setkute & Dibb, 2022) and (Xu et al., 2014) highlight the importance of industry-specific contexts, indicating the need for more targeted insights into digital trends reshaping B2B businesses. These findings underscore the necessity for research addressing broader digitalization implications for B2B business models, along with ethical and regulatory considerations and the barriers to facilitating the successful integration of digital technologies in B2B operations.

Now, let's delve into a detailed analysis of each research gap and its implications. Table 1 provides a structured overview of the identified gaps, followed by an in-depth analysis of each, highlighting their significance and potential avenues for future research.

**Table 1: Research Gaps**

References	Research Gap	Analysis
Annosi et al. (2021)	Digitalization within food supply chains to prevent food waste	Investigate digital solutions' effectiveness in enhancing supply chain visibility, improving inventory management, and reducing food loss and waste.
Appel et al. (2020), Daniel Zeng et al. (2010)	Future trends and implications of social media in marketing	Understand emerging social media trends' impact on marketing strategies, including ephemeral content, AR/VR integration, and influencer marketing
Batrinca & Treleaven (2015)	Techniques and tools for social media analytics	Explore and evaluate emerging methodologies like natural language processing and machine learning for extracting insights from social media data.
Ben-Daya et al. (2019), Xu et al. (2014)	Integration of Internet of Things (IoT) in supply chain management	Investigate IoT technologies' integration into supply chain practices, including implementation challenges, security considerations, and benefits
Fu et al. (2020), Pournader et al. (2021)	Artificial Intelligence (AI) applications in supply chain management	Understand AI applications' impact on addressing supply chain challenges and evaluate adoption barriers and performance implications.
Gao et al. (2023)	Impact of E-commerce and digital marketing adoption on MSMEs' financial performance	Investigate the relationship between digitalization and financial performance in MSMEs, especially considering the impacts of crises and epidemics like COVID-19.
Hänninen et al. (2018), Parfenov et al. (2021), Paulus-Rohmer et al. (2016), Ritter & Pedersen (2020)	Digitalization in retailing and distribution logistics management	Examine digital technologies' interplay with organizational strategies and market dynamics in retailing and distribution logistics management.
Setkute & Dibb (2022)	Barriers to digital marketing in small B2B firms	Understand and address barriers to digital marketing adoption among small B2B firms, such as limited resources and organizational resistance to change.
Grewal et al. (2020), Schiff et al. (2020)	Future trends and implications of technology on marketing	Investigate emerging technologies like AI and blockchain and their impact on consumer behavior, market dynamics, and competitive strategies.
Krichen et al. (2022), Tonelli (2017), Taherdoost & Madanchian (2023)	Blockchain applications in modern business models	Explore diverse applications of blockchain in different industries and contexts, including smart contracts, transparency enhancement, transaction cost reduction, and its role in building smart cities.

Schiff et al. (2020), Wirtz et al. (2019)	AI ethics, policy, and governance	Examine ethical implications, regulatory frameworks, and governance mechanisms surrounding AI adoption and deployment for promoting responsible AI practices.
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#### 4. CONCLUSION

The examination of digital trends in B2B unveils a dynamic landscape with transformative potential. Key trends identified in the literature review, based on reviewing 22 articles, present challenges and opportunities for growth. E-commerce and digital marketing integration stand out, enabling operational efficiency, global expansion, and competitive advantages (Appel et al., 2020; Gao et al., 2023). Embracing e-commerce and digital marketing empowers businesses in a rapidly evolving marketplace, meeting customer needs while fueling profitability and growth.

Additionally, integrating social media analytics in marketing offers unique opportunities for B2B enterprises to grasp consumer behavior, boost brand visibility, and make strategic decisions (BATRINCA & TRELEAVEN, 2015). Despite challenges like management resistance and technical limitations, social media analytics adoption promises to reshape consumer interaction paradigms and drive innovation in B2B marketing. Additionally, IoT technology in supply chain management revolutionizes operations, providing unparalleled efficiency, security, and traceability (Whitmore et al., 2015). By leveraging interconnected devices and real-time data analytics, businesses optimize supply chain performance, reduce risks, and enhance operational visibility, driving sustainable growth and resilience in B2B operations.

Furthermore, business model innovation, fueled by blockchain technology, redefines exchange mechanisms and fosters collaboration among stakeholders (Krichen et al., 2022). Innovative blockchain-based business models create opportunities for value generation and strategic alignment, empowering B2B enterprises to navigate digital transformation and foster sustainable growth in today's data-driven economy. Additionally, the integration of big data and artificial intelligence (AI) in business operations unlocks fresh growth prospects and drives industry-wide transformation (Annosi et al., 2021; Pournader et al., 2021). By harnessing data-driven insights and predictive analytics, organizations optimize sales forecasting, supply chain management, and customer engagement, driving efficiency and competitiveness in the digital age.

Amidst the transformative potential of digital trends, research gaps, and future study opportunities emerge. These gaps underscore the necessity for comprehensive, interdisciplinary research addressing digital transformation implications for B2B. Exploring practical technology adoption challenges and industry-specific barriers can offer valuable insights into B2B digital trends (SETKUTE & DIBB, 2022; XU ET AL., 2014).

Moreover, opportunities for future study abound in exploring emerging technologies and their impacts across diverse domains, conducting more empirical studies and case analyses, and addressing ethical and regulatory considerations associated with digital transformation (RITTER & PEDERSEN, 2020; SCHIFF ET AL., 2020). Longitudinal studies on social media's long-term impact, comprehensive analyses of AI governance ethics, and targeted investigations into industry-specific challenges offer crucial insights for B2B decision-making.

This review underscores digital trends' transformative potential and emphasizes ongoing research importance. Effectively understanding and leveraging these trends enables B2B enterprises to navigate the digital landscape, drive growth, and remain competitive.

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# INFORMATION SOCIETY AND ELECTRONIC GOVERNMENT IN THE REPUBLIC OF SERBIA

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**Abstract:** *Information society implies a developed society and economy that enables optimal use of information technologies. The development of such society requires certain changes in the economy and society in general - the transition to an information society. Along the way, some of the challenges are: training population for application of new technologies, enabling mass access to electronic public services for all segments of population, enabling conditions for electronic business in all areas, adopting new standards and harmonizing laws with new ways of doing business. Numerous driving forces that need to be included are: scientific - research and educational institutions, the economy, the telecommunications and banking sectors, as well as civil society organizations.*

**Keywords** *information society, electronic government, public sector, local self-government*

## 1. INTRODUCTION

The development of the information society in the Republic of Serbia (Serbia), among other things, is based on the United Nations Resolution Transforming our world: Agenda for Sustainable Development until 2030. The global indicator framework was adopted by the General Assembly on 6 July 2017 and is contained in the Resolution adopted by the General Assembly on Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development.

Regulating the information society is an important part of harmonizing legal framework of Serbia with the European Union, which relies on the United Nations Resolution. The creation of legal framework for construction of an information society, harmonized with development of technology and international standards, began systematically after 2003. The main guidelines in that process, apart from strategic documents of the European Union, as well as in Government documents: Strategy for development of information society and information security in the Republic of Serbia for the period from 2021 to 2026, Strategy for development of new generation networks until 2023, Strategy for development of digital skills in the Republic of Serbia for the period from 2020 to 2024, Public administration reform strategy in the Republic of Serbia for the period from 2021 to 2030, Program for development electronic government in the Republic of Serbia for the period from 2023 to 2025. etc. In accordance with strategic documents and laws and by-laws that regulate the field of information society, numerous activities have been carried out at the national and local levels for more than a decade. In order to evaluate the level of development of the information society, it is necessary to continuously monitor the degree of realization of activities in accordance with the appropriate indicators, especially in the field of electronic government. With that goal, in 2020 a questionnaire was defined, composed of three parts, with the aim of examining the administrative, technical and financial capacities of local self-governments significant for the mentioned area. The survey was conducted for the first time in 2021, and is carried out every two years, so this paper presents the results from 2023. Measuring the degree of development of eGovernment at the national level is done in accordance with international indicators established by the United Nations e-Government Development Index and the European Union – e-Government EU Benchmark. This paper presents the results of Serbia measured during 2022.

## 2. INFORMATION SOCIETY AND E-GOVERNMENT

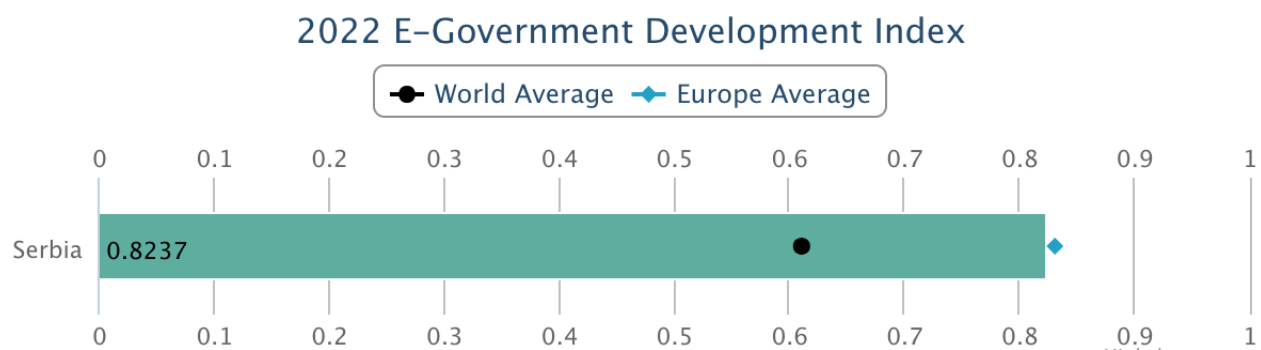
The information society conceptually defines a society and economy in which there is optimal use of available technologies. The digital transformation requires the inclusion of technologies in every aspect of society. There are numerous definitions of the information society. One of the most comprehensive was given by Manuel Castells in his trilogy *The Information Age: Economy, Society and Culture*. According to Castells (Castells M, 1998) "information is the core of the network society. The information age is marked by a new social era that emerges in parallel with the development and expansion of computer networks, the basic characteristic of

which is the so-called informational capitalism, which represents a new, sharper form of capitalism initiated by the penetration of new technologies.” Webster definition is also often used “In the information society, the production and exchange of goods and services mostly takes place through information-communication technologies, as well as the criteria that determine it: technological, economic, work/professional, spatial and cultural.” (Webster, 2014).

Nevertheless, one of the key parameters by which the development of the information society can be evaluated is the implementation of e-Government at the national and local level. That is why it is important to invest in improvement of ICT infrastructures, to create new electronic services for citizens and the economy, to work on information literacy of the population, and use all available resources that new technologies provide.

## 2.1. E-Government index at the national level

Digitization is one of the key elements of economic growth and has been a priority of the Government of Serbia since 2016. In the last decade, the reform of public administration and digitalization of services has been accelerated. The priorities set in this way influenced the assessment of the development of the information society and electronic services by leading international bodies. Serbia is ranked 40th out of 193 countries in the United Nations e-Government Survey 2022 (UN, 2022), with a score of 0.82370. E-Participation Index is about 0.80680, Online Service Index is 0.85140, Human Capital Index amounts to 0.83320 and Telecommunication Infrastructure Index is 0.78650. Given that it received the lowest rating for citizens' participation, Serbia published new e-Participation module on the eGovernment Portal in 2023.



**Figure 1** E-Government Development UN index 2022

Serbia has achieved significant economic growth in the information technology (ICT) sector. ICT accounted for 6% of GDP in 2023, according to the Statistical Office of the Republic of Serbia, and generated international visibility for the Serbian economy. The report of the National Bank of Serbia confirms that the total exports of ICT services for January and February 2024 continued with intense growth, increased by 22 percent compared to the same period last year, and amounted to 609 million euros. For the sake of comparison, the total amount of export of ICT services for the whole 2015 was 611 million euros, almost the same amount as for only the first two months of this year.

The number of global IT companies establishing development centers in Serbia is increasing. In the Global Innovation Index 2022 Report, Serbia is ranked 26th in the ICT segment (United Nations, 2022). The Innovation Fund and the Development Agency of Serbia finance innovation activities for product development, which also affects better positioning of the domestic IT industry on the global market. Some of the measures are tax breaks for research and development, especially in the field of ICT.

The e-Government Benchmark measures the level of digitization of public services in Europe. It examines user-centricity, transparency, key factors and cross-border services based on 14 indicators, on a scale of 0 to 100 points. Serbia showed remarkable growth of +8 points increase, with total score of 56 points. (European Commission, 2023). The aggravating circumstance is that Serbia is not a member of the EU, and therefore cross-border services are not possible, so it is expected that the European average of 70 points will be reached in the near future.

Over 2 million citizens of Serbia use the e-Government Portal. Research is being conducted to enable the improvement of user experience in using the Portal. New functionalities are being established and e-Pisarnica service is being announced, through which citizens will be able to conduct every procedure online.

Serbia is also committed to the digital inclusion of vulnerable groups. The Strategy for Improving the Position of Persons with Disabilities in the Republic of Serbia for the period from 2020 to 2024 contains special

measures and activities relevant to this issue. The Strategy for the prevention and protection of children from violence for the period from 2020 to 2023 also included a number of measures to support digital inclusion.

In the framework of public administration reform, the single electronic register of Serbian citizens and the eZUP information system (i.e. the Government Service Bus), that delivers G2G services and eliminates the need for citizens to engage in document collection from different public services, promises to advance inclusion through digital technologies. Its effect is particularly evident in remote and underdeveloped areas, saving time and resources for provision of public services to citizens. In terms of improving network infrastructure, Serbia launched rural broadband development program, starting with implementation in 2021, with the aim to bridge digital divide by providing free access to the internet in public places in remote areas and ensuring that affordable services are available to all citizens throughout the country. Significant regulatory changes are also planned for digital inclusion in the field of education, including the Regulation for the activity of Resource Centres for Assistive Technologies (supporting schools for inclusive education), and the Regulation for distance learning and the rigorous application of the Instructions for development of teaching materials in line with the universal design principle.

## 2.2. E-Government index at the local level

The analysis of the capacity of local self-government for the application of regulations in the field of information society was carried out during 2023 with the following goals:

- examination of the existing capacities of local self-government in the field of information society;
- determination of need to improve the capacity of local self-government units in this area;
- evaluation of consequences in practice due to the lack of application of existing, changed or new competences of cities and municipalities, from the aspect of European standards in this area.

The analysis is based on the collection of information directly from representatives of cities and municipalities through an online questionnaire. The target group of respondents were heads of city and municipal administrations, administrators of bodies on the e-Government portal and employees responsible for the introduction and development of electronic administration for electronic administration tasks (information system tasks in local self-government).

The selection of local self-government is defined in accordance with the following criteria:

- territorial coverage, i.e. even representation of regions according to administrative-territorial division and nomenclature of statistical territorial units (level 2);
- type of local self-government (city or municipality), including city municipalities;
- the level of development;
- the size of local self-government in relation to the number of inhabitants, i.e. equal representation of both larger and smaller;
- representation of local self-governments in which national minorities have exercised the right to official use of languages and scripts of national minorities.

The questionnaire is composed of three parts, with the aim of examining the administrative, technical and financial capacities of local self-government in the field of electronic administration. The questionnaire has a total of 86 questions, of which 38 are in the administrative area, 41 in the technical area, and 7 in the area of financial capacity.

### 2.2.1. Research results

The part of the questionnaire related to (institutional) **administrative capacities** included questions concerning the capacity of employees to perform tasks in the domain of electronic administration and information technologies, level of their knowledge about the institutional and strategic framework of Serbia and knowledge of European directives, questions regarding the need for improvement of knowledge and skills of employees, as well as internal organization and regulation, citizen participation and use of electronic systems.

The results show that the majority of local governments (74.6%) do not have an employee who deals exclusively with electronic government. They believe that in Serbia the institutional framework in this area is not clearly defined, with explanation that the competences and obligations of local self-governments in the field of electronic administration development are not clearly defined. This is an indicator that the Law on Electronic Government should be changed. 52% of local self-governments adopted internal acts in the areas of personal data protection, information security, electronic communications, electronic administration, interoperability, open data, electronic identification, electronic signature, electronic seal and electronic delivery. Further, 19% of local self-governments do not know what should be regulated.

Local governments have also declared that they need support in the implementation of regulations, in creation of model regulations, in training of employees for digital skills and advisory support, as well as communication with the state institutions.

As for **technical capacities**, 70% of employees have their own computer equipment for work. As for the Internet access, 70% have access to the Internet via cable Internet, 51% have access via DSL (xDSL, ADSL, SDSL...) connection, and 11% via mobile Internet. The average internet download speed is around 80 mb/s, with the most common being 100 mb/s. The majority of local self-governments (61.76%) confirmed that they allow citizens to submit requests electronically when conducting procedures. 67.65% of them have a system for managing electronic documents, but only 45.59% issue acts in electronic form, while even fewer of them (26.47%) uses an electronic seal for certification of documents. Delivery by electronic means is made by 44.62%, mostly to the party's e-mail address. Regarding technical improvements, respondents state the following:

- that it is necessary to form an IT department,
- to provide funds for the purchase of equipment and network LAN infrastructure,
- to provide additional education in the field of information security,
- to have optical Internet, better and more modern equipment with licensed software and infrastructure equipment: servers, data storage systems, uninterruptible power supply devices,
- to develop software application solutions for multiple business processes,
- to create a redundant system for data security, and to obtain space on the state cloud for off-site backup needs,
- to have professional training IT administrators.

Regarding **financial capacities**, one of the key questions was whether funds were allocated for the improvement of ICT. 73% answered positively. 48.28% answered that they implemented projects from donor funds on the topic of improving information technologies and electronic administration. However, they believe that it is necessary to invest much more in ICT infrastructure than it was budgeted insofar.

### 3. CONCLUSION

Bearing in mind that the process of digital transformation, including harmonization of the regulations of Serbia with the acquis of the EU, brings new obligations and new opportunities, with new jobs that require special knowledge and skills in working with large data sets, artificial intelligence systems and other technologies, it is necessary to continuously improve the administration at the national and local level. Below are recommendations for improving the government's capacity to carry out activities related to the further development of the information society:

- It is necessary for the administrative bodies to harmonize internal acts with the regulations in the field of information society, taking into account the optimization of actions and application of new technologies.
- It is necessary to adapt the system of professional training of employees to the various needs of the information society, to introduce permanent training of employees who work in electronic government jobs, and to work on the standardization of the Professional training program in this area.
- Through the policies of balanced development, to establish a system for monitoring the development of electronic government and determine a way to overcome the challenges of the lack of qualified employees, as well as the lack of financial resources for investing in adequate equipment.
- Digitization of the public sector requires continuous training of officials. Professional development programs must include digital literacy and work with specialized software. It is also necessary to build the digital competences of poor population groups, in order to avoid deepening the digital divide.
- It is necessary to enable the reuse of public sector data through public-private partnerships. Innovative solutions can provide better services based on open data.
- The application of artificial intelligence systems, video identification and other technologies that require mass processing of personal data require a constant review of the way such data is used. Therefore, it is necessary to regulate the way of applying artificial intelligence, video identification using video surveillance and ensure their limited and legal application. That implies update Law on Personal Data Protection and adoption of an action plan within the recently adopted Personal Data Protection Strategy.

The information society has introduced new expectations for citizens of the 21st century. It is necessary to raise the ladder even more, to be more responsible towards the citizens, more proactive, so that the state is always accessible in a simple way. It is necessary to use the established infrastructure and systems of e-Government for mass digitization and the provision of services via the Internet, but with a special focus on user experience. Electronic services must be simple and unique from start to finish, all information easily accessible, and user satisfaction at the highest level. Accessibility is an important aspect of providing services by enabling physical access to facilities for people with disabilities, creating unique administrative offices throughout the country, providing Internet access even in the most inaccessible areas, as well as increasing citizens' information literacy with the aim of increasing the number of e-Citizens who want services "at a click".

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# DIGITAL LEARNING MANAGEMENT SYSTEMS IN NONFORMAL EDUCATION

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**Abstract:** *This paper was written as a literature review of the contemporary teaching practice in nonformal education with the future opportunities of using Blockchain technologies. The paper focuses on nonformal second language education in virtual environment using Learning Management System, specifically in Korean language acquisition. This paper contributes to the field of modern education by demonstrating how LMS platforms like Moodle can effectively support language learning. At the end of the paper, the authors conducted a test in Moodle LMS course environment and later provided the participants with a survey. In the survey, most of the participants were for the implementation of modern technologies into the language learning practice, which could serve as a guideline to other language professors teaching in modern method.*

**Keywords:** *nonformal education, future language education, Moodle LMS, Korean language*

## 1. INTRODUCTION

The classic definition of nonformal education is quoted as “any organized education activity outside the established formal education system.” This type of education occurs in an organized learning environment, with teacher’s assistance, yet it is less structured and more skill-oriented, flexible in timing and the goal acquisition is more immediate. The teaching is learner centered and less theoretical. This type of education is not limited by age and student’s formal education level and background, thus giving an opportunity to all interested and motivated students to thrive and develop in their expertise. Although the lines between formal, nonformal and informal education are thin, informal education is mostly reserved for the teaching and learning taking place in everyday life situations, while formal education usually happens at schools. (Radcliffe & Colletta, 1989) (Eshach, 2007)

One of the most common goals of nonformal education students is foreign language acquisition. In the age of ubiquitous computing and Web3, students and teachers, as well as learning environments must accommodate new technologies in order to enhance the language learning process. This may seem as challenging, but it is noted that in 2022 83.24% of Serbian households have Internet access. (statista, 2023) This data shows us that learning in the modern age doesn’t have to take place at specific institutions but can also take place on the Internet from any place and at any time. Particularly in the area of informal language education, many students prefer learning through the modern media, chat applications and applications for learning languages. This type of learning poses as a non-colloquial and unorganised learning environment. The users of these types of applications are usually unprofessional in teaching and don’t have prior knowledge of the language, which can lead to negative results in the learning process. The study material should be well organized by a professional teacher who provides the students with structured study materials and a system that provides materials orderly and can also be used for grading students.

For that reason, many educators and educational institutions have incorporated Learning management systems into their teaching practice. Learning management systems, or LMS for short, serve as platforms for course and learning material accessing on digital devices. (Alfalah, 2023) A Learning Management System (LMS) is any software that integrates training on the web, simulates classroom lectures, supports online course maintenance, and integrates human resource systems. Consequently, LMSs are considered the foundation of e-learning. (Yildirim et al., 2004) It is managed by educators and used by students as an entry point into the educational process. LMSs usually feature options for forums, chat, grading, test management and marking student performance. They are the keystone for blended learning environment. It is notable that, for now, LMSs are more course than student centric, restricting students only to specific activities, for a limited time. (Yasar & Adiguzel, 2010) It is predicted that, in the future, paths and models personalized for each student will be enabled. Although it is challenging to technically support large variety of interlinked data, tools and channels, these obstacles will be overcome. With the use of Artificial Intelligence, student experience could be boosted and personalized. Personalized avatars could serve as teachers and a Virtual learning environment could be incorporated. (Rakoczi, n.d.) Also, with the help of Artificial Intelligence,

lecture material, video, or text, could be translated into many languages and thus available for students all around the world to access and understand. It is already present in YouTube videos where artificially, the creator speaks in their voice but in different language, explaining complex math problems. (3Blue1Brown, n.d.)

## **2. LEARNING MANAGEMENT SYSTEMS**

The significance of e-learning technologies has increased since the early 21st century with their integration into organizational workflows. To facilitate administrative education processes and employee training, the concept of LMS was introduced. This allows managers, administrators, instructors, and trainees to have a comprehensive infrastructure supporting the creation, storage, assignment of learning activities, and assessment of trainees' knowledge. An LMS utilizes internet technologies to manage interactions between users and educational materials, offering discussion forums, chat, self-assessment, quizzes, multimedia content such as videos or audios, and more. By employing these technologies, an LMS aims to manage and monitor the learning process and users' performances.

Every LMS should be designed to facilitate effective and easy usage of materials and tools for users, instructors, and administrators, while technical elements should meet equipment requirements, security criteria, and budget constraints. LMS user interfaces should be accessible, well-organized, aesthetically pleasing, and easy to navigate. The navigational interface should have flexible design and clarity to aid users in navigating the interface. Each LMS should reflect the educational culture of the institution using it. Educational program objectives should be relevant, consistent, clear, contemporary, and proportionate to the user's knowledge level and the organizational culture of the institution.

Communication within the LMS should be straightforward among users, educational materials, and instructors. Learning material should be personalized in order to positively impact users' learning processes and courses should include self-assessment tools for the users. The system should maintain users' motivation for educational materials. To foster group awareness among users, the system should enable content sharing within and outside the LMS. Instructors should have the ability to back up data at any time, monitor user and educational material performance, coordinate material distribution within the system, and provide timely feedback. (Yildirim et al., 2004)

### **2.1. Examples and features of Learning Management Systems**

An LMS that further personalized the user experience by incorporating avatar-to-avatar communication is SLOODLE. This LMS is made in collaboration of Moodle LMS and Second Life. In this learning environment, students create their avatar that is mobile in the space, as well as other objects, and interact with other avatars and objects in the learning environment. This feature makes the course that the student is attending personalized and student-centric. (Yasar & Adiguzel, 2010)

Some of the most prominent LMSs are the learning lab, Classter, Blackboard and Moodle LMS. They offer a streamlined approach in teaching, course personalization, AI assistance, study materials gamification, and behavior management systems. Other notable features of LMSs are providing language options for users, certification after the course completion, time-tracking learning and working on the course subject, gamification of the study materials and problem solving in different virtual worlds to explore, etc. Providing students with real-life-like situations in game is especially important in language learning, as student encounters with real life situations in which the certain vocabulary is used. (EGO!LMS, n.d.) (edX Enterprise, n.d.) (The Learning Lab LMS, n.d.) (Classter, n.d.)

One of the most widely used LMSs is Blackboard LMS. Blackboard LMS features flexible and interactive virtual classroom environments with an option to record lectures. It is used to create, distribute, track, and manage training or educational materials delivered synchronously or asynchronously to the students. During an examination in an institution of higher education in Saudi Arabia, satisfaction of the students of both genders was examined. With no significant gender difference, students enhanced their skills and subject efficiency in the virtual classroom, compared to traditional teaching methods. It was noted that the students developed a deeper connection with the faculty staff through the Blackboard LMS. (Elfeky & Elbyaly, 2023)

### **2.2. Moodle LMS**

Moodle LMS is the most used LMS globally, as it is used in 242 countries of the world. Moodle LMS provides its users with a free solution for educational page creation, hosting personalized courses with additional materials. Moodle, started its development as a Doctoral thesis of Martin Dougimias in 1999. It is an open-source LMS designed for teachers, students and administrators. Many users argue that Moodle LMS developers lead innovative e-learning technologies due to the strong community interest and support, as well

as collaboration and knowledge sharing. Teachers and course managers can manage roles and permissions for each course, thus protecting the sensitive data and materials, such as test questions and results. Moodle is free to use in 17 languages of the world with accuracy of 100%, ensuring a broader reach among users from various countries.

In practice, it has been found that Moodle LMS delivers the best results when used in conjunction with face-to-face teaching, or blended learning. Within the system, there can be additional educational activities, links to relevant content, tasks that students can create independently, or literature that students should read before class. The quizzes and tests section gives instructors insight into the extent to which students have mastered the intended material. Tests can be taken multiple times, and each attempt is automatically recorded. (Khan, 2012) (moodle, n.d.)

### **2.3. Modern learning environments and digital challenges**

Although most of Serbia's households have internet access, not all the members of society are digitally literate. This is reflected on teachers and students in all types and levels of education. Teachers and students that use digital resources and online LMSs should have access to a guide, tutorial, or a workshop where usage of digital classroom tools would be presented to them. Since the student interface, study materials and overall workflow depend on the teacher and their digital literacy and Moodle LMS skill, the teacher must ensure that they are providing the students with a good system usage experience and teaching performance. (Phillip Bhalalusesa et al., 2023) In the fashion of making traditional education more interactive and personalized, teachers should pay close attention when designing the educational media. Since the problem for teachers presents the unfamiliarity with innovative learning models and practices, making them more optimal for the students of today. The learning process should attract student attention now more than ever, in the age of the industrial revolution 4.0 and rapid media and information sharing. In order to increase motivation among students, teachers should use interactive learning environments provided by learning management systems. (Chasani & Yennita, 2023)

Screentime is defined as the time spent on digital media and devices such as computers, tablets, phones and other. Before the pandemic, average screentime of US children aged 8-18 was 7.5h a day, with children aged 11-14 at 9h a day. With education operating remote during the pandemic, these hours increased and well exceeded recommended 1-2h a day. Screentime among people of all ages is becoming a big concern. Moreover, the media consumed, and information shared during that long screentime is usually non-educational. During the pandemic, excessive media consumption has led to negative impact on children health, especially eye problems, but affecting physical, cognitive and emotional development. (Wiguna et al., 2024)(Panjeti-Madan & Ranganathan, 2023) After the pandemic, this led to children, young adults and adults being inseparable from their screens and consuming excessive amounts of media and information, leading to poor real-life social connections and educational results.

As Moodle LMS is by now the most used LMS, providing all the necessary tools for course creation, authors advise the teachers to dive into the world of hybrid education and exploit the student need for digital devices and channel their screentime into a constructive and future oriented media usage. LMSs should provide students with adequate study materials, video and audio lessons, quizzes, tests, and real-life practical games where students can apply the educational content they have learned.

## **3. DEVELOPMENT OF A KOREAN LANGUAGE COURSE ON MOODLE LMS PLATFORM**

By focusing on the use of learning Management Systems like Moodle LMS to teach the Korean language online, this paper explores the role technology plays in facilitating modern education. The practical implementation of theories analyzed above focuses on student assessment in the Korean language via Moodle LMS on-site tests. The assessed grade rewards a student with a token that could be visible on the Blockchain, thus representing the student's achievements in Korean language education. These tokens could be shared within a future portfolio stored on the Blockchain. Tokens correspond to 6 TOPIK levels in Korean language proficiency, or international A1-C2 levels. For the sake of time economy, testing is conducted only at the 1st level of assessment.



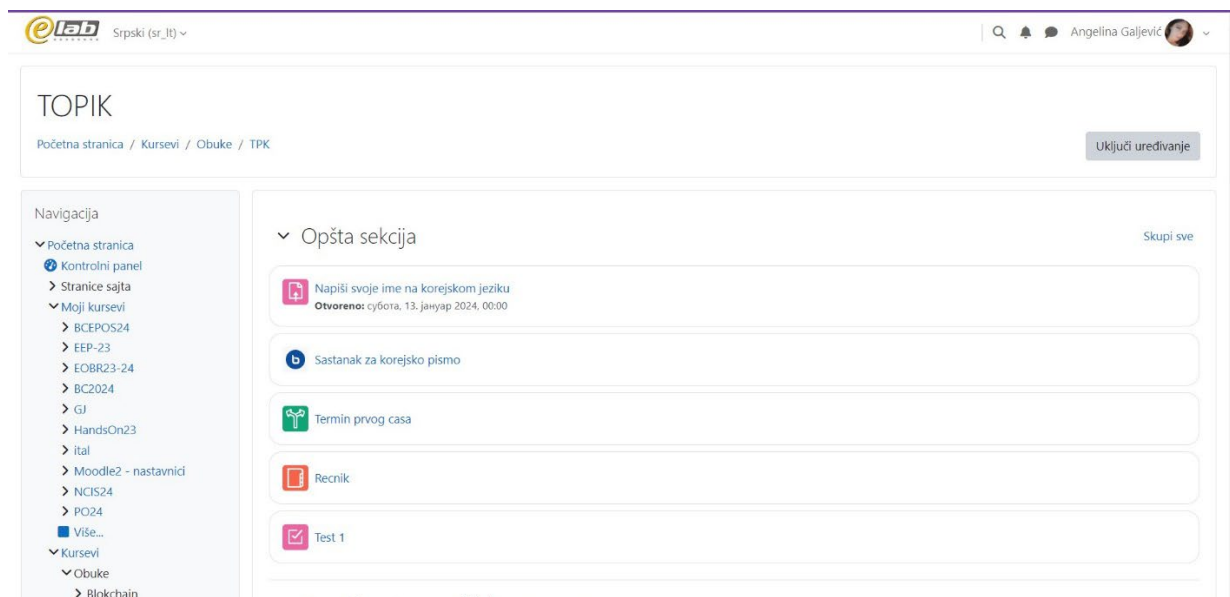


Figure 1: TOPIK course page in Serbian

Competencies achieved in this testing correspond to achievement of a TOPIK I-1 level. By passing the test, the individual confirms that they can use basic language abilities necessary for everyday activities, such as introducing themselves, shopping, ordering food, understanding, and expressing concepts about themselves, family, and hobbies, weather conditions, and other topics. The individual knows about 800 basic words and can form simple sentences with an understanding of basic grammar. They can also form and understand practical and simple sentences used in everyday life. (OFFICIAL, n.d.)

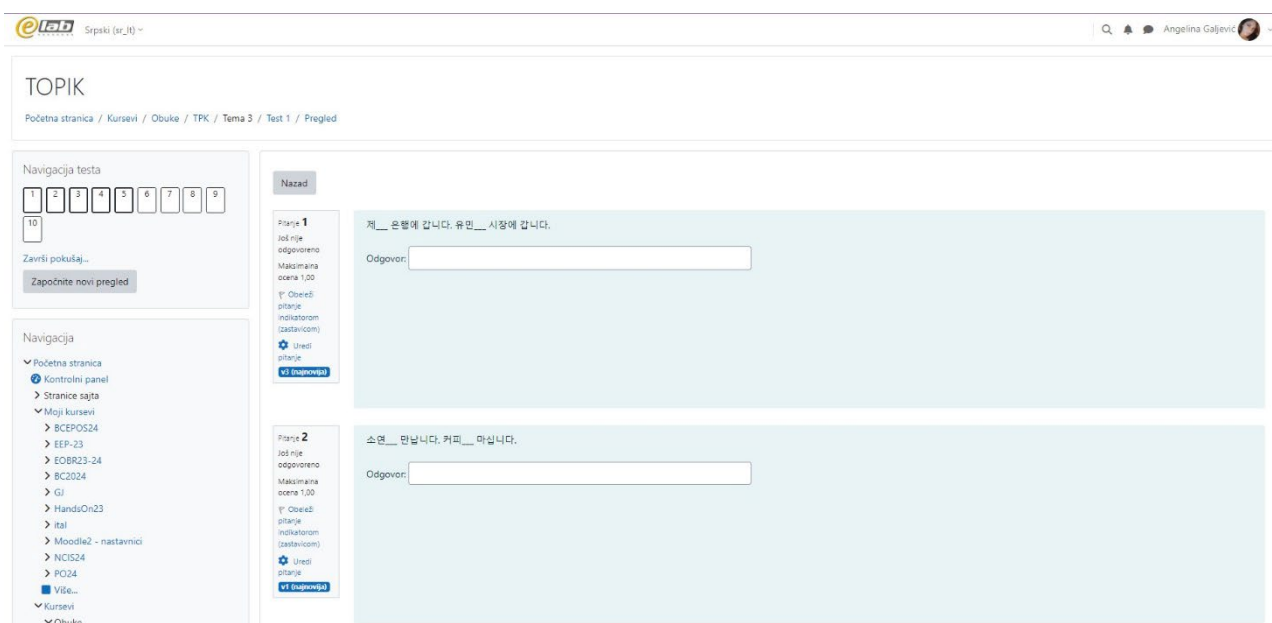


Figure 2: First two questions of the test for Korean language students

As this paper has a goal of initiating research of contemporary educational practices in Serbia's second language learning environments, research was conducted. The first research was conducted on a small portion of Korean as a second language students and should be conducted on a larger scale for other second language students in Serbia to paint the true picture of students' enthusiasm for contemporary tool and LMS usage in language learning practice. The survey results provide insights into niche learners' preferences and engagement with different types of learning experiences-specifically, the balance between traditional, instructor-led lessons and self-study with pre-recorded materials. This contributes to a better understanding of how students engage with technology-based learning.

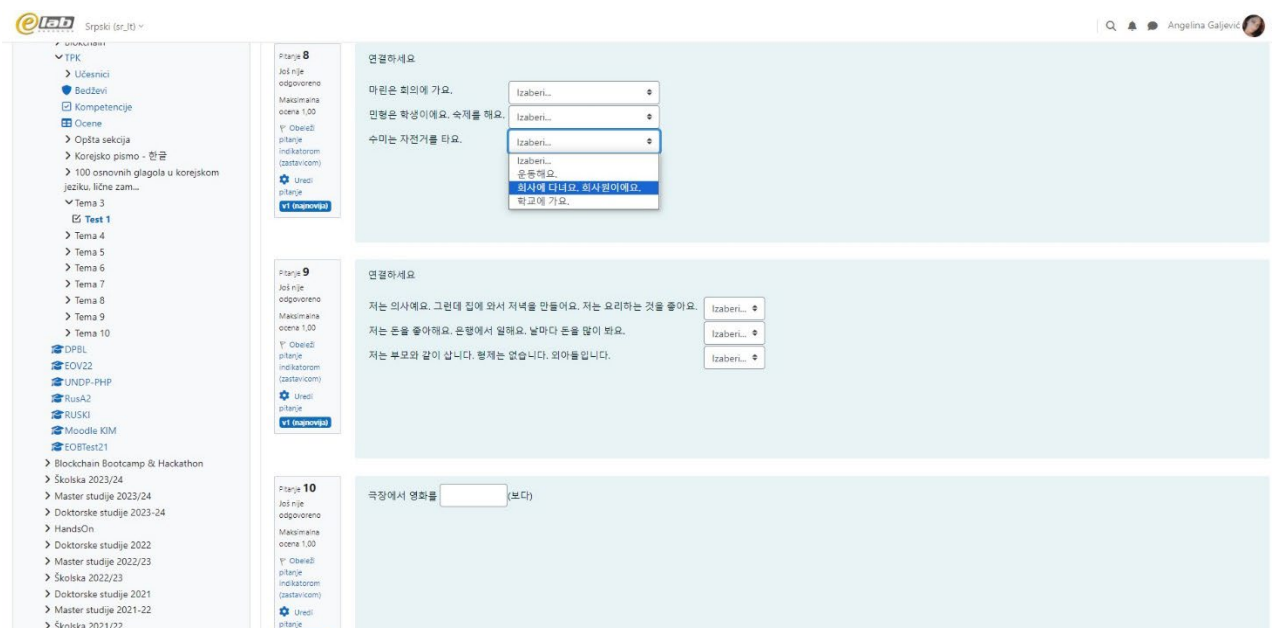


Figure 3: Last three questions of the test for Korean language students

Testing and the subsequent survey were conducted through Moodle LMS course environment and Google Forms for survey collection. The survey was based on two-choice questions and short answer commentary. There was a total of 14 participants of various ages, out of which 10 were female and 4 were male.

The test covered real-life Korean language practice, focusing on grammar and vocabulary aligned with the TOPIK I-1 level, using multiple-choice and short-answers questions.



Figure 4: Token for achieved TOPIK I-1

Out of 14 participants, 13 indicated a willingness to study Korean language via Moodle LMS. When asked to choose 1-on-1 work with a professor over self-study with a provided video lessons, responses were evenly split, with a comment that occasional live lessons would be preferred over fully virtual learning environment with pre-recorded lessons. The comments in favor of the self-study materials were flexibility, motivation for further exploration and additional practice material. The same pattern translated to the next question where individuals were asked if they would prefer Moodle LMS based study over live lessons. Again, they answered 50% yes and 50% no, with the comments such as that testing on Moodle LMS is preferred over live testing, but that studying live is better, and on the other hand that the Moodle LMS and the virtual environment provide infinite possibility of tool utilizing and lesson creativity. These findings can help educators design more flexible course structures. It also indicates the importance of offering a blend of both approaches to cater to different learning styles and needs. This emphasizes the need for the educational system as a whole to embrace flexibility and innovative approaches to learning, which is crucial for contemporary education.

All the participants were pleased with the test that the group was provided with. The positive response to the Moodle-based test and the willingness to use technology for learning a second language reflect broader trends in education toward technology-enhanced learning among the students.

As the very last question, the participants were asked if they would prefer that their competency level would be provided as a token to the future employer via Blockchain network, where 10 out of 14 were in favor and found it very helpful, while 4 didn't see the necessity of that practice and thus were against. The final question about competency level certification via Blockchain reflects a growing trend in digital credentials and verifiable learning outcomes. This aspect can inspire further discussions about the future of education credentials and how technology like Blockchain can play a role in providing secure and verifiable proof of skills on a wide-spread platforms.

Blockchain is one of the most rapidly rising technologies of the 21st century. Its development started as a distributed ledger for crypto currency transactions, but it soon gained its trustworthiness as a P2P network that ensures the legitimacy of the information shared. It has a high potential of usage in healthcare, housing, and education. (Wenhua et al., 2023) In education, it serves as a timestamped, legit proof of the acquired educational level of an individual, assuring a future employer of the employee's competency level. Korean language is rising in demand today, as South Korea, "the economic tiger," is developing further into the global economic market. Thus, this way of demonstrating the competency level is credible and likely to gain popularity in the near future.

#### **4. CONCLUSION**

This paper contributes to the field of modern education by demonstrating how LMS platforms like Moodle LMS can effectively support language learning, providing valuable insights into student preferences and offering a view into the future of education with technology-based certification. It underscores the importance of flexibility, the balance between different teaching methods, and the potential role of emerging technologies like Blockchain in education. As can be seen through the survey answers, the people interested in learning Korean language online are not as willing to learn in a fully digitalized manner. In the authors' opinion, the population in Serbia is not yet ready for the newest technologies, even though these technologies are slowly entering the Serbian market. Testing was officially conducted on a small part of the population, but Korean language professors can confirm a higher demand in hybrid or 1-on-1 lessons in comparison to self-study video materials. Expansion of usage and classroom implementation of these products is expected.

In the future, it is predicted that Metaverse, AI, Blockchain and other rising technologies will play a big part in the educational system. The rise of artificial intelligence tools like Chat GPT and AI Quiz Maker has revolutionized education. Augmented Reality, Virtual Reality, and the Metaverse allow for practical application, enabling visualization of concepts and safe experimentation. In language learning, this means simulated conversations with native speakers and virtual visits to museums. Augmented Reality can bring textbook characters to life and showcase historical figures, enhancing students' engagement and understanding. (Insider, n.d.)

Introducing modern didactic tools into foreign language teaching requires educating a new generation of teachers and students willing to embrace the latest and innovative teaching methods. Currently, many still believe that in-person teaching is far superior, dismissing online education. However, the education sector must embrace hybrid learning, gradually introducing students to the opportunities offered by modern software and hardware solutions for enhanced language learning. Incorporating these technologies could further improve Serbian education as a whole and lead to the global education 4.0.

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# MARKET COMPETITION BETWEEN DES

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**Abstract:** *This paper explores the adaptation of traditional competition theories to the context of digital ecosystems (DEs). Supported by an extensive literature review and a solid theoretical framework, this study examines how competitive relationships impact the growth and functionality of digital ecosystems. We analyze the unique structural characteristics and competitive concerns associated with digital platforms, which operate as central hubs in star network structures. Using well-known examples from the tech industry, such as the competition between Apple's iOS and Google's Android, Microsoft's strategy of incorporating additional services, and the competition among music streaming services, this paper aims to simplify and clarify the complex nature of digital competition and its wider effects. The paper aims to highlight how digital ecosystems deviate from traditional market frameworks and propose adjustments to competition policies to address these changes effectively.*

**Keywords:** *digital ecosystem, digital economy, competition policy, moligopoly*

## 1. INTRODUCTION

In the era of the digital economy, the concept of digital ecosystem (DE) has emerged as a framework for the analysis and understanding the complex interplay between various actors, technologies, and markets. As businesses tend to digitalize their operations (Kronblad & Envall Pregmark, 2021), the dynamics of competition have been significantly reshaped, giving rise to a new market model where traditional industry boundaries blur, and DEs become drivers of innovation and value creation.

The development and sustainability of DEs have been linked to the broader concept of the digital economy, which encompasses the dynamic interactions and competition among various entities in the digital space (Ilchenko, 2021). As companies increasingly transition their activities to digital platforms and ecosystems to maintain global competitiveness, the economic implications of these transformations become a critical area of study (Lipovenko et al., 2022).

Hein et al. (2019) define DE as a network of organizations, individuals, and technologies that interact and co-evolve to create value through digitally enabled processes. DEs appears in various forms, from e-commerce marketplaces to social media platforms, each characterized by its unique mixture of participants and usually complex business interactions. The infrastructure of DEs is purposively developed to facilitate the production, marketing, distribution and sale or delivery of various products and services.

Petropoulos (2020) distinguishes between two groups of DEs: (i) aggregators and (ii) marketplaces. Aggregators are platforms that offer end users valuable services, along with facilitating interactions with third-party producers or service providers. Marketplaces are platforms whose core business is to create efficient and purposeful connection between consumers and suppliers of goods and services. Typical representatives for the first group are online search engines (e.g. Google) and social media platforms (e.g. Facebook, Instagram) while the second group is represented by online marketplaces such as booking.com, Amazon and Google Play.

The phenomenon of DEs has gained attention in various economic theories, with the primary aim to understand the process of value creation, innovation, and competition within these complex networks (Suseno et al., 2018). Economic theories, such as platform economics (Spulber, 2018) and two-sided markets theory (Filistrucchi et al., 2014) offer alternative perspectives that better capture the dynamics of DEs. These theories emphasize the significance of value creation through interactions among versatile stakeholders and the role of digital innovation capabilities in driving economic growth (Suseno et al., 2018; Xie et al., 2023).

The existing fund of knowledge on DEs within the digital economy is multifaceted, encompassing various dimensions such as value creation, innovation, entrepreneurship, and competition. In this research paper, we aim to explore the market competition between DEs within the context of the digital economy.

## 2. THEORETICAL BACKGROUND

Market competition refers to the rivalry between firms operating within the same market, competing for market share, consumers, and profitability through various strategies such as pricing, product differentiation, and marketing efforts (Yu & Liu, 2022). Historically, at the beginning of competition policy development, monopolies were identified as the biggest threat for the market competition (Bunn, 1949). Competition policy comprises a set of rules that regulate competition on the market. In that context, competition policy should protect the competition process, not individual market participants. The market competition within DEs attracted substantial attention in the literature and practice. Current fund of academic knowledge provides vague conclusions regarding DEs impact on market competition and the need to significantly adjust antitrust law to address the challenges imposed by them.

The emergence of digital ecosystems has significantly altered traditional market dynamics, leading to the adoption of new competitive strategies, and posing challenges for competition law frameworks (Lianos, 2022). Multi-sided platforms and ecosystems challenge conventional views of competition by creating value chains that extend across different market segments, thereby modifying competitive strategies and market configurations (Rochet & Tirole, 2003). Jacobides & Lianos (2021) stressed the important role of DEs in competition law in theory and practice and offered a comprehensive understanding of the legal and regulatory dimensions influencing market competition within DEs.

The main goal of competition policy is to secure fair and appropriate competition between current and potential market players (Lončar & Milošević, 2013). The other frequently stated objectives of competition policy are dispersion of economic power and economic integration (Niels et al. 2016). Unrestricted entry of new market participants and the absence of barriers to entry intensify competitive pressure.

Hylton (2019) believes that the significant market dominance of large platforms is mostly attributed to economies of scale rather than anticompetitive behavior. According to the author, there is no distinct feature of digital platforms warranting a revision of antitrust regulations and should not impede the enforcement of antitrust legislation. The similar conclusions are shared by Veljanovski (2022) who thinks that there is no significant and urgent need for the reform of competition law.

Traditional competition theories often focus on market dominance, barriers to entry, and the behavior of firms with significant market power. However, in DEs, these theories need adjustments to address the digital market dynamics. Innovative technology development, rise of the internet, big data, artificial intelligence, machine learning, and block chain are strongly changing industry of DEs. The openness of digital infrastructures, the governance of platform interactions, and the enforcement of fair play are all areas where traditional theories may fall short.

According to Petropoulos (2020), competition issues in DEs often involve a star network structure, where each user is connected to a central hub or platform. This platform supplies the infrastructure and helps users interact with each other. To manage this, platforms do three main thing: they use open digital infrastructures, that let various stakeholders to manage their services and content; they create rules for governance and put resources into enforcing these rules to ensure a balance between controlling the platform and motivating users to participate actively and create value; they establish fair and effective systems for resolving disputes to address any unfair practices quickly.

Key features of DEs can lead to economic dynamics where platforms gain more control over the ecosystem and cause the market to tip in favor of one player. In multi-sided platforms, one side of the market can gain extra value from interacting with the other side (Kapoor, 2018). By attracting potential customers on the one side, platforms can get higher benefit from advertising. CMA (2020) illustrates the high concentration of advertising revenues in platforms such as Google and Facebook. Digital goods and services are typically produced at a significant fixed cost but no or insignificant variable cost (Varian et al., 2004). Once set up, digital companies can quickly grow by reaching more users with minor marginal cost of customer acquisition.

Machine learning and artificial intelligence have greatly increased the value of data for digital companies. By gathering, analyzing, and combining large amounts of data, companies can enhance their products and expand into new areas. Since machine learning works better with more data, companies with access to large data sets can improve their services more than those with limited data (Martens, 2020). The value a user gets from joining a platform can increase as more users join the same platform. This leads to a wider and better

range of products and services, making the platform even more valuable and attracting more users and developers in a positive feedback loop.

The interaction of above mention forces can make the ecosystem more economically dependent on the platform that facilitates most interactions between different users. The platform that first attracts many users can dominate the ecosystem. In other words, in DEs, we often see not just competition within the market, but competition for the market (Iossa et al. 2021). Competition concerns in DEs include several critical aspects. First, platforms can exploit their central position to exercise significant control over market participants, potentially resulting in monopolistic behaviors. Second, due to the network effects inherent in DEs, as the value of the platform increases with each additional user, high entry barriers are created for new entrants. Third, platforms often accumulate vast amounts of data which they can use to consolidate their market position and edge out competitors. Lastly, overcontrol by platforms may slow down innovation if the rewards for participants are not set up right.

Cunningham et al. (2018) explores the concept of killer acquisitions, which suggest that established firms strategically acquire potential competitors to eliminate future competition. This phenomenon has raised concerns regarding its impact on market competition and innovation, leading to discussions on the implications for competition policy and antitrust regulations. By exploring killer acquisitions within DEs, the study enhanced understanding of competitive behavior and strategic decision-making in the digital marketplace.

The negative impact of DEs on market competition is advocated by Koski et al. (2020). The authors investigated the impact of acquisitions by major US-based technology firms on market entry dynamics and venture capital financing across various product markets globally from 2003 to 2018. Their findings suggest that these acquisitions led to decreased market entry rates and reduced venture capital funding indicating a "kill zone effect." Particularly during the 2010s, when technology firms gained more access to user data, this effect intensified. Additionally, acquisitions of platform companies by technology giants were found to decrease market entry in non-platform markets, with a notable decline in available venture capital financing observed in the US compared to the European Union.

The comprehensive theoretical background highlight the complexity of competition within digital ecosystems and underscore the necessity for an understanding of these dynamics for effective competition policy formulation. The current fund of academic knowledge, while extensive, offers some conclusions, suggesting a pressing need for tailored antitrust regulations that can better address the digital realities. As DEs continue to influence global markets deeply, the recalibration of competition policies must be prioritized to foster fair competition and encourage innovation, ensuring the long-term sustainability of digital markets and protecting the interests of all market participants.

In the next part of the paper, we will present the case study analyses with the aim to investigate the nature of competition that can appear between DEs. These case study will illustrate the practical implications of theoretical concepts discussed and provide real-world examples of how DEs interact competitively across various sectors. By examining specific instances of competition between famous DEs, the following part of the paper aims to highlight the unique challenges and opportunities that these digital interactions present. Through the following analyses, we intend to offer deeper insights into how digital ecosystems can both foster innovation and pose new challenges for competition policy, thereby guiding more effective regulatory practices and strategies.

### 3. CASE STUDY ANALYSIS

The case study analysis explores the complex competition within DEs at three levels: (i) between platforms, (ii) between platforms and their complementors, and (iii) among the complementors themselves. By looking at examples like Apple's iOS versus Google's Android, Microsoft's strategy of integrating other services, and the competition among music streaming services, this analysis shows how these relationships influence the growth, operation, and competition of DEs. DEs involve complex interactions that stretch across many industries. This case study looks at how platforms and their complementors, compete in ways that go beyond traditional industry limits. This competition affects not just their market share but also how these ecosystems grow and innovate. The study uses the term "mologopoly" (Petit, 2020), a mix of oligopoly and monopoly competition, to help explain these complex dynamics.

Apple's iOS stands as a prominent example of a digital ecosystem with vast influence. As the operating system for all of Apple's mobile devices, iOS not only provides a seamless, user-friendly interface but also serves as a gateway for a multitude of applications and services tailored to enhance user experience. Its integrated environment supports a wide range of functionalities from basic phone operations to advanced computing

capabilities that cater to both personal and professional needs. The exclusivity of iOS, being available only on Apple hardware, creates a unique market niche that supports Apple's brand loyalty while also fostering a tightly controlled ecosystem. This control allows Apple to ensure security and functionality but has also been a point of contention in discussions about market competition, as it limits the degree of inter-platform operability.

Google's Android OS exemplifies a vast and open digital ecosystem that contrasts sharply with Apple's iOS. As an open-source platform, Android allows a wide range of manufacturers to adapt and use its system, resulting in a diverse array of devices that cater to all segments of the market, from budget to premium. This openness has enabled Android to capture the largest share of the global smartphone market, fostering a rich, competitive environment for app developers and hardware manufacturers alike. Android's flexibility allows for extensive customization and integration, offering users and developers more control over their devices. However, this same openness can lead to fragmentation, with variations in device capabilities and user experiences across different manufacturers and models. This ecosystem moves on its ability to be highly inclusive, yet faces challenges in maintaining uniformity and security across its landscape.

The rivalry between Apple's iOS and Google's Android shows a direct competition between two big mobile platforms. Each platform tries to attract more users and developers by offering unique features, better security, and improved user experiences. This competition leads to constant technological improvements and affects the plans of developers and advertisers who want to connect with the most active and largest groups of users.

Microsoft's strategy of integrating a range of services into its platforms exemplifies its approach to creating a comprehensive digital ecosystem. By embedding services such as the Edge browser, Microsoft Stream for media streaming, and Microsoft Teams for messaging and collaboration directly into its Windows operating system, Microsoft ensures that users have immediate, seamless access to a broad suite of essential tools. This integration enhances productivity and convenience by enabling users to navigate, communicate, and collaborate without ever leaving the Microsoft environment. The strategy not only boosts user engagement and satisfaction by providing a unified experience across multiple functionalities but also strengthens Microsoft's market position. It creates stronger barriers to entry for competitors and encourages user loyalty by offering a cohesive, adaptable and flexible platform that effectively meets a wide range of digital needs.

Microsoft's strategy of adding browsers, media streaming, and messaging features into its Windows operating system shows how a platform can compete with its complementors. By integrating these features, Microsoft took over valuable functions that other companies provided, increasing its control over the ecosystem.

Spotify, Deezer, Tidal, and Apple Music represent the leading competitors in the fiercely contested music streaming industry. Each platform strives to distinguish itself through unique features: Spotify offers algorithm-driven music discovery, Deezer provides a vast library with high-fidelity sound, Tidal appeals to audiophiles with its lossless audio quality and strong ties to artists, and Apple Music leverages its integration across Apple devices and exclusive content deals. These services compete not just on music catalogs and streaming quality but also on user interface design, playlist curation, and global market reach. As they vie for dominance, they continually innovate and refine their offerings to enhance user engagement and increase their subscriber base, thereby driving the evolution of how music is consumed and appreciated worldwide.

This situation highlights how platforms can take in innovations from complementors, which might limit outside innovation but strengthen the platform's own market position. The competition between music streaming services like Spotify, Deezer, Tidal, and Apple Music shows how companies that offer similar services can compete within the same ecosystem. Each service tries to stand out by offering large music collections, exclusive content, and customized experiences for users. This competition not only affects what consumers choose but also encourages improvements in technology and services as each platform aims to attract more users and increase their spending.

The close connection between different levels of competition is important for understanding how they impact the health and development of ecosystems. The 'moligopoly' competition framework shows how these types of competition are linked, with actions at one level influencing results at another. For example, strong tactics by platforms might decrease the variety of complementors, while strong competition among complementors can boost innovation but might also result in fewer companies dominating the market.

Considering the implications for competition policy, policymakers must take into account the complex competition dynamics when designing regulations for digital markets. Traditional antitrust approaches may not fully address the competition interactions in DEs. Therefore, a customized approach that addresses the specifics of 'moligopoly' competition is crucial for promoting healthy competition and preventing anti-competitive practices in DEs. This case study analysis underscores the complexity of competition in DEs across multiple levels. Understanding these dynamics is critical for stakeholders, including regulators,



companies, and developers, to navigate and succeed in these environments. Future policies and business strategies should reflect the realities of ecosystem-based competition to enhance innovation, consumer choice, and market health.

#### 4. CONCLUSION

This paper has provided a detailed exploration of the competition dynamics within DES, emphasizing the relationships at multiple levels. The extensive literature review and solid theoretical framework used in this study have provided a deep understanding of these competition environment, which is crucial for anyone involved in the tech industry such as DE, from business strategists to policymakers. The concept of "moligopoly," discussed in this paper, offers a new perspective on these interactions, showing that competition in DE involves more than just fighting for market share.

The examples of Apple's iOS versus Google's Android, Microsoft's strategy of integrating features, and the rivalry among music streaming platforms like Spotify and Apple Music illustrate how these ecosystems are constantly evolving and influencing technological advancements and market dynamics. When considering the rules for competition policy, it's important for policymakers to recognize the complex ways that companies compete in digital markets. Traditional rules might not fully capture the unique interactions in DEs. Therefore, a tailored approach that specifically addresses the unique type of competition called 'moligopoly' is essential to keep competition fair and prevent unfair practices in DEs. This case study highlights how complicated the competition is in DEs, occurring at many different levels. It's important for everyone involved, from government regulators to businesses and software developers, to understand these interactions. Future rules and business plans should take into account how competition works in these ecosystems to encourage innovation, offer more choices to consumers, and maintain a healthy market.

In summary, the insights from this research emphasize the need for well-informed strategies and policies to manage competition in digital markets. As these markets grow and change, understanding their complex competitive structures will be key to promoting innovation and fair competition. This paper contributes to the broader conversation on digital competition, suggesting directions for future research and policy development that keep pace with the rapid changes in the digital economy.

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# WEB 3.0 IN DIGITAL FASHION

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**Abstract:** *This study focuses on the development and presentation of an NFT fashion collection using Web3 technologies, particularly Non-Fungible Tokens (NFTs), and explores their transformative impact on creativity, ownership, and interaction in digital fashion. The primary problem is to address the identified challenges of successfully presenting and profiting from digital fashion collections in the current landscape while ensuring authenticity and transparency amid the digital content saturation and preparing for entry into the metaverse. The project involves curating a bespoke NFT fashion collection using tools like Clo3D for 3D garment design and visualization, followed by minting and showcasing on a fashion specific NFT platform. Through this research, the aim is to demonstrate the potential of NFTs and other Web3 technologies to elevate virtual fashion experiences and drive innovation within the digital fashion landscape, highlighting their pivotal role in reshaping the future of the fashion industry.*

**Keywords:** *Web 3.0, NFT, Artificial Intelligence, Augmented Reality, Digital Fashion*

## 1. INTRODUCTION

Web3 technologies have profoundly transformed the fashion industry, reshaping traditional practices and enabling innovative digital experiences. Non-Fungible Tokens (NFTs), artificial intelligence (AI), and Augmented Reality (AR) are standout technologies driving this change. This paper explores the potential applications of Web3 technologies in digital fashion, focusing on creating and showcasing an NFT fashion collection. NFTs have revolutionized the authentication, ownership, and trading of digital assets like fashion items and collections online (Shilina, 2022). AI has advanced personalized virtual fashion experiences, from AI-driven design tools to virtual fitting solutions. Augmented Reality enhances user engagement through virtual try-ons and immersive brand experiences, bridging the physical and digital realms of fashion. This study will provide a practical demonstration by illustrating the process of developing an NFT fashion collection using software like Clo3D, a powerful tool for 3D garment design and visualization. Furthermore, the minting and showcasing of this collection on a fashion specific NFT platform will be showcased, highlighting the integration of Web3 technologies into the creative and commercial aspects of digital fashion. By examining these applications, this research aims to shed light on the transformative potential of Web3 technologies in the fashion industry, showcasing how they enable new forms of creativity, ownership, and interaction within the evolving landscape of digital fashion.

## 2. WEB 3.0 IN FASHION INDUSTRY

The convergence of Web 3.0 technologies with the fashion industry is poised to redefine the landscape of digital creativity and commerce. Web 3.0 represents the next phase of internet evolution, characterized by decentralized protocols, enhanced interactivity, and the integration of emerging technologies such as non-fungible tokens (NFTs), artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) (Hassan et al., 2023). These advancements are reshaping how fashion brands engage with consumers, produce digital assets, and innovate within the digital realm.

This chapter explores how Web 3.0 technologies are transforming the fashion industry. It examines the use of NFTs in digital fashion, emphasizing their role in enabling ownership and authenticity in the digital realm. Additionally, it analyzes how AI optimizes design processes, personalizes customer experiences, and promotes sustainability in digital fashion ecosystems. Furthermore, the chapter investigates how VR and AR technologies are reshaping virtual fashion showcases, interactive retail experiences, and virtual try-on solutions, revealing the synergies between advanced technologies and fashion creativity while addressing the opportunities and challenges of adopting Web 3.0 in the industry.

## 2.1. Web 3.0 technologies

Web 3.0 is an advanced technology aiming to enhance the web experience by introducing a more intelligent, decentralized, and user-centric approach (Hassan et al., 2023). By utilizing technologies like blockchain, artificial intelligence (AI), Internet of Things (IoT), virtual reality (VR), augmented reality (AR), and non-fungible tokens (NFTs), Web 3.0 improves security and privacy while giving users greater control over their content.

In the digital realm of Web 3.0, where extensive data collection and storage occur, ensuring data security is crucial. Blockchain technology, along with advanced AI tools, becomes an indispensable solution for maintaining the integrity, privacy, and security of this data (Cannavò & Lamberti, 2020). It facilitates transparent digital value transactions and grants users full control over their sensitive information through authentication and consensus mechanisms. Furthermore, the implementation of encryption and hashing functions further enhances information security in this digital space (Gadekallu et al., 2023). Fueled by advancements in computing power and big data, AI has rapidly evolved to deeply impact daily life, optimizing user experiences in the Web 3.0 era through closed-loop workflows encompassing perception, decision-making, behavior, and feedback amidst extensive data generation from devices and intelligent systems (Gan et al., 2023). NFTs represent a groundbreaking concept reshaping the landscape of digital ownership and creativity. They provide authenticity, indivisibility, and transparent ownership of digital assets like art, collectibles, and virtual real estate (Wang et al., 2021), while also offering monetization options for creators through smart contracts, royalties, and transparent provenance.

IoT plays a critical role in Web 3.0 by connecting devices and objects to the internet, enabling data-driven decision-making and transformative applications across industries like fashion and textiles. This connectivity enhances efficiency, facilitates smart manufacturing, and fosters innovative consumer experiences in the evolving digital landscape (Ramaiah, 2021). Sensors, which are devices capable of tracking information on consumer behaviour and movement within stores, are integral to this process, providing valuable data for optimizing business operations (Shaminn, 2019). The significance of VR technology for Web 3.0 lies in its capability to create immersive and realistic experiences within digital environments, enhancing interaction and engagement across various fields. VR's evolution has been fueled by advancements in hardware and software technologies, making it more accessible and appealing to consumers, while also opening up new avenues for virtual commerce and marketing strategies within the digital landscape (Bieñkowska, 2023). AR technology integrates digital information with real-world environments, enhancing user perception by overlaying virtual content (Liu, Balakrishnan & Saari, 2024). Widely deployed across devices like smartphones and AR glasses, AR significantly improves online shopping experiences, increasing purchase intent through immersive and interactive environments. Studies highlight AR's impact on consumer engagement and brand experiences, showcasing its potential to transform marketing and retail strategies in Web 3.0.

## 2.2. NFT in digital fashion

A digital asset known as an NFT represents real-world objects like art, music, in-game items, and video content (Hassan et al., 2023). These tokens hold the potential to drive significant innovation in the fashion industry within the framework of Web 3.0. NFTs offer a significant opportunity to authenticate luxury items, addressing challenges faced by brands in verifying product authenticity in the virtual realm (Sung, Kwon & Sohn, 2023). By leveraging NFTs, fashion brands can create digital copies of their prestigious products and ensure their authenticity through blockchain technology, providing additional security and consumer trust in purchasing digital and physical items within the Web 3.0 ecosystem (Ferrini, Huber & Batt, 2023). This form of digital ownership within Web 3.0 not only facilitates purchasing but also trading of these unique digital goods. NFT owners can resell them on specialized markets, offering an exceptional opportunity for investment and trading within the digital ecosystem. Through these activities, NFTs become pivotal drivers for both consumers and brands, adding an additional layer of interaction, ownership, and market opportunities within the Web 3.0 landscape.

The increasing influence of NFTs within blockchain-based virtual environments like Decentraland and The Sandbox (Awear, 2023) opens new perspectives for the fashion industry. By leveraging this technology, fashion brands can offer digital clothing, accessories, and other fashion items that allow users to personalize their avatars in virtual spaces. The appeal of these platforms to the fashion industry was particularly evident during the Metaverse Fashion Week, where renowned brands such as Tommy Hilfiger, Dolce & Gabbana, and Karl Lagerfeld showcased innovative NFT collections, presenting new models on virtual runways and exploring the possibilities that NFT technology offers in the world of fashion.

NFTs are becoming essential in the gaming world, offering luxury fashion brands a new market perspective. Users can personalize characters, enhancing gaming experience and engagement with the brand (Sung,

Kwon & Sohn, 2023). Louis Vuitton's "Louis: The Game" exemplifies this trend, allowing players to collect virtual items and NFTs, creating innovative brand experiences. This blend of fashion and NFTs connects brands with consumers, especially younger audiences, paving the way towards a digital future.

### **2.3. AI in digital fashion**

Artificial Intelligence is playing a transformative role in digital fashion, enabling innovative experiences and personalized interactions within virtual environments. By leveraging AI technologies like machine learning, deep learning, and reinforcement learning, digital fashion platforms can analyze vast amounts of data, enhance computer vision, process natural language, and create lifelike virtual entities (Poupi et al., 2022). Through AI integration with blockchain technology, digital fashion ecosystems benefit from increased transparency, security, and efficiency. AI also facilitates real-time decision-making and operational improvements, enhancing user interactions and support services (Yang et al., 2022).

AI's capabilities extend to avatar creation, allowing for highly personalized and realistic virtual representations based on user data analysis. Companies such as Ready Player Me demonstrate the success of AI-driven avatar technology in digital fashion, promising a revolution in how digital identities are shaped. In general, AI is shaping dynamic and interactive environments in digital fashion, revolutionizing user experiences and interactions within virtual spaces. This integration with technologies like VR, AR, and blockchain enriches digital fashion, creating immersive and innovative realms where reality and virtuality converge (Poupi et al., 2022).

### **2.4. VR and AR in digital fashion**

Virtual reality technology enables users to immerse themselves in entirely digital environments, providing a sense of real presence and interaction distinct from the physical world (Mystakidis, 2022). VR relies on specialized equipment like VR headsets and multisensory devices to deliver immersive experiences through visuals, sounds, tactile sensations, and motion, creating a convincing illusion of reality within the digital realm. In the context of fashion shows, which historically served as a primary means of advertising and promoting fashion brands, traditional shows faced challenges in reaching a broad audience due to limitations in space and time. To overcome this, fashion shows are transitioning to digital formats, utilizing VR technology to facilitate interactive evaluations of clothing, promotion, and even direct purchases (Ahn, Bae & Kim, 2023). Avatars play a crucial role in VR, representing users within virtual environments and allowing for unique forms of personal expression and interaction beyond traditional online platforms (Mystakidis, 2022). The combination of avatars and VR technology fosters a strong sense of presence and facilitates novel social interactions and community building within virtual spaces.

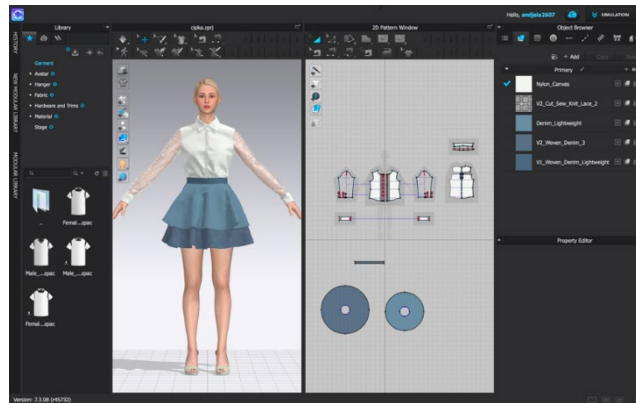
AR technology expands the possibilities of virtual worlds by allowing users to experience alternate realities directly within their real environment. Through sound, visual displays, scents, and tactile sensations, AR integrates computer-generated content into everyday life (Schmalstieg & Hollerer, 2016). The development of smart devices such as smartphones and AR glasses enables mobile access to AR experiences, liberating the technology from the constraints of large screens or specific devices and making it widely accessible to users (Lee et al., 2021). In the realm of digital fashion, AR is transforming the industry by introducing innovative ways to engage consumers and elevate shopping experiences. Virtual fashion shows, made possible by AR technology, enable fashion brands to present their latest collections in immersive digital environments, reaching a global audience without geographical limitations. Users can participate in these virtual events from anywhere, gaining a front-row seat to the latest trends and designs. Moreover, AR facilitates interactive try-on experiences where users can virtually test clothing and accessories, customize colors and styles, and make informed purchasing decisions (Song, Baek & Choo, 2020). This personalized approach not only enhances user engagement but also drives sales and fosters creativity in how fashion brands connect with their audience.

## **3. DEVELOPMENT OF NFT FASHION COLLECTIONS**

In the dynamic intersection of fashion and technology, the emergence of NFT fashion collections signifies a significant moment - a fusion of creativity and innovation pushing into uncharted territories. Through the lens of NFTs, new realms of creativity are explored, blurring the lines between the physical and digital worlds, with endless possibilities. This amalgamation of technology and fashion represents a milestone that opens doors to new inspiring pathways and opportunities previously unimaginable. As designers and technologists continue to collaborate and push the boundaries of what's possible, the evolution of NFT fashion collections promises to revolutionize the way we perceive and interact with fashion in the digital age.

At the heart of our creative endeavor lies Clo3D, a powerful software platform renowned for its prowess in 3D garment simulation and visualization. Through its intuitive interface and robust features, designers transcend

the limitations of traditional sketching, immersing themselves in a virtual realm where fabrics drape effortlessly and designs come to life with unparalleled realism. By harnessing the capabilities of Clo3D, we embark on a transformative journey to redefine the landscape of fashion creation.



**Figure 1:** Clo3D user interface

During the process of creating a garment in Clo3D, the first step involves drafting a 2D pattern, which serves as the blueprint for the garment's shape. Following this, materials for the garment are chosen, including textures, colors, and other material attributes. Once materials are selected, the fabric's behavior is simulated on a virtual mannequin to visualize how the garment will drape and conform when worn (Huang & Huang, 2022). During simulation, adjustments are made to refine the design, such as adding buttons, belts, or other embellishments, as well as experimenting with colors and patterns for desired aesthetics. Through iterative refinement, the design is optimized until the desired result is achieved, possibly involving fine-tuning fit, altering detail arrangements, or selecting alternative materials. Upon reaching satisfaction with the design, the garment can be exported in various formats for further visualization, presentation, or production purposes. This process enables the creation of complex and authentic garments with a high level of detail and realism.

The interface of Clo3D, as depicted in Figure 1, provides intuitive tools and features that facilitate seamless garment design and simulation. Additionally, designers can utilize the platform's extensive library of pre-existing garment templates and customizable elements to streamline the design process and explore creative possibilities. Using Clo3D's interface, designers can effortlessly navigate between different stages of garment creation, from initial pattern drafting to final refinement, ensuring efficient workflow and precise execution.

In the realm of NFT fashion collections, the marriage of artistic vision and technological innovation heralds a paradigm shift in the way we perceive and engage with fashion. Through the creative lens of Clo3D, coupled with the transformative power of blockchain, we embark on a journey of limitless possibilities, where digital couture transcends the constraints of the physical world, and creativity knows no bounds. As we navigate this uncharted territory, we redefine the very essence of fashion, crafting not just garments, but a legacy woven from pixels and blockchain immutability.

Introducing the Lavish Glamour collection, featuring the first model of dress in a series of three elegantly designed garments crafted using CLO3D. Each dress in this collection boasts a slim fit, a striking one-shoulder bow detail, a flattering sweetheart neckline, and waist bows for added charm. The collection includes three stunning variations: a chic beige dress, perfect for parties with its shorter length, and two longer options in navy blue with beige accents and rich burgundy, both exuding sophistication and luxury. Crafted from satin, these dresses not only look exquisite but also offer a luxurious feel, making them the perfect choice for any glamorous occasion. Figure 2 depicts the beige dress on a mannequin within the CLO3D software, while Figure 3 presents the navy-blue dress. This collection exemplifies the seamless integration of technology and design, offering a glimpse into the future of digital fashion creation.

The Virtual Wardrobe presents an exclusive NFT collection consisting of three outfits, each carefully designed to reflect different styles and occasions. The first ensemble, known as the Dragon outfit, is crafted from fabric featuring a dragon print, paying homage to Japanese culture. In Figure 4, the outfit is showcased on a mannequin to provide a more immersive experience. The second outfit, named the Blue Laguna outfit, features an elegant white shirt with navy details paired with a dark blue skirt adorned with a bow and belt. This ensemble, depicted in Figure 5, strikes a harmonious balance between sophistication and casualness, perfect for various settings from office to evening gatherings.



**Figure 2:** Gold dust dress on avatar



**Figure 3:** Royalty dress

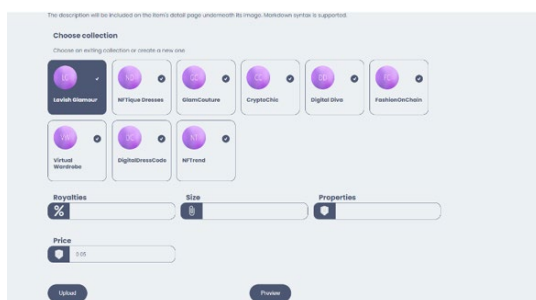


**Figure 4:** Dragon outfit on avatar

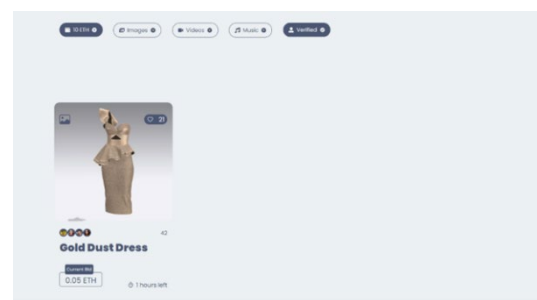


**Figure 5:** Blue lagoon outfit

After the NFT is created, the subsequent process involves minting it, essentially converting it into a unique digital asset on a blockchain network. This minting process typically entails associating the NFT with specific metadata, such as its title, description, and other relevant information, as described in Figure 6. Once minted, the NFT is ready to be listed on an NFT marketplace, where it can be bought, sold, or traded by collectors. This listing process, showcased in Figure number 7, involves uploading the NFT along with its associated metadata onto the marketplace platform, making it available for public viewing and potential transactions. The image likely illustrates this process visually, depicting the steps involved in minting and listing an NFT on the marketplace.



**Figure 6:** Create NFT page



**Figure 7:** Store with added NFT

## 4. CONCLUSION

The fusion of Web 3.0 and digital fashion represents a pivotal moment in the industry's evolution, presenting boundless opportunities for innovation and artistic expression. The achieved results highlight the enhanced security, verifiable ownership, and new creative possibilities that NFTs bring to the digital fashion industry. By harnessing tools like Clo3D for crafting fashion NFTs and minting them on marketplaces, we witness a

seamless integration of technology and design, shaping a future where creativity knows no bounds. As we navigate this dynamic landscape, it's evident that the convergence of fashion, technology, and blockchain promises to redefine the very essence of fashion creation, ushering in an era where digital fashion becomes a cornerstone of the industry. The study showcases the process of curating and presenting an NFT fashion collection using Clo3D, providing insights into the transformative potential of Web3 technologies for fashion. Future directions involve further exploration of NFT and Web3 applications to enhance authenticity, ownership, and interaction in digital fashion ecosystems. This work lays a critical foundation for advanced research and implementation of innovative solutions that will shape the future of fashion in the digital age.

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# EXAMINING THE ANTECEDENTS OF THE ADOPTION OF AI TECHNOLOGY AMONG PROSPECTIVE HEALTHCARE WORKERS

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**Abstract:** Significant research has showcased the potential of artificial intelligence in healthcare and expanding its role in nursing education. For the technology to be implemented and sustainable, it needs to be used and willingly accepted. Prospective healthcare workers form their attitudes about certain technologies during schooling. The main goal of this paper is to examine the antecedents of the adoption of AI technology among prospective healthcare workers. When presenting technology to students, it is assumed that AI-based systems or applications have been tested and have security certifications. An integrated adoption model utilizes core dimensions of the UTAUT and TAM extended with trust and perceived substitution crisis. The model is planned to be evaluated. The results of this research will give insight into the readiness of students to accept AI technology and help teachers present emerging technologies in the right way to prospective healthcare workers through modern curricula.

**Keywords:** Artificial Intelligence, Technology Acceptance Model, Healthcare, Nursing Students, Smart Healthcare

## 1. INTRODUCTION

AI is not a new concept. It was formally introduced at the Dartmouth Society in 1956 (Council of Europe, 2023), and it has been used in clinical decision support systems since the 1970s (Prakash & Das, 2021). Today is one of the leading technologies in the world. Artificial intelligence embodies a novel breed of software capable of autonomously making decisions, learning, and advancing without the need for human intervention. Artificial intelligence systems learn and improve based on the large amounts of data they constantly receive. These qualities allow them to adapt to new situations as quickly and efficiently as possible or to solve a problem optimally. In other words, machines can function instinctively and complexly, commonly referred to as having the ability to “mimic the human brain” (Sun, Yin, Xu, & Zhao, 2023), which is the ability to think through computers or make decisions like humans do (Sun, Yin, Xu, & Zhao, 2023). AI is one of the most fascinating and rapidly evolving fields of computer science and it possesses the capacity to reshape many aspects of our lives in the years to come. AI technology is already being used in gaming and entertainment, education (Ocheja, Agbo, Oyeler, Flanagan, & Ogata, 2022), security, finance and banking, transportation, and many other fields in the healthcare system (SoluLab, 2023). AI in healthcare has the potential to diversify the practice of medicine improving the quality, efficiency, and accessibility of health services. Besides, it tends to improve the quality of life for patients and health professionals. For example, AI can process extensive datasets from various sources, including medical records, images, diagnostics, and symptoms, and identify patterns that can help diagnose diseases (Chen, et al., 2022) or predict their outcomes.

Despite its early stages, a numerous study shows that AI systems can revolutionize utilization for medical diagnosis (Alowais S. , et al., 2023). AI is very successfully applied in the field of dermatopathology (Wells, Patel, Lee, & Motaparthi, 2021) when recognizing different changes on the skin. For example, AI as a component of a predictive medicine, aids in diagnosing skin cancer by comparing images of skin lesions with a database of documented cases (Secinaro, Calandra, & Secinaro, 2021). AI is increasingly being integrated into nursing care to improve efficiency, accuracy, and patient outcomes and bring a higher standard of care (Kwak, Ahn, & Seo, 2022). Some of the applications are in the domain of patient monitoring, medication management, workflow optimization, and remote patient monitoring. AI can assist radiologists in detecting abnormalities in chest X-rays, mammograms, or MRI scans, and provide suggestions for further actions (Alowais, Alghamdi, & Alsuhebany, 2023). Doctors and other healthcare workers can be assisted by guiding different medical procedures (Civaner, Uncu, Bulut, Chalil, & Tatli, 2022). AI can help oncologists in crafting tailored treatment regimens for patients battling cancer, taking into account their genetic profile, tumor

attributes, and response to previous therapies. AI can also optimize medication dosages, monitor drug interactions, and prevent adverse events (Junaid, Usman, Aditya, & Williams, 2021).

Despite obvious contributions, there are several concerns related to AI implementation. AI in healthcare may involve decisions that affect human lives, such as diagnosis, treatment, and so on. This raises ethical questions about responsibility. Besides, there are possible reliability and errors in AI systems. AI in healthcare may lead to potential social inequalities, like discriminating groups of people, changing the roles of healthcare professionals and patients, and loss of human interaction. There are some considerations that AI-based technologies can replace a lot of human tasks and human-to-human interaction, and that can lead to the reduction of employees (Civaner, Uncu, Bulut, Chalil, & Tatli, 2022) (von Gerich, et al., 2022). Such possibilities often cause fear among nurses and other medical personnel, and consequently, there is an aversion to AI technologies as assistive technologies in healthcare setting. Concern about data privacy and security refers to the fact that AI relies on large amounts of sensitive data, such as medical records, and genomic and biometric data. And that raises the risk of cyberattacks, identity theft, and usage of unauthorized parties. Moreover, different countries have different laws and regulations regarding data protection which may limit sharing and transfer of data.

Researching factors that contribute to users' acceptance of AI in the healthcare and educational sector is required. Studying and recognizing factors that influence intentions of future healthcare workers, medical organizations and schools can take actions to provide a better acceptance of IT innovations, and thus increase use of emerging technologies in the healthcare system as supplementary technologies (Rodic, Stevanovic, Labus, Kljajić, & Marija, 2023) (George, Darine, Nadim-Nicolas, & Beatrice, 2022). For a technology to be used and beneficial, it needs to be accepted by the users (Kelly, Kaye, & Oviedo-Trespalcacios, 2023). there has been a surge in studies focusing on the antecedents of AI acceptance by healthcare workers or medical students.

This paper aims to explore the readiness for the adoption of AI technologies as supplementary technologies in healthcare settings among future healthcare workers.

So, the research objectives are:

- provide an insight into antecedents of adoption intention of AI technologies in healthcare setting
- propose an innovative research model to access predictors of adoption intention of AI technologies.

## **2. AI ADOPTION MODEL**

### **2.1. Background**

Technology acceptance of AI among medical students is an important topic that explores the factors that influence the willingness and readiness of future doctors and other medical workers to use AI in their clinical practice. Research in this area provides insights into the current state of knowledge, attitudes, and behaviors of medical students regarding AI, as well as the challenges and opportunities for integrating AI education into medical curricula.

In our research, we include well-established models for examination of acceptance of AI, like Technology Acceptance Model (TAM) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Thong, & Xu, Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology, 2012) (Gansser & Reich, 2021) model. UTAUT has been already used to study technology acceptance of AI among medical students, and it proposes that four key constructs affect the intention and behavior of users: performance expectancy, effort expectancy, social influence, and facilitating conditions. Some studies have also extended this model by adding other variables, such as habit, hedonic motivation, trust (Li & Qin, 2023), and task complexity (Tran, i drugi, 2021). The Theory of Planned Behavior (TPB) is a theory that connects attitudes and behavior, proposed by Icek Ajzen (Ajzen, 1991) and others. A study (Gursoy, Chi, Lu, & Nunkoo, 2019) stated that these technology acceptance models (i.e., TAM and UTAUT) should not be used for intelligent technology and they propose an AI Device Use Acceptance model (AIDUA) that includes two result phases - willingness and rejection. According to a systematic review by Chen et al. (Mingyang, i drugi, 2022), the awareness and usage of clinical AI among physicians and medical students are still low, although the majority of them have positive attitudes and are optimistic about the potential of AI in healthcare. However, there are also concerns about the reliability, accuracy, and ethical implications of AI, as well as the possible replacement of human doctors by machines. The review also suggested that the acceptance of clinical AI varies by specialty, country, and level of training.

A cross-sectional survey by Li and Qin (Li & Qin, 2023) found that medical postgraduate students demonstrate a heightened awareness and propensity to utilize medical AI compared to undergraduate students. The survey also revealed that the intention to use medical AI is positively influenced by antecedents such as performance expectancy, habit, hedonic motivation, and trust. The authors recommended that medical education should focus on enhancing the skills and competencies in using medical AI (Li & Qin, 2023).

Author Kwak and others in the study (Kwak, Ahn, & Seo, 2022) examined ethical considerations among students in the healthcare area. The study showed that older students show a higher level of ethical awareness than younger students, as well as positive attitudes towards AI. At the same time, there exists a direct positive link between ethical awareness and positive attitudes towards AI, but there is no significance of the influence of ethical awareness on behavioral intention.

A survey by Doumat et al. (George, Darine, Nadim-Nicolas, & Beatrice, 2022) assessed the knowledge and attitudes of medical students in Lebanon toward AI. The survey found that most students possess a fundamental grasp of AI and its current use in medicine, but also have misconceptions and gaps in knowledge. The survey also revealed that students have positive attitudes toward AI and are willing to use it in their future practice, but also have concerns about its reliability, safety, and impact on the doctor-patient relationship. The authors recommended that medical education should incorporate AI into the curriculum and provide more training and exposure to AI for students (Han, i drugi, 2019).

## **2.2. Model of AI acceptance**

We proposed a model of acceptance of AI based on TAM (Davis, 1989), TPB (Ajzen, 1991), and previous related research.

The constructs of the research model were developed utilizing the theories from recent literature. The model has been made up of seven constructs, and six of them have direct or indirect effect on adoption intention (Davis, 1989) of AI technology in healthcare setting. The proposed research model is shown in Fig 1.

### **Intention to adopt/use (IU)**

Construct Behavioral intention from (Davis, 1989), (Ajzen, 1991) was redefined as Intention to adopt/use due to the nature of AI technologies that are probably not yet in use in clinics. It is defined as a factor that expresses the intention or readiness to accept AI technologies among healthcare students in their future practice. The Intention to adopt/use is influenced by the Attitude (AT) which is the general impression of the technology.

### **Attitude (AT)**

Attitudes are influenced by various stimulus factors, including perceived usefulness, basic knowledge, and personal innovativeness. It is found that attitudes strongly correlate with behavioral intention (Venkatesh, Brown, Maruping, & Bala, 2008).

### **Perceived usefulness (PU)**

Perceived usefulness is the degree to which a person believes that using a particular system would enhance ones job performance (Davis, 1989) and is hypothesized to be a fundamental factor of user intention acceptance according to findings from other studies (So, Ismail, & Jaafar, 2021).

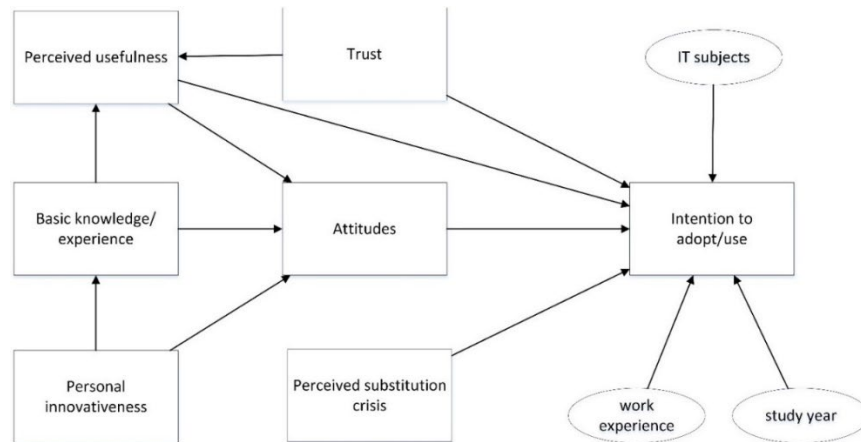
### **Basic knowledge/experience (BKE)**

It's crucial to provide nurse informatics education to all nursing practitioners and students. Integrating basic AI-based technology knowledge across all nursing career stages is equally vital (von Gerich, et al., 2022). The advancements in AI have outpaced the evolution of medical education. Basic knowledge assumes at least some experience or routine gained through practical teaching or seminar papers. According to (Fishbein & Ajzen, 1975) (Venkatesh, Brown, Maruping, & Bala, 2008) experienced users lead to can be a support in maintaining and increasing the actual use of AI technology. Considering the above and previous research (Li, Jiang, Jong, Zhang, & Chai, 2022) (Gado, Kempen, Lingelbach, & Bipp, 2021) we include construct Basic knowledge/experience that has a direct influence on attitudes and perceived usefulness.

### **Trust (TR)**

When it comes to health services or services, people usually make a distinction when comparing them to any other field. Healthcare is a typical service that is perceived to have risks and health data are confidential and sensitive. Thus, trust is an important factor. If an institution that requires personal data cannot be trusted, then individuals lose trust and will not use the services of that institution. Trust is a subjective attitude and presents a general tendency to trust others or technology (Wanner, Herm, Heinrich, & Janiesch, 2022). If technology or service cannot be trusted by the user, the user is unlikely to perceive the technology as

valuable or useful. According to some studies (Prakash & Das, 2021) (Dhagarra, Goswami, & Kumar, 2020) (Gefen, Karahanna, & Straub, 2003) trust is positively associated with perceived usefulness to use emerged technology in healthcare setting. Trust as a predictor of technology acceptance has been widely recognized as a factor that significantly impacts user behavior in the adoption of emerging technologies (Liu & Tao, 2022) (Choung, David, & Ross, 2023) (Zerilli, Bhatt, & Weller, 2022). Thus, as trust was recognized as an essential factor in emerging technology acceptance, we extended our model.



**Figure 1:** Proposed model of artificial intelligence acceptance among future healthcare workers

### Perceived substitution crisis (PSC)

The rapid advancement of intelligent technology brings new challenges for employees, like increasing employees' job insecurity, being dependent on AI, decreasing diagnosis capacity due to AI, and negative behaviors, such as silent behavior and workplace incivility (He, 2023) (Fan, Liu, Zhu, & Pardalos, 2018) (Verma & Singh, 2022). These barriers served as a potential barrier for medical and healthcare students to adopt AI technology in their future practice. Along with other factors, we also joined perceived substitution crisis as a factor that has an impact on IU.

### Moderating effect of work experience, study year, IT subject

Besides, in the research model, the intention toward adoption/use of AI technology is influenced by work experience, study year, and IT subjects during studies. A study by Venkatesh et al. (Venkatesh, Brown, Maruping, & Bala, 2008) (Misra, Mahajan, Singh, Khorana, & Rana, 2022) reported that a longer user experience with technology enables users to more effectively leverage technical resources. In previous research, we found a positive impact of seniority on the acceptance of emerging technologies in healthcare setting. When it comes to education in healthcare informatics, health workers' curricula are mainly represented through elective courses. As a result, a lot of future healthcare workers are left without basic knowledge about the application of IT in healthcare and practical experience in that area.

## 3. CONCLUSION AND FUTURE WORK

Artificial intelligence is transforming the healthcare sector by enhancing the quality, efficiency, and accessibility of medical services. AI can help diagnose diseases, recommend treatments, monitor patients, and discover new medications. AI can also reduce errors and lower costs. However, AI in healthcare encounters obstacles including ethical and legal dilemmas, concerns regarding data integrity and security, as well as issues surrounding human expertise and trust. AI in healthcare must adhere to the principles of beneficence, non-maleficence, autonomy, and justice, and respect the rights and dignity of patients and health professionals. An innovative curriculum must be designed to equip nursing students with the skills to embrace AI-based technologies in their future roles. This curriculum should offer practical experiences in digital healthcare technologies, encompassing AI, as well as education on AI ethics and algorithms. Besides, course and education should alleviate anxiety associated with adopting AI technology in healthcare setting (Chen, et al., 2022). Even though an educated medical professional will more readily accept AI-based technology, there are barriers to introducing AI into the medical curriculum. The curricula are already loaded enough and there is a lack of time to implement new modules. There is a problem performing exercises for professional students because AI technologies are not yet certified and licensed for use in healthcare settings. Finally, there is the need for a well-planned academic structure to serve as the knowledge base for AI-based courses and their implementation.

Our future work will consist of the evaluation of the proposed model among prospective healthcare workers (nurses, physiotherapists, midwives, radiology technicians, and more). Besides, our future work will consider

including a wider range of participants, such as current healthcare professionals, to gain a more comprehensive understanding of the factors influencing AI adoption in healthcare. The assumption is that many students and healthcare workers lack familiarity with the concept of AI, except for the applications familiar to their generation such as ChatGPT. Thus, respondents of our future evaluation will be briefly introduced to the concept of AI technologies in healthcare setting, benefits, and potential risks. Also, it is necessary to point out that the use of AI in healthcare means applications or systems that have been tested and approved for use in a healthcare environment.

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# COMPARATIVE ANALYSIS OF TECHNOLOGIES FOR MOBILE APPLICATION DEVELOPMENT

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**Abstract:** *The development of mobile applications has undergone significant changes over the past two decades, driven by the accelerated development of newer and more advanced mobile devices and development technologies. Today, there are several different options for mobile application development, and choosing the right approach often presents a challenge for developers. This paper aims to conduct a comparative analysis of various approaches to mobile application development, as well as to compare programming languages and frameworks for their development and it can be used as guide that should provide less experienced mobile app developers with assistance in selecting the most suitable option for development.*

**Keywords:** *mobile applications, native, cross-platform*

## 1. INTRODUCTION

Over the past decade, the popularity of mobile applications has significantly increased, with currently about 86% of the population owning smartphones (approximately 7 billion people), and all of them to a greater or lesser extent using mobile applications (Stocchi et al., 2021). According to research from August of last year, the Android operating system holds 70.77% of the market share, while the iOS operating system holds 28.52% (Afzal, 2023). The remaining market share is negligible compared to these percentages, so only these two operating systems and frameworks for developing mobile applications for them will be discussed in the rest of the work.

The subject of this paper is to review the most significant technologies for mobile application development and their comparative analysis based on various criteria. The thesis aims to determine the justification for using modern technologies for cross-platform mobile application development and to compare their performance with applications created using traditional methods, employing programming languages defined for mobile operating systems. Additionally, the aim is to determine which technology is most suitable for developing applications for the Android operating system, the iOS operating system, and cross-platform development.

## 2. FRAMEWORKS FOR MOBILE APPLICATION DEVELOPMENT

Creators of mobile applications, before development, must decide on which platforms their application will be available, on and often opt for cross-platform development, targeting both Android and iOS (Boushehrinejadmoradi et al., 2015). However, in certain situations, mobile application development is done exclusively for one platform. This approach has long been the only option for developers and today it has certain advantages over cross-platform development. Therefore, first, we will discuss single-platform development methods, followed by cross-platform development.

### 2.1. Development of applications for Android

Android, the dominant mobile operating system, boasts over a billion apps on its Google Play Store (Sokolova, Perez & Lemercies, 2017). Developed by the Open Handset Alliance within Google, it's based on Linux and supports app creation for Android and Linux devices (Kochayun, 2017). Key reasons for building Android apps include its massive user base, simplicity in deploying apps on Google Play Store compared to iOS, and abundant APIs that streamline development, cutting down on time. Moreover, Android's open platform allows any registered distributor to produce and sell devices, expanding accessibility and potential

user reach (Ardito et al, 2020). Enhanced by Google services, Android devices offer seamless features like geolocation and internet usage, further enriching user experience.

## **2.2. Development of applications for iOS**

The iOS operating system, initially designed for iPhones and later extended to iPod Touch, and iPad, hosts over 1.8 million apps on its App Store, catering to approximately 1.5 billion users. Developing for iOS offers access to a large user base, a unified market, and a high-quality OS, enhancing user experience and device popularity (Wang, 2022). However, iOS app development is restricted to Macintosh devices, a significant limitation. Nonetheless, Apple integrates the iOS SDK into all its devices, enabling developers to create, test, and launch apps on a single device. Unlike Android, which offers various development environments, iOS development mandates the use of Xcode. This IDE, akin to Eclipse or Visual Studio Code, facilitates app creation for all Apple portable devices (Tashildar et al, 2020). iOS applications were initially created exclusively using the Objective-C programming language, and since 2015, the Swift programming language has gained significant popularity.

## **2.3. Cross-platform applications development**

Since the launch of the first smartphones, devices have operated on pre-existing and tested operating systems, each with their separate standards, programming languages, development tools, and separate marketplaces where users can download applications. This distinction between operating systems has always posed a challenge for developers because each platform represents a large market of potential users. Two main approaches to this problem are focusing on one platform and losing many potential customers or developing applications for both platforms (in this case, considering only Android and iOS), which requires investing much more time and resources. The first solution presented to developers who want to develop applications for multiple platforms without writing the same code multiple times for each platform is called m-site development. This development is based on web technologies such as HTML, CSS, JavaScript, and the created application runs within the mobile device's browser. These applications do not need to be adapted to a specific platform because they are implemented within the browser and are designed to run on smaller screens. However, the performance of these applications has been poor due to their reliance on the speed of interaction between the server and the client, which in turn depends on the internet connection. Additionally, there was a problem with the appearance of the applications because they could not implement the design of native applications (Zohud & Zein, 2021).

Another development concept for mobile applications often implemented using an Ionic framework is the development of Progressive Web Apps (PWA). These applications are created within web browsers using web technologies and are designed to operate solely within them, without accessing the native functionalities of the mobile device. This type of development is often the fastest and most cost-effective, but it comes with numerous drawbacks regarding design and functionality. When creating an application, this approach is typically used initially for testing applications within browsers. With the introduction of advanced concepts, it is necessary to transition to emulators or mobile devices (Nunes, 2021).

The latest approach to mobile application development is multi-platform development, which encompasses several different techniques, such as hybrid development, cross-compilation, application interpretation, etc. Hybrid applications involve using web technologies, similar to the m-site approach, but the applications are not run within the browser; instead, they run within a web container that has better access to the device's functionalities. However, the design issue, which is not always consistent with native applications, remains unresolved. Other types of multi-platform application development involve translating the original application code into native code for a specific platform (Latif et al, 2017). The goal of multi-platform mobile application development is to create a single application using a unified codebase that can run on various platforms. Recently, this approach has become very popular and widely accepted in the industry, leading to the development of various options for developers (Zohud & Zein, 2021). Currently, React Native is the most popular framework for multi-platform development, and in analysis, we will include some other popular frameworks - Ionic and Flutter.

## **3. METHODOLOGY FOR COMPARATIVE ANALYSIS**

With the rapid development of the mobile devices and applications market, technologies used in creating these applications are also evolving. Consequently, there is already enough different frameworks, development approaches, techniques, etc., among which the most optimal solution should be chosen. The set of factors to consider when selecting technologies for mobile application development includes compatibility with platforms, ease of development, development support, application performance, scalability, security, development costs, framework dependencies, available development time, required memory space



for the application, device battery consumption, frequency of major framework changes, and the developer's own experience.

The first step in choosing a framework for development is selecting the platform on which the application will run. If it is necessary to create an application only for Android devices, the best approach is undoubtedly using Java or Kotlin and developing it in Android Studio. There are certain differences between these two programming languages which will also be the subject of analysis, as the choice between them needs to align with the project's requirements. If the need arises to develop an application solely for iOS devices, the situation is slightly more complicated than with Android. This is because Mac OS devices, necessary for the development of these applications in Objective-C, Swift, or even Flutter, are less common compared to Windows/Linux computers. If the programmer possesses the hardware required for iOS application development, they should choose between Objective-C and Swift. However, if that is not the case, options include React Native and Ionic (Zucic, 2023). The second step is to review the factors and determine which factors are most significant for the specific case of application development. The factors to be considered for the comparative analysis include ease of development, development support, performance, scalability, security, development costs, framework dependence, development time availability, device memory, memory usage, battery consumption, framework update frequency, application updates and reusability, and programmer experience. The values of factors are arbitrary and vary from case to case. The third step in the analysis is determining their values based on project requirements, market research, technological factors, monetization, regulatory factors, etc. In the following, there is a table with all the factors and corresponding weights that have numerical values between 1 and 5 depending on their significance.

**Table 1:** Overview of all factors for research with corresponding weights

Factor	Weight
Ease of development	2
Development support	3
Performance	5
Scalability	3
Security	5
Development costs	1
Framework dependence	3
Development time availability	2
Device memory	3
Memory usage	4
Battery consumption	4
Update frequency	3
Application updates, reusability	2
Programmer experience	3

Each factor is rated on a scale from 1 to 10, and the sum of all factors multiplied by their weights is 440. In the comparative analysis for Java and Kotlin or Objective C and Swift, the framework dependency factor is neglected, so their total sum of factors with weights is 410. The rating of the framework/language is obtained as a percentage of the total sum for the given framework in the overall sum of all factors.

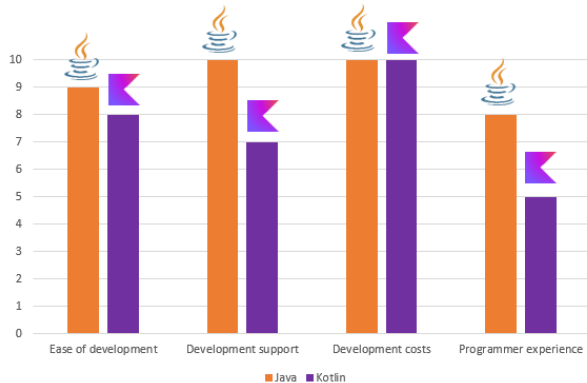
#### 4. ANALYSIS OF RESULTS AND DISCUSSION

When choosing to develop an application exclusively for the Android platform, there are two main options: Java and Kotlin. Kotlin was created as an improvement over Java and is primarily oriented towards mobile application development. In the following analysis, the factors for choosing a programming language in comparison to Java and Kotlin are presented.

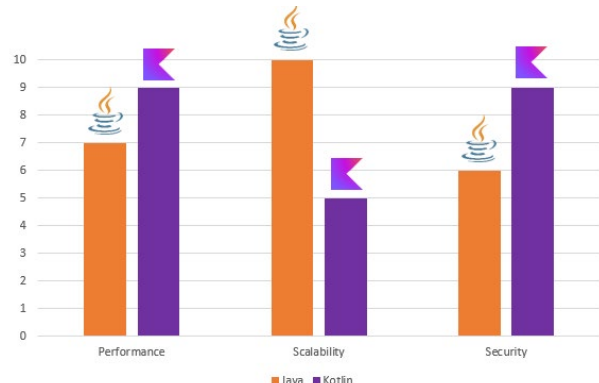
Java, being an older language, serves as the foundation for many newer languages, rendering it a convenient choice for development ease. Both languages boast high ease-of-use ratings. Java enjoys robust support owing to its popularity, with a vast developer community, resources like courses, documentation, and problem-solving solutions, along with numerous development tools. With approximately 17 million developers familiar with Java and 5 million with Kotlin (Grid Dynamics, 2023), Java proves more accessible for novice programmers due to its simplicity. Conversely, Kotlin demands a higher level of experience and deeper understanding of the language. Development costs for both are minimal, with a fixed \$25 registration fee for publishing on the Google Play Store (Nandbox, 2023). The use of both programming languages and their development environments is free (Figure 1). Both Java and Kotlin compile to the JVM, ensuring similar performance levels. However, Kotlin's simpler syntax contributes to slightly better performance. A difference lies in Kotlin's lazy loading feature, which accelerates incremental app rendering. Kotlin excels in building

smaller Android apps, while Java offers greater scalability (Dechalert, 2021). Java is versatile for mobile and other software development. Kotlin shines in application reliability, mitigating null value-related issues often encountered in Java apps (Figure 2).

In terms of device memory usage, there are small differences between these two. Typically, Kotlin occupies slightly less device memory, but on the other hand, Java consumes less RAM because Kotlin performs additional steps in translating code to the JVM. As a result, Kotlin applications consume more battery on the device. In terms of these factors, both languages are very similar, with average performance in terms of battery preservation and device memory (Figure 3).

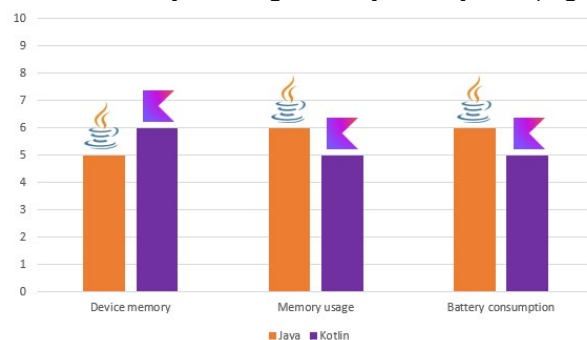


**Figure 1:** Ease of development, development support, development costs, and programmer experience

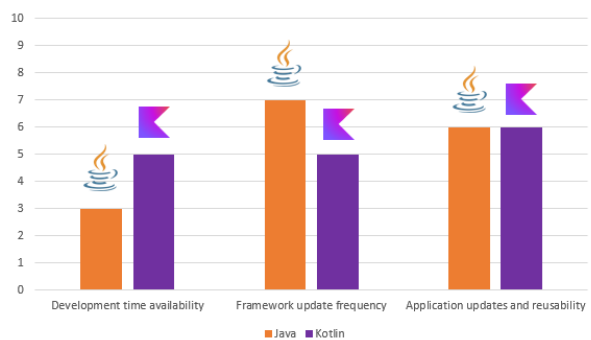


**Figure 2:** Performance, scalability, security

Kotlin development usually takes slightly less time than Java, enabling faster creation of new program versions. However, Java holds an advantage in terms of reusability due to its extensive array of libraries, add-ons, and development tools amassed over its lifespan. While Kotlin releases new versions approximately every four months, Java follows a more structured release schedule, with updates every six months and major changes every three years (Figure 4).



**Figure 3:** Device memory, memory usage, and battery consumption



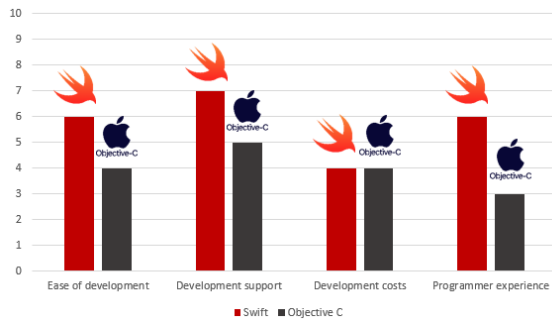
**Figure 4:** Development time, update frequency, and application updates

At the end of the analysis, Java has a total score of 279/410, while Kotlin has a slightly lower score of 252/410. The rating for Java for mobile application development is 6.8, and for Kotlin, 6.15. From this analysis, it can be determined that Java still represents the best option for Android application development, mainly because this programming language has been around for a long time, has a well-established community of developers, and numerous learning resources, and ensures easier application development. However, in terms of performance, Kotlin presents a better solution, which suggests that it may have an increasing number of users in the future, making development easier for new developers.

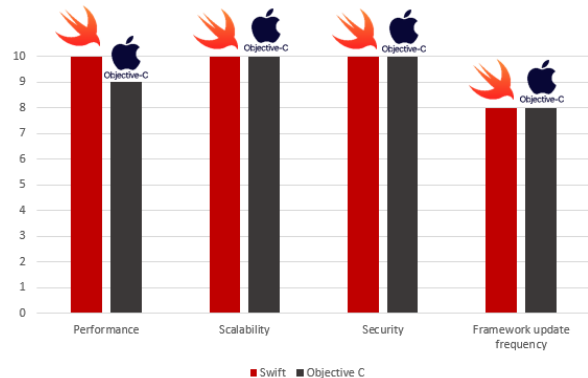
When it comes to developing a mobile application exclusively for the iOS, there are two valid options: the Objective-C and Swift programming language. Swift was created as an improvement to Objective-C in 2014, and since then, many mobile applications for iOS have been developed exclusively using it. However, some aspects of the operating system are still created using Objective-C. Both Swift and Objective-C, rooted in the C programming language, embrace object-oriented principles. Swift stands out with its modern and simpler syntax, making iOS development more approachable. Despite Objective-C's earlier inception, Swift's developer community has swiftly grown. Swift offers richer resources and extensive documentation. However, iOS development, whether with Swift or Objective-C, presents a steeper learning curve compared to Android. Moreover, publishing on the App Store incurs a \$99 fee per application, alongside higher hardware costs, making iOS development more costly than Android (Figure 5). iOS applications generally outperform Android counterparts due to better hardware and software optimization on iOS devices. Among

iOS programming languages, Swift offers superior performance compared to Objective-C, thanks to its optimized nature and automatic memory management. Swift also receives more frequent optimizations through updates. iOS apps are renowned for their scalability and reliability, attributed to stringent App Store submission requirements necessitating thorough testing (Figure 6).

Similarly, iOS applications demonstrate better memory usage, RAM, and device battery savings compared to Android applications. Applications created using Swift have slightly better performance in terms of memory usage (Figure 7).

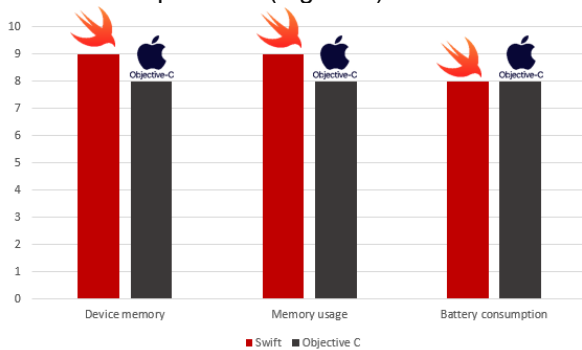


**Figure 5:** Ease of development, development support, development costs, and programmer experience

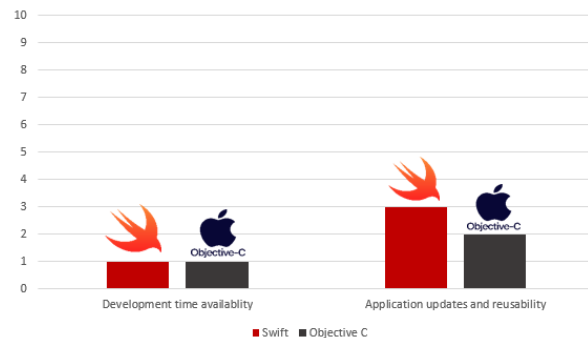


**Figure 6:** Performance, scalability, security, and update frequency

In terms of development time, iOS applications typically require more time to develop than Android applications due to stricter tests for placing on the App Store. In this regard, updating an application is also more challenging. However, with the Swift language, updating is somewhat simpler and faster due to greater code reuse capabilities (Figure 8).



**Figure 7:** Device memory, memory usage, and battery consumption



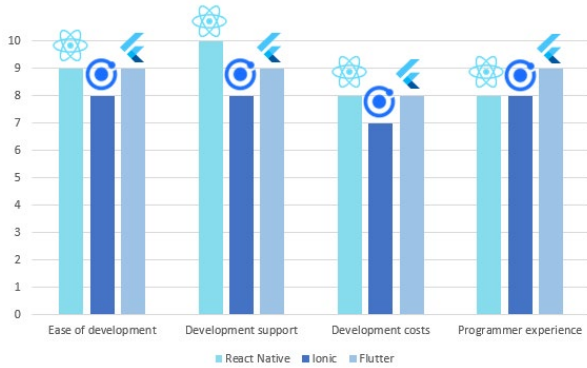
**Figure 8:** Development time, application updates, and reusability

The total score for Swift is 312/410, and for Objective-C, it's 279/410. The overall score for Swift is 7.61, and for Objective-C, 6.8. A notable increase in the overall scores of these two languages compared to Android languages can be observed, largely due to the better performance of iOS applications. Additionally, Swift has proven to be the better choice, making it the clear solution for iOS application development. When it comes to developing cross-platform applications, there are two possible solutions. The first is to create separate code for each platform using one of the previously analyzed languages, which requires additional time. The second option is to choose one of the frameworks for developing cross-platform applications. The most well-known frameworks for such development are ReactNative, Ionic, and Flutter.

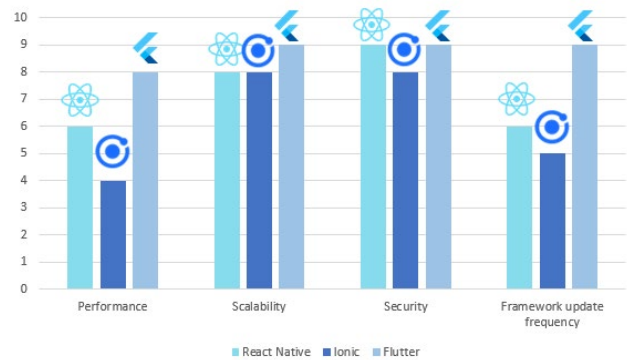
ReactNative and Flutter boast well-organized documentation with clear examples and development instructions. While ReactNative has a large developer base, interest in it has waned in recent years, with Flutter now counting around 2 million developers, slightly more than Ionic and ReactNative. Development costs primarily hinge on the platform, but Flutter and ReactNative are entirely free, whereas Ionic provides both free and paid versions (Blanco & Lucredio, 2021). These popular frameworks are increasingly favored, making them accessible to less experienced programmers. Flutter is considered slightly more beginnerfriendly, although React Native and Ionic are also relatively straightforward (Figure 9). The performance of applications developed with these frameworks can vary significantly, generally falling short of native app performance. However, Flutter can achieve nearly native performance for less complex applications due to its use of the FlutterEngine, rendering animations notably faster than other frameworks. Ionic typically exhibits the weakest performance as it generates hybrid apps, resulting in longer conversion times to native elements. Regarding scalability, all three frameworks lag slightly behind native apps, with Flutter standing out as the most reliable due to its FlutterEngine and Just-In-Time/Ahead-of-Time compilation

capabilities. ReactNative and Ionic are also scalable but to a lesser extent than Flutter. In terms of reliability, Flutter and ReactNative perform slightly better than Ionic, which faces additional challenges related to web development. Updates are regularly issued for all three frameworks (Dorfer, 2020) (Figure 10).

Cross-platform frameworks typically require slightly more memory due to an additional layer of abstraction needed for code translation. Ionic apps tend to consume the most memory. In terms of working memory, all three frameworks demand more resources than native apps because they utilize a JavaScript engine for code execution. ReactNative consumes the most RAM due to its JavaScript Bridge (Shevtsiv & Striuk, 2021). Additionally, in terms of battery consumption, cross-platform apps exhibit weaker performance compared to native ones (Figure 11).

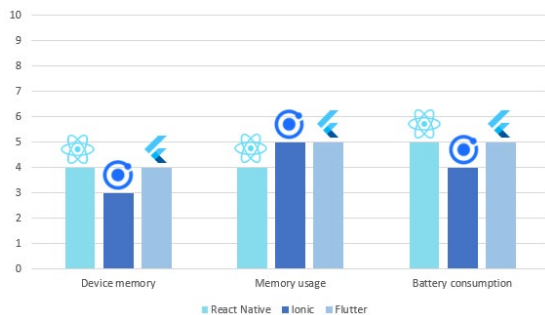


**Figure 9:** Ease of development, development support, development costs, and programmer experience

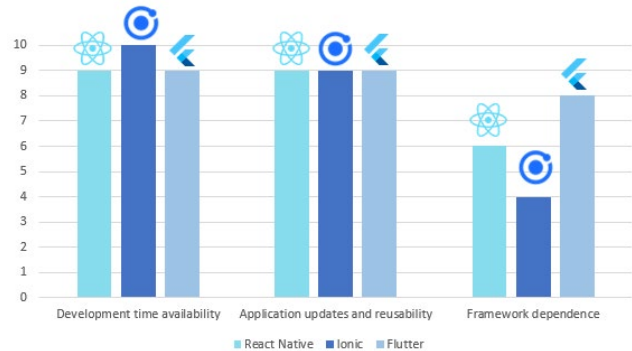


**Figure 10:** Performance, scalability, security, and update frequency

When it comes to mobile app development time, frameworks hold an edge over native development. All three frameworks offer relatively fast and straightforward development. Similarly, application updates and code reuse possibilities are comparable across the board. In terms of reusability, Flutter and ReactNative enjoy a slight advantage over Ionic (Figure 12).



**Figure 11:** Device memory, memory usage, and battery consumption



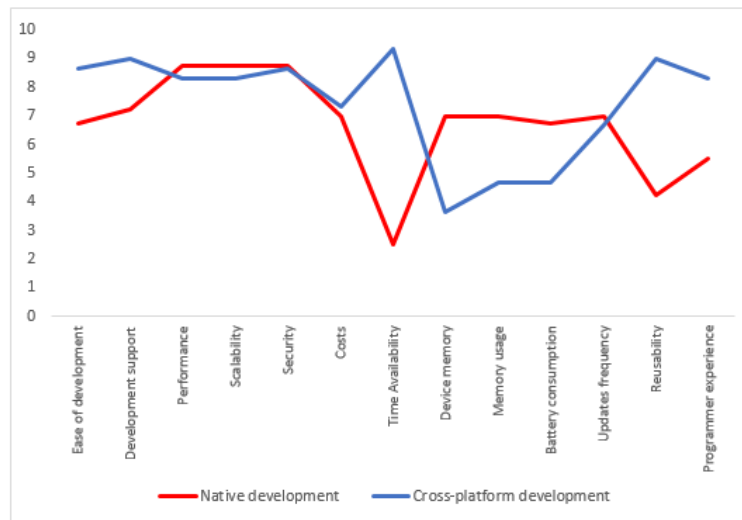
**Figure 12:** Development time, application updates, and framework dependency

**Table 2:** Analysis of languages and frameworks for mobile application development

Factor	W	Java	Kotlin	Swift	Obj-C	ReactN	Ionic	Flutter
Ease of development	2	9	8	6	4	9	8	9
Development support	3	10	7	7	5	10	8	9
Performance	5	7	9	10	9	6	4	8
Scalability	3	10	5	10	10	8	8	9
Security	5	6	9	10	10	9	8	9
Development costs	1	10	10	4	4	8	7	8
Framework dependence	3	-	-	-	-	6	4	8
Development time	2	3	5	1	1	9	10	9
Device memory	3	5	6	9	8	4	3	4
Memory usage	4	6	5	9	8	4	5	5
Battery consumption	4	6	5	8	8	5	4	5
Update frequency	3	7	5	8	8	6	5	9
Application updates	2	6	6	3	2	9	9	9
Programmer experience	3	8	5	6	3	8	8	9
		279	252	312	279	299	265	331

The total score for the ReactNative is 299/440, overall rating of 6.8, for Ionic it's 265/440, overall rating of 6.02, and for Flutter it's 331/440, overall rating of 7.52. From the above, we can see that Flutter is the best

choice in most cases when selecting a framework for developing cross-platform mobile applications. Although Ionic has the lowest overall score among all development approaches, in situations where extremely rapid mobile application development is needed, it represents the best possible solution. The following is a table 2 with all frameworks and languages along with ratings for each factor, as well as a graph comparing the average ratings of languages and frameworks (Figure 13).



**Figure 13:** Comparative analysis of native and cross-platform development

## 5. CONCLUSION

After reviewing all relevant technologies for mobile app development, it's clear that traditional development using native technologies is the best option when there are sufficient resources available. Such applications have the best performance, user experience, user interface design, and capabilities for manipulating device functionalities. The reason for this is the direct integration with the device's operating systems, allowing applications to quickly access advanced functionalities such as animations, camera, user gestures, etc. However, in most cases, time is crucial in the dynamic mobile app market, which is why frameworks for cross-platform development have been created and their popularity is growing. They still don't have the performance that native applications can have, but they are rapidly evolving, so it can be expected that such applications will achieve top performance, and then there will be no need for native development. Currently, the best solution, both in terms of performance and development simplicity, is the cross-platform framework Flutter. It should be noted that the final choice depends on the specific case of mobile app development, but whenever the situation allows, preference should be given to native development.

Using Flutter for creating mobile applications offers several significant advantages for businesses. Flutter's single codebase allows developers to build applications for multiple platforms simultaneously, which accelerates the development process and reduces the time required to launch the app, giving businesses a competitive edge by reaching the market faster. Despite being a cross-platform framework, Flutter provides performance close to native applications, ensuring a smooth and responsive user experience. Leveraging Google's Material Design, Flutter ensures applications have a consistent and visually appealing design across different platforms, enhancing user experience and strengthening brand identity. The framework allows for the development of a single application that can run on both mobile and desktop operating systems, significantly reducing development costs and simplifying the testing process. With Flutter, businesses do not need to hire separate development teams for each platform, reducing overhead costs and simplifying project management. Backed by Google, Flutter receives frequent updates and improvements, ensuring the framework remains up-to-date with the latest technological advancements and continues to provide robust performance and new features. Given Google's investment in Flutter, it is likely to be adapted to support future technologies, making it a sustainable choice for long-term projects. In summary, adopting Flutter for mobile app development offers a strategic advantage by reducing costs, accelerating the development cycle, and ensuring high performance and design consistency.

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# DEVELOPMENT OF A MOBILE APPLICATION PROTOTYPE USING THE DESIGN THINKING METHOD

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**Abstract:** *In an era of rapid technological changes and a strong trend toward digitalization, the importance of adaptation for university institutions is crucial to remaining competitive in the market. This paper focuses on the development of a prototype mobile application "e-student", with the goal of improving student satisfaction. The application design aims to optimize processes and enable quick access to information, which, in today's era where user attention is ever-decreasing, is a very important factor. Through the design thinking methodology, this research presents the development of the application in five steps, from identifying student needs to the application prototype and testing. This method has enabled the creation of an interface that fully caters to students' needs and their dynamic lives. This work encourages university institutions to think about the rapid development of technology and its integration with student services.*

**Keywords:** *e-business, mobile applications, design thinking, user interface (UI), user experience (UX)*

## 1. INTRODUCTION

Quick and easy access to information, as well as simplicity in using applications, represent very important criteria for users. A key factor that stands out is the concept of user experience, which refers to the usability of the application (Hassenzahl & Tractinsky, 2006), or the successful execution of tasks with minimal thought and effort by the user. In addition to the user experience (UX), the user interface (UI) of the application itself is equally important; users are accustomed to beautiful interfaces, and it can be said that the design, or the visual appearance of the screens, attracts users, while the experience turns them into regular users.

The main reason for addressing this topic is the growing popularity of design, which is increasing daily due to the emergence of artificial intelligence tools that significantly enhance its capabilities. Furthermore, one of the reasons is the necessity for university institutions to adapt to constant technological changes, as well as the desire of students to manage their academic lives in a simple and efficient manner at any time and from any place. This paper presents the main aspects of mobile applications, the differences between user interface (UI) and user experience (UX), and the steps of the design thinking methodology based on which the development of the e-student application prototype is shown in Chapter 4. The methodology led to the design of an application that aimed to showcase the importance of adhering to trends and addressing everyday challenges faced by students.

The main goal of this paper is to develop the e-student mobile application prototype using design thinking methodology. The creation precedes the research of user needs and expectations, while after creating the interface, the testing process follows, which will contribute to a better understanding of the user experience (UX) when using such applications and provide sufficient input for a new increment of development and upgrade.

This work will provide guidelines for further application development through five simple steps in the academic field. The application's contribution will be visible through improved user experience (UX), greater student satisfaction, future project development, and innovation stimulation.



## **2. THEORETICAL ASPECTS**

### **2.1 Mobile Business**

According to a 2015 study by UNICEF, 91 percent of citizens in the Republic of Serbia own a mobile phone (Попадић & Кузмановић, 2016). Nine years have passed since that study, and today it is impossible to imagine a day without a mobile phone, with the number approaching 100 percent and an increasing number of people becoming dependent on their phones. These percentages highlight the importance of mobile business in the 21st century and the rapid increase in the number of services that are performed via mobile devices or through applications. Applications that run on mobile devices are programs developed with the aim of enabling the execution of processes on the go, at any time, from any location (Radenković et al., 2015), (McLean et al., 2018). Each mobile application can be installed on a device by downloading from: 1) Google Play Store for Android device users; and 2) App Store for Apple device users. In a few clicks, a user can install an application on their phone and, with a few additional steps, perform a specific process, whether it's in commerce, banking, learning, entertainment, or other aspects of life (Radenković et al., 2015). The application of apps is diverse, making it a challenging task to categorize each application according to (Islam & Mazumder, 2010), the following categories are shown: 1) communication; 2) games and entertainment; 3) display and processing of multimedia content; 4) productivity; 5) education; and 6) service applications.

### **2.2 Designing User Interfaces and User Experience**

Before starting the application design process, it is important to understand the clear distinction between user interface design and user experience design. User experience design focuses on retaining users within the application and creating a positive experience during use. Accordingly, user experience focuses on the user, their needs, and problems when using the application (Milda Puspita & Apriyanti, 2023), (Indriana & Adzani, 2017). Without a user interface, there can be no user experience, thus, the concept of user interface design relates to the visual elements that the user sees on each screen, including their shape, text, colors, size, and more (Yanfi & Nusantara, 2023), (Blair-EarlyAdream & Zender, 2008). The combination of these two areas results in a final product that can be sold on the market.

The key characteristics of user interface design encompass activities that directly contribute to creating the visual and functional aspects of an application. To craft this part of the application, it is essential to define a color palette, select typography, and ultimately design high-precision screens that are attractive to users. On the other hand, user interface design involves researching the target group, where the focus is entirely on understanding their needs and behaviors. After conducting research and identifying user preferences, we create empathy maps and user journey maps, engage in ideation, and culminate the process with testing by test groups. These are all steps that precede the creation of an ideal application that ensures maximum user satisfaction.

Designing mobile applications is a complex task, but it can be made easier by examples of best practices based on principles defined by many designers over a long period of time and a vast amount of work experience. Just as there are rules in every job that must be followed for the job to be successfully completed, so in designing mobile application interfaces, it is necessary to adhere to eight principles in order to achieve the desired appearance of the application (Reid, 2021), (Norman, n.d.): 1) Alignment and Balance - allows for a harmonious and structured display of elements on the screen; 2) Contrast - Contributes to highlighting important information and elements, as well as improving readability through the use of different shapes, colors, and sizes; 3) Empathy - encourages a user-centered approach, focusing on the user's needs; 4) Repetition - contributes to the cohesion of all elements on an individual screen; 5) Proportion - enables clear reasoning about elements in the design relative to their size; 6) Movement - contributes to interactivity and enhances user enjoyment while using the application; and 7) White space - contributes to the readability and clarity of the screen.

## **3. METHODOLOGY**

A widely used methodology for creating user interfaces is the Design Thinking method, which places its primary focus on the user and their needs (Suci et al., 2021). According to (Darmawan et al., n.d.; Jevtić & Dekić, 2020) this method is implemented through five very clear steps, which are shown in Figure 1.





**Figure 1.** Design Thinking Methodology Steps

- **Empathize**

Empathy represents the first step in which all focus is based on understanding and analyzing the user's needs. By conducting research through surveys, relevant data can be collected and used to identify the feelings and problems users encounter when using similar applications. This step enables the creation of a user empathy map.

- **Define**

Based on the previous step and the data collected about the user, the problems that the application aims to solve and the goals it seeks to achieve are defined. The defining phase results in the creation of a user persona, a representation of the typical application user, complete with goals, problems, and demographic characteristics.

- **Ideate**

The third step of this method involves identifying various ideas to solve the problems defined in the previous steps. Brainstorming is the most popular method for generating a large number of ideas. As a result of this phase, clear ideas and effective solutions are obtained, which can be illustrated through a user journey map (user flow diagram) showing the clear steps of user movement through the application.

- **Prototype**

In this phase, it is necessary to create low-fidelity wireframes, which are sketches of the application screens. These sketches provide a simple display of screens as placeholders for pages' elements. Tools like Figma and Adobe XD can connect all screens into a meaningful prototype. Only after evaluating the low-fidelity wireframes does the process move to the final high-fidelity screens. This phase resulted in a prototype for the application.

- **Test**

The final phase of the method involves testing all previously created screens. We identify application flaws based on user feedback. This phase yields information that further iterative processes use to enhance the user interface and experience.

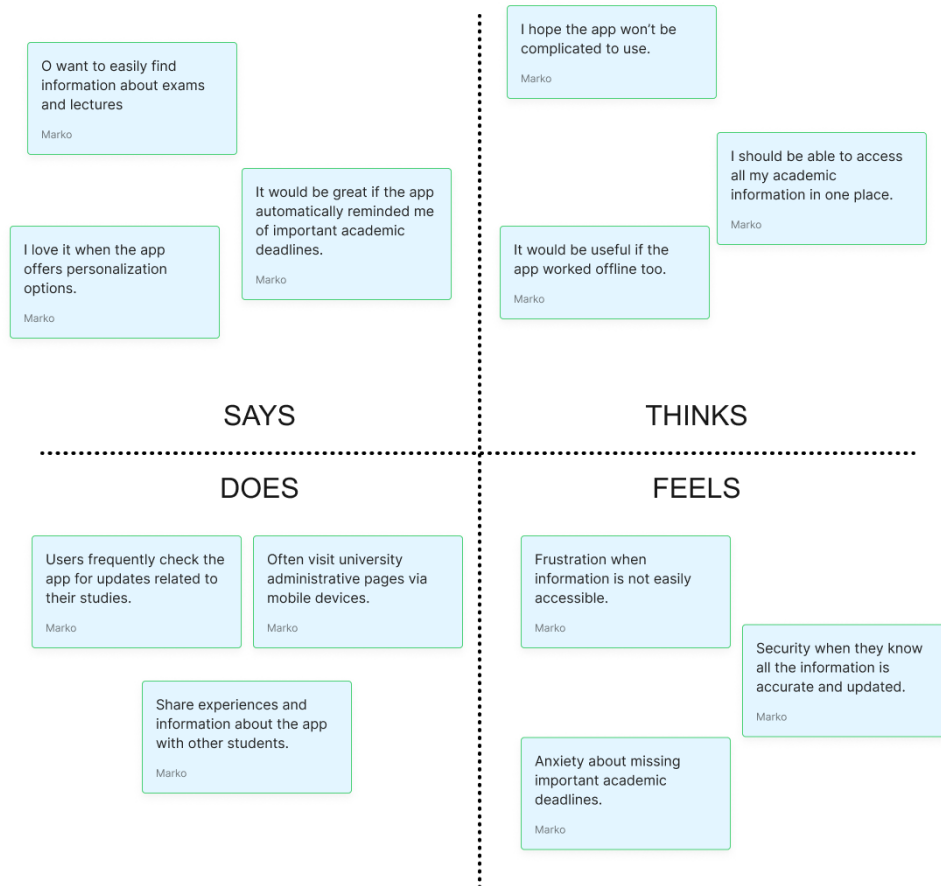
## 4. IMPLEMENTATION

By identifying the need to improve the system through which students access important information and manage their academic studies, an opportunity was recognized to develop a mobile application designed to meet all students' needs and solve their problems. The application gives them a better experience during their studies and allows them to apply and integrate with all university systems. The main goal is to increase the efficiency of managing student obligations by providing the opportunity for timely information and proactive management of responsibilities such as midterm exams and final exams.

The text below details the development of the mobile application through the five phases of the design thinking methodology. The entire process culminated in the development of a mobile application prototype, which prioritizes ease of use and significantly enhances the user experience by reducing information search time.

## 4.1 Empathize

Based on personal study experiences, the experiences of coworkers, and overall study satisfaction, we have discovered the essential components for constructing an empathy map. Figure 2 displays the map partitioned into four quadrants.

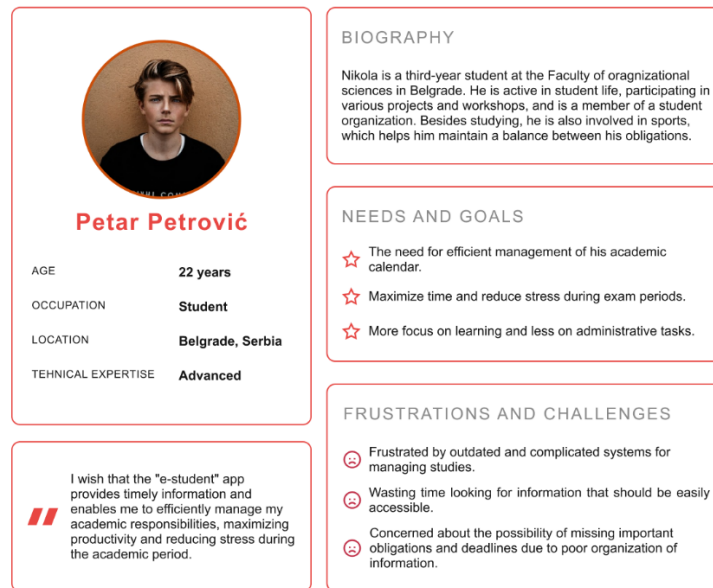


**Figure 2.** Empathy map based on student experience

Figure 2 displays four different groups that describe the user's experience of the studying process, providing an in-depth explanation of their opinions, activities, and feelings. From the analysis of the user's preferences in the first quadrant, it is noticeable that they have an increased tendency towards efficient information finding, a need for periodic reminders of deadlines, and a need for customization options within the application. The second quadrant represents the user's opinions, indicating a preference for an easy-to-use application that provides all information in a unified interface. The third quadrant relates to the user's actions, namely their frequent usage of a mobile device to access the website. They actively seek out new information and subsequently share it with their colleagues. The fourth quadrant depicts the user's emotional state when studying, highlighting their worry when faced with difficulties in finding knowledge, as well as their need for assurance and prompt updates regarding deadlines.

## 4.2 Define

A user persona, representing the typical user of the student application, has been developed based on the identified feelings and needs. Figure 3 displays the visual representation of the typical user, highlighting the key characteristics like demographic information, biography, needs and goals, frustrations, and challenges that identify them.

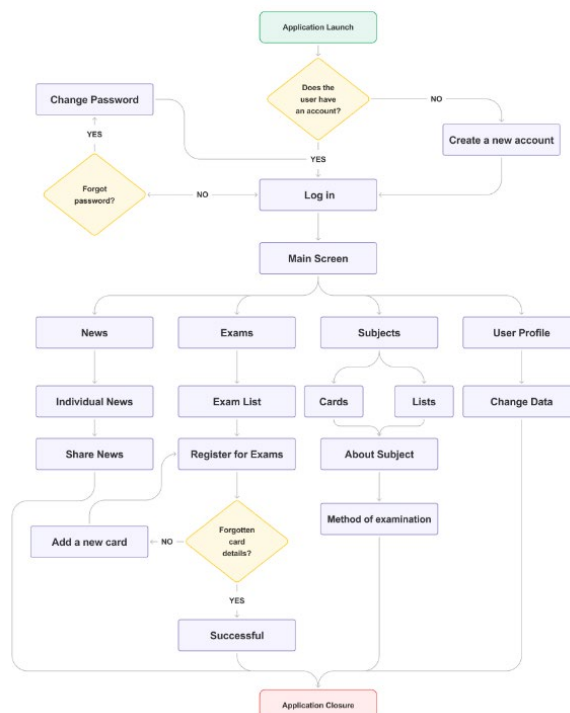


**Figure 3.** User persona - typical user

During the definition phase, the application's target user was identified as Petar Petrović, a twenty-two-year-old student from Belgrade who is dedicated to his academic progress at the Faculty of Organizational Sciences. His active involvement in student activities and initiatives shows his dedication and enthusiasm for collaboration. Petar, who has significant technological skills, prefers easy user interfaces that allow him to effortlessly use mobile applications in his daily life. He strongly desires effective administration of his academic responsibilities, aims to minimize stress during exam periods, and endeavors to maximize the time dedicated to studying. Petar encounters challenges stemming from antiquated educational systems and frequently wastes time seeking fundamental information, exacerbating his worry about meeting academic deadlines. He aims to discover an application that consolidates credible information and helps manage academic responsibilities, ultimately leading to enhanced academic achievement and contentment.

### 4.3 Ideate

Based on the previous two phases, a user journey map through the application, or user flow diagram, has been created. Figure 4 displays the "route" a user takes while using the application, along with all available alternatives.



**Figure 4.** User flow

After evaluating the user flow diagram, which outlines each possible step a user may encounter, the next phase of application development involves designing the user interface for the mobile application.

#### 4.4 Prototype

Using the empathy map and user persona as a base, a visual identity has been created for a mobile application named "e-student" which targets students. The application's logo, the specified color scheme, and the chosen typography are all part of the identity.

A minimalist logo has been designed that symbolically depicts a "framed student," representing the community and a significant stage in the lives of young individuals. The logo's pictogram, featuring an elevated hand, symbolizes the qualities of drive, tenacity, and a sense of community affiliation. The selected shade of blue for the circular border surrounding the figure symbolizes stability, trust, wisdom, and knowledge, all of which are crucial for achieving scholastic achievement and growth. The application uses the Lato typeface due to its extensive versatility and effortless legibility. Every headline and paragraph establishes distinct dimensions, ensuring a well-defined hierarchy and structure for the text. Lato is highly effective because of its versatility. It can be used in a wide range of circumstances, from small text sizes to enormous headlines, making it an excellent choice for creating a lively and professional appearance for the application.

The chosen color palette embodies the visual representation of the Faculty of Organizational Sciences, with its subjects serving as illustrative examples throughout the application. The application primarily features various blue colors, with the intention of fostering a sense of security during use. Figure 5 displays the elements of the visual identity.



**Figure 5.** Logo, colors, and font

After considering the previous phases and designing the application's identity, the design for all screens has been completed. The user flow diagram illustrates that the process begins by launching the application. This is followed by the display of a sign-in screen where the user is required to input their email and password. If the user has not previously established an account, there is an opportunity to creating a new one. If a user forgets their password, they have the option to reset it through email, which will then grant them access to the application. Figure 6 illustrates the basic screens of the designed application.

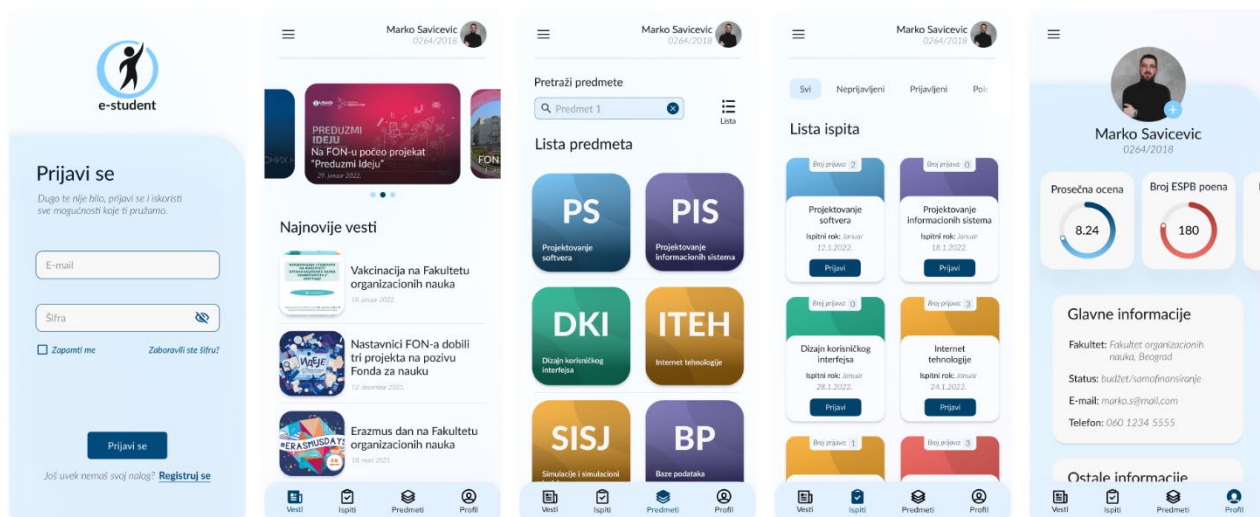


Figure 6. Essential screens

After successful login, the user will be taken to the homepage, where they will be provided with the most important and latest information from the faculty. The news articles are organized chronologically based on their publication date, and each article can be read in every detail. Every news item includes a sharing feature, allowing users to easily share the most recent information with their contacts, including the ability to share across various platforms. The user can view a summary of exams, which are organized into different categories: all, unregistered, registered, passed, and failed. The exams are visually represented by cards of different colors that signify association with a specific department. The exam card displays the following information: the current number of exam registrations, the subject's name, the exam date, and an option to register for the exam.

Figure 7 displays screens that represent the exam registration process. If the number of a student's applications for an exam is zero, the student has the option to register without paying the registration fee. In this case, the data entry fields are disabled. Additionally, there is an option to add a new payment card, after which the student can choose from which account they wish to register for the exam. The user's account is visually represented in the form of payment cards.

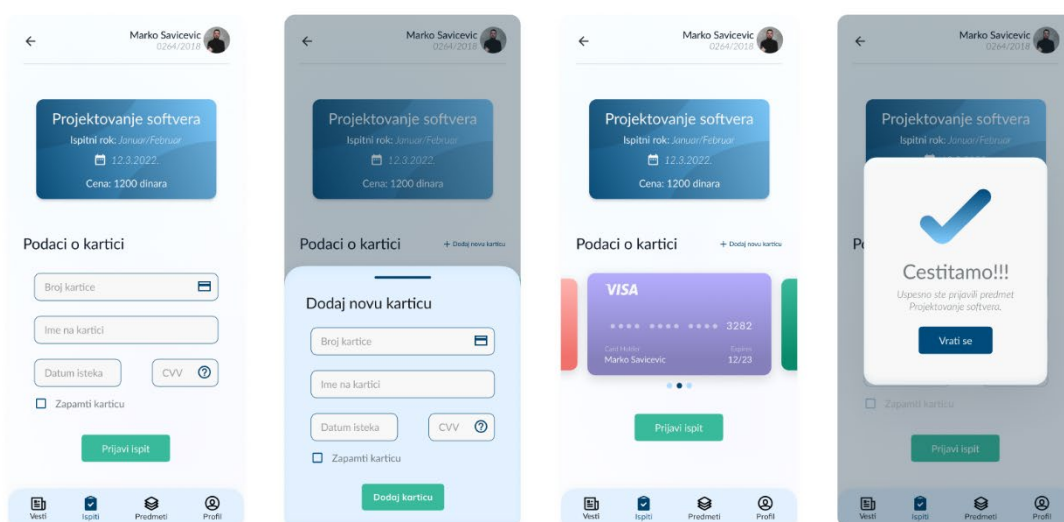


Figure 7. Exam registration process

Users see a list of courses in the form of cards in the course display section of the app. There is an option to change the display of courses to a list view, as well as a search field for faster course finding. Selecting a specific course opens a detailed view with information about the course, department, number of ECTS points, semester, course website, and contacts for professors and assistants. The selected course also displays a description and the examination method. The user's profile displays basic personal information and study statistics in the form of graphs, providing the user with better insight into essential information. In addition,

options are available for changing personal data and profile settings. A prototype of the entire application has been created in Figma, which allows for the simulation of the app's use and can serve in the next phase of testing.

#### **4.5 Test**

The final step in the design thinking method is testing, which ensures that the application meets the needs of the end-user. Testing is conducted through interactive cycles, leading to continuous improvements and changes in the application. Some of the well-known tests that can be applied include heuristic evaluation and cognitive walkthrough (Jevtić & Dekić, 2020), which require more engagement and time. By applying testing methods, optimization of the user experience is enabled; thus, this phase is planned after validating the presented solution in the next steps of research.

### **5. CONCLUSION**

This paper presents the process of creating a user interface for a mobile application for students using the Design Thinking method. The main goal was to illustrate the principles of design and the entire process of designing a mobile application. Another goal is to demonstrate the importance of understanding users and taking a multidisciplinary approach to the work.

The designed application aims to improve students' information access and enhance their satisfaction during their studies. With its appearance and new functionalities, the application will allow the institution that develops it to keep up with new technologies and to focus more on student satisfaction. The application is designed for mobile devices, which is a key feature considering that more than 90% of users today access information via mobile devices.

The paper explains the process of developing the mobile application using the Design Thinking methodology of iterative development. The principles of designing mobile applications are displayed, and a relevant depiction is given for each step of the method. Key differences between designing user interfaces and designing user experiences are stated.

In the practical part of the paper, the visual identity is shown, consisting of a logo, color palette, and typography that runs throughout the application. For the purposes of creating the interface, an analysis of the typical user was conducted, and a user flow diagram, or a map of user movements through the application, was created. After all analyses, the user interface and all screens of the application where the user can find themselves during use were displayed. Finally, a prototype that represents a simulation of using the application, created in Figma, is shown.

Future directions of development and research will focus on revising and evaluating the created screens of the application, all with the aim of improving and removing deficiencies identified based on the last step of the methodology (Test). In the future, the development of a dark theme for the application is also planned. After evaluation and testing, an agreement with interested parties and the programming of the application are planned.

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# DEVELOPMENT OF A HYBRID APP BASED ON A REST API

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**Abstract:** *This paper examines the theoretical principles and applications of Application Programming Interfaces (APIs), and particularly, the REST (Representational State Transfer) architectural style. Striving to connect diverse software systems across the internet, API developers have worked on creating unified standards and best practices. REST has emerged as the dominant paradigm for API design thanks to its simplicity, scalability, and robust security features. Furthermore, guidelines for providing well-documented and designed APIs and the appropriate status codes and representation formats are examined. Finally, to illustrate these principles with a practical application, a public REST API from a massive multiplayer online game "World of Warcraft" is used as an example. Seamlessly integrated with an Ionic and Angular hybrid application, it helps players track ever-changing game data whenever they want, both from their PCs and phones.*

**Keywords:** *Application Programming Interface (API), REST, Angular, API architecture, web development*

## 1. INTRODUCTION

The modern digital world is characterized by a wide array of applications and data of all kinds. Today, many software systems require interoperability, the ability to communicate and connect with other programs. It's easy to imagine the need for the data required for the operation not being available within one application's own environment, but instead, it being necessary to connect to a completely different program. Additionally, an application may need to perform an operation on its data that is already implemented in another program. These programs don't necessarily have any technical connections to each other.

The theoretical principles are described in Section 2, with Subsection 2.1 explaining the definition of API and its use in web development, and Subsection 2.2 delving into REST as an architectural style. Section 3 documents the development of a companion app for the game World of Warcraft, with Subsection 3.1 detailing system design and Subsection 3.2 showcasing an implementation in Angular and Ionic frameworks. Section 4 concludes the paper and outlines future development directions for the application.

## 2. THEORETICAL BACKGROUND

### 2.1. API Architecture

An Application Programming Interface, or API, represents a modern solution to the problem of interoperability. Broadly speaking, an API should be an abstraction of a specific problem and a specification of how clients interact with software systems that solve that problem (Reddy, 2011). The term "application" in this context refers to a computer program. The term "interface" is included because of the broader familiarity with the concept of a "user interface" which represents a way of using an application intuitive to the user, that is, a human. Similarly, the term "programming" indicates that the interface will be used by a program. A server application is said to "expose" an API to other applications. Client applications are said to "call" the API.

In web development, APIs are typically accessed through endpoints. These are usually URLs that serve as access points through which clients communicate with the application (Murphy, 2024). They should be implemented in a way that is intuitive to understand. Efficient API management is essential for companies to open their assets in a secure and scalable way (De, 2017). API endpoints are usually listed in the API specification. A good specification should include a detailed list of all endpoints, with examples of how to use them properly, as well as error cases. Today, there are a few dominant standards for writing API specifications, the most well-known being *OpenAPI* (formerly known as *Swagger*), *API Blueprint*, and *RAML (RESTful API Modeling Language)*. Additionally, it's possible to develop APIs in two commonly accepted ways, which some authors refer to as "code-first" and "contract-first." The first approach dictates writing the API documentation



only after writing and testing the code, while the latter prioritizes the specification, which the programmer adheres to when writing the code (Kamili, 2023). Beyond just looking at interoperability, scalability is increasingly becoming a problem that API technologies need to address in today's world. The ever-increasing number of internet users itself poses a challenge, but more importantly, the proportional increase of users with mobile devices, which have less processing power than traditional computers, has caused a shift of functionality from the client to the server and further burdened existing API solutions (Yegoshyna et al., 2019).

## 2.2. REST API

In his doctoral dissertation at UC Irvine, Roy Fielding defined the REST (Representational State Transfer) architecture as "the way the modern web should function" (Fielding, 2000). Today, REST represents the dominant architectural style for API development. Fielding popularized and formalized certain ideas and concepts, and his dissertation attracted significant attention from the scientific community at the time. It's important to note that REST is not a protocol or standard but rather an architectural style. For an API to be called a "REST API," it only needs to satisfy prescribed principles and constraints (Gupta, 2023). Hypothetically, this means that any protocol could implement these requirements, but HTTP is used in almost all cases. The point of a REST API is to provide access to standard database operations in an intuitive way. Domain objects of a specific system, when designed according to REST architecture, are called "resources," and the state of a resource at any given time is referred to as the "resource representation" (Massé, 2011). This representation usually reaches the client in the shape of some well-known data transmission format. Fielding chose to view software design not as a traditional architecture starting from a blank slate and gradually building up to the desired system, but rather as introducing constraints on already existing streams (Fielding, 2000). REST is a well-documented and widely-used paradigm today, as it is noted that many developers moved on to it, rather than using the earlier SOAP and RPC architectures (Neumann et al., 2018). Table 1 explains the introduced constraints, which later became better known as the "principles" of REST.

**Table 1:** Constraints of REST (adapted from Fielding, 2000)

Constraint	Explanation
Client-server	Web is a system based on client-server architecture, so both of them could be coded in different programming languages.
Statelessness	A response to a specific request should be the same at any given moment.
Uniform interface	Everything that exists on the web is a resource, and the client receives a representation of the resource, along with descriptive messages. The API should ensure that the same data belongs to only one identifier (URI - Uniform Resource Identifier).
Caching	For efficiency, the server designates whether the data in the response is suitable for caching, usually through a mediator. If the mediator receives a request and has already requested the same resource from the server recently, it will send the cached response.
Layered system	The system should be designed so that it appears as a monolith to the client. When interacting with the client, the client should not be able to know if its interacting to the server itself or through a proxy server.
Code-on-demand	Along with static resources, responses can sometimes contain pieces of executable code, such as user scripts in JavaScript, or applets in Java.

Most of the publicly available "REST APIs" aren't fully compliant to these principles (Neumann et al., 2018). To realize the statelessness principle, the object which reaches the client is actually just a representation of the resource. To make it readable for the program that requests it, it should be adapted to one of the well-known representation formats. *JSON (JavaScript Object Notation)* is one format for transmitting data in modern REST APIs and beyond, gaining popularity and becoming the most common format of transferring data on the web (Pezoa et al., 2016). An older format that is still widely used is *XML (eXtensible Markup Language)*, which is also readable for both humans and computers. The majority of APIs work with one of these two formats, but there's also *YAML (YAML Ain't A Markup Language)*, a language similar to *JSON* but without quotes, brackets, and commas, designed to be more readable to humans. There's also *BSON (Binary JSON)* and other binary formats suitable for applications where responsiveness is critical (Kumre, 2022). Further REST API principles today include security. "Stateful REST API fuzzing" is a method to thoroughly test these services by automatically generating a sequence of requests to simulate real situations (Atlidakis et al., 2020).

A well-designed REST API should use specific status codes for specific results of executing client requests. Studies have showed that APIs which are poorly-documented lead to errors because of the programmer's unfamiliarity with them (Zhong & Su, 2013). Also, comparative analysis of REST API style guidelines published by different companies have also shown inconsistency on what is considered "intuitive" (Murphy et al, 2017). Following standards for developing and describing APIs also facilitate testing and unit testing because they depend on document description (Ehsan et al., 2022). Rules for designing REST APIs require that each method respects certain constraints. Rules for these methods were outlined in by Massé. For example, the API should cover all methods, not just GET and POST as often happens. The PUT method should be used to update a mutable resource or insert a stored resource, but POST should be used to execute controllers and create new resources within a collection (Massé, 2011). Reliably determining the essence of a response message is why having a comprehensive dictionary of status codes is crucial. For efficiency and readability of responses, both for programmers and computers, the REST API architecture uses status codes as part of the HTTP response. HTTP defines 40 status codes divided into five categories (Berners-Lee et al., 1999).

### 3. DEVELOPMENT OF AN APPLICATION BASED ON REST API ARCHITECTURE

This paper examines and makes use of the REST API provided by Blizzard Entertainment for their game World of Warcraft (WoW) on Blizzard Developer Portal. WoW is a 20 year old game at the time of writing this paper, but it continues to thrive with regular updates and expansions. Functioning on a subscription-based model along with selling expansion packs approximately every two years, WoW is estimated to be one of the highest-grossing games in history, becoming the best-selling game on its release (Nardi & Harris, 2006). The task of the example application presented in this paper is to provide accurate data for the PvE (Player vs Environment) aspect of the game. Tackling challenges within the game environment, the PvE players strive to work together and use their combined mechanical and communication skills and synergies to overcome non-player enemies. The idea of the application is to provide players with up accurate information about certain details of in-game content, for both casual and competitive playstyles, while making use of the Blizzard Developer Portal REST API for WoW. In order to communicate with this API, the application was registered on the portal and a client secret was provided to facilitate OAuth 2.0 protocol authorization.

#### 3.1. SYSTEM DESIGN

The application presented in this paper covers the following five use cases:

1. Displaying the WoW Token Price: WoW introduced a token system allowing players to swap real money for in-game gold or subscription time. As the in-game economy is live, token prices change weekly and vary by region. This application aims to exhibit the current token price.
2. Showing Current Dungeons and Affixes: Dungeons are the core team-based PvE content in WoW, demanding coordination and individual skill. The task here is to showcase available dungeons for the current week along with their affixes.
3. Displaying Guild Leaderboard: Guilds are player associations focusing on common goals, often tackling the game's most challenging content together, such as Mythic raids. The application should present a leaderboard of guilds, considering not only the top positions but also the entry into the top ranks.
4. Showing Mythic+ Group Leaderboard: The application needs to display the top groups, character names, their classes, and the level and time taken to complete dungeons for the current rotation. Character classes determine their role in the group.
5. Displaying Hall of Fame per Raid: A table should showcase guilds that have completed each raid in order, along with their region and faction affiliation.

When implementing APIs it is useful to have a documentation page that lists available routes, along with their successful calls and errors cases. For the purpose of demonstrating that, a Swagger page has been created for this application, following the OpenAPI 3.0.0 specification standard. Authorization has also been added (through OAuth 2.0) and is required for the Blizzard API to recognize the registered applications. Figure 1 showcases the page and the available routes.

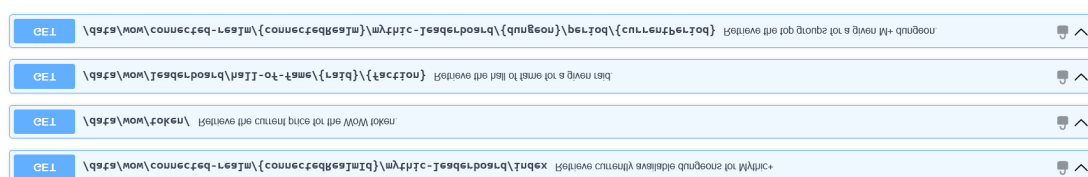
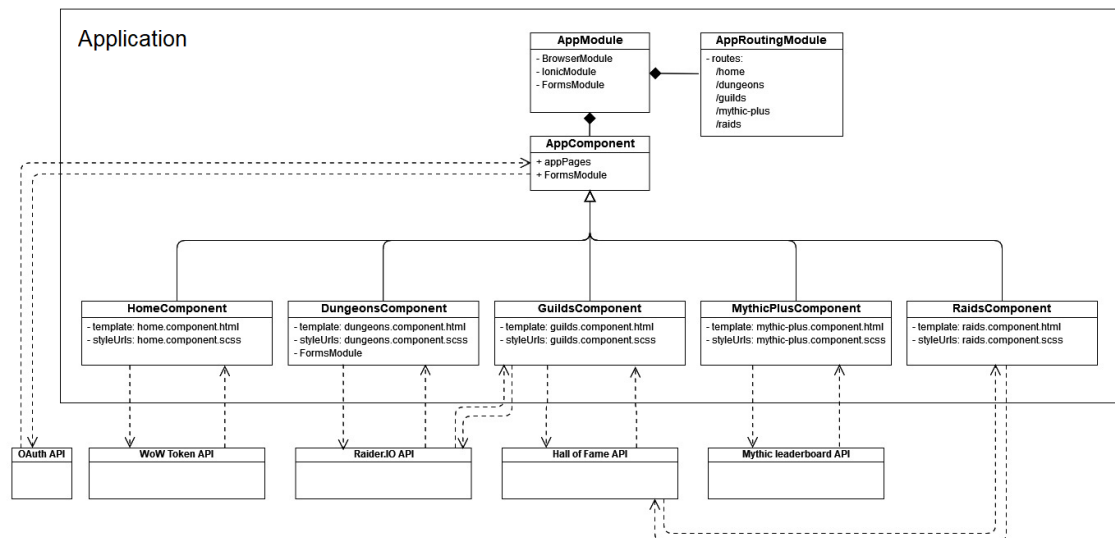


Figure 1 - Swagger documentation for the used routes of the API

## 3.2. IMPLEMENTATION

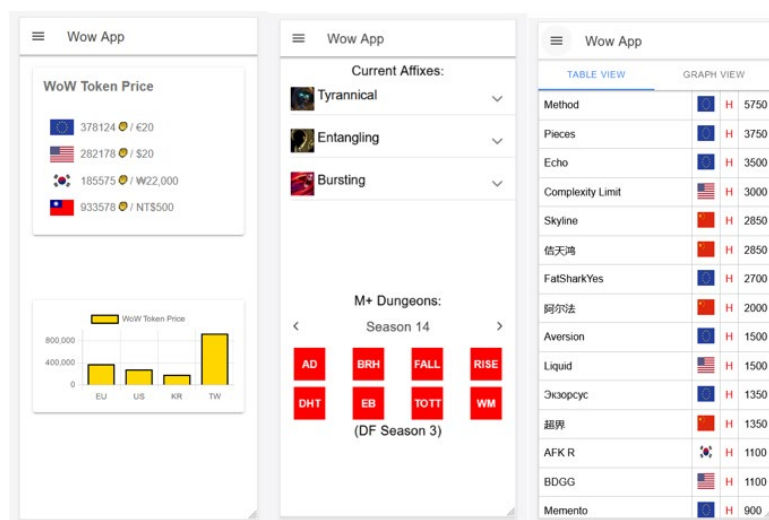
The implementation of this case study utilized Ionic and Angular, frameworks tailored for multi-platform development. Ionic offers extensive UI component libraries, facilitating the development of visually appealing hybrid applications for both Android and iOS (Chaudhary, 2018). Angular is also an open-source framework, for the TypeScript language. The component diagram of the Angular application can be seen on Figure 2.



**Figure 2 – System Architecture**

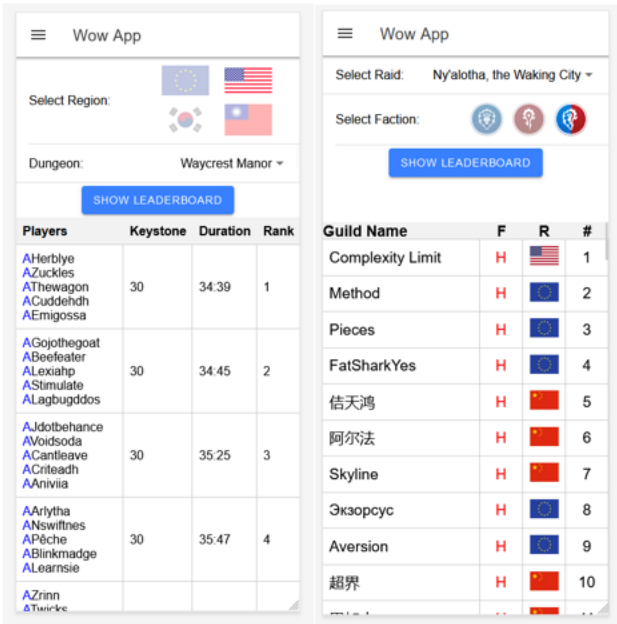
Angular follows the architectural pattern of Model-View-Controller, where components act as both Views and Controllers. The view role is fulfilled by HTML templates and the accompanying logic provided in the component's TypeScript files makes up the bulk of the controller functions. When a component is instantiated (rendered on screen), Angular creates an instance of that component's class. instantiation of components happens when the user selects an option from the navigation menu, activating one of the routes listed in the AppRoutingModule. This entire flow is enabled by the AppModule, which combines the routing module with the BrowserModule, to run this application in the browser and handle DOM manipulation directives, and the IonicModule, providing its UI components. The system communicates with Blizzard's Game Data APIs portal to get the primary sources of data for displays (Blizzard Entertainment, 2024). Additionally, it works with Raider.io, a community-run website, where information isn't available of the main site (Raider.IO, 2024).

Screen forms for use cases 3, 4 and 5 are shown in Figure 3. In Figure 3(a) a simple list of numbers and graphs displays the current WoW Token price. Figure 3(b) shows the current affixes and dungeons in the rotation. The screen form in Figure 3(c) shows a table view of the guild top list based on their calculated scores.



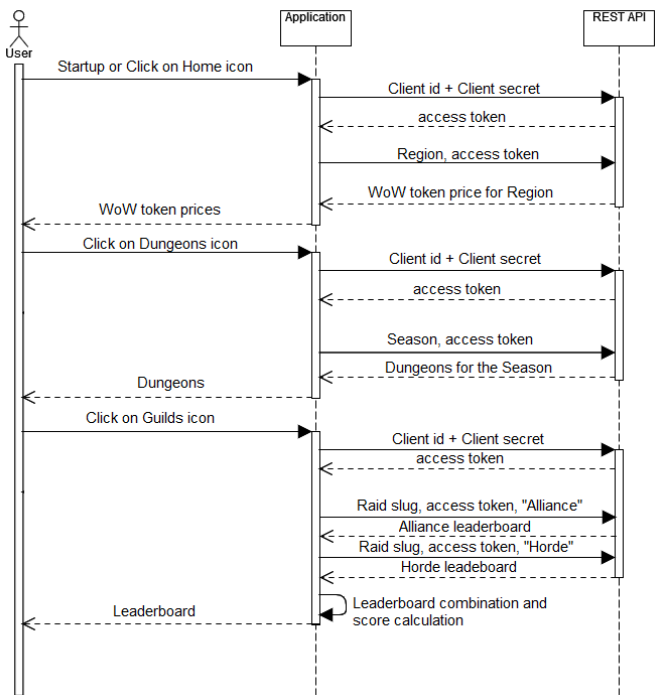
**Figure 3 – Screen forms displaying (from left to right) (a) the WoW token price, (b) dungeon and affixes, and (c) the guilds leaderboard**

Similarly, screen forms for use cases 4 and 5 are shown on Figure 4. As seen in Figure 4(a), the user is required to select a region and the dungeon for which they wish to retrieve the top list of dungeon groups. The table below the button lists the five members of each group, the keystone level and the time it took for the groups to complete it. In the screen form shown on Figure 4(b) the user selects the raid and the faction, with the option to select both factions available as well. The resulting table displays the guild names with their respective factions, regions and ranks.



**Figure 4** – Screen forms for the (a) top dungeon groups per region and (b) top raiding guilds

One typical use case execution, following the screen forms from Figure 3, is displayed on Figure 5. Client id and client secret are sent every time to ensure the Blizzard API of the user's authenticity, so they can track the data in cases of misuse or overuse. After that the application is allowed to communicate with the APIs it needs to access. In the case of the third use case, the application is required to calculate the score because of the different factions it retrieves through the APIs.



**Figure 5** – A sequence diagram of the communication of the application with the API

## 4. CONCLUSION

Application Programming Interfaces have helped connect the modern ecosystem of web technologies. Through expedient and reliable exchange of data between software systems, seamless integration and interoperability has been achieved. The example of the Blizzard Developer Portal and its REST API for World of Warcraft serves to illustrate the many advantages of this landmark architectural style. Even as modern technologies continue to develop, REST APIs will remain a cornerstone of collaboration and connectivity.

This paper endeavoured to explain the principles and illustrate the implementation of REST API in the case of enhancing the gaming experience. It outlined the essential constraints of REST and the importance of well-documented APIs. The example of a companion app for the game is explained, as well as how it communicates with the REST APIs, was explained in some detail, with provided architectural diagrams, screen forms and sequence diagrams. Use cases were outlined in the design phase, and implemented in Ionic and Angular.

Future directions for this paper could include building more use cases to cover other parts of the game, using the available APIs, such as the real time Auction House (the game's stock market), or classes and group compositions statistics for dungeons. These compositions could be calculated based on the compositions of the optimal groups, and recommended to the player to try out on their own. Improvements to the UI/UX aspect of the application could also be included, as well as adding integrating a database and its own REST API.

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# DEVELOPMENT OF A METAVERSE NFT FASHION MARKETPLACE

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**Abstract:** *The goal of this paper is the development of the Metaverse NFT fashion marketplace. To develop such a solution, it is necessary to create an appropriate NFT Marketplace, for which the following technologies can be used: Ethereum Blockchain, Solidity, Pinata, MetaMask, Hardhat and ReactJS. The contribution of the paper is to show the methodological procedure of developing such a marketplace and its integration with the Metaverse. The significance of the paper is to assist those involved in fashion design and new technologies in utilizing it as a model for their new creations.*

**Keywords:** *NFT, Metaverse, Blockchain, Fashion Industry*

## 1. INTRODUCTION

This paper outlines the methodology for developing an NFT marketplace specified for the fashion industry and seamlessly integrating it with the emerging concept of the Metaverse. The significance of the Metaverse and its role within the fashion industry is highlighted, emphasizing the pivotal role of the NFT marketplace in this context. Specifically, the paper aims to present the methodological process of creating an NFT marketplace and the technologies utilized for its development. Furthermore, it will demonstrate the integration of this marketplace with the Metaverse, showcasing its potential impact on the fashion industry.

Fashion's significance in the Metaverse is multifaceted: it serves as a vehicle for cultural expression and identity, fosters social interaction and community building, creates new market opportunities for brands, fuels innovation and creativity in design and technology and promotes accessibility and inclusivity. From virtual fashion shows to customizable avatars, fashion plays a central role in shaping the identity and economy of the Metaverse, making it a vital aspect of digital culture and innovation (Gonzalez, 2020).

The NFT marketplace facilitates the distribution of fashion NFTs to the Metaverse by providing a platform for buying, selling and trading these digital assets. Users can browse through a variety of fashion NFTs, ranging from virtual garments to accessories and choose to purchase those that align with their personal style preferences and virtual identities. Additionally, NFT marketplaces often incorporate features such as auctions, bidding and limited edition drops, adding an element of scarcity and exclusivity to the digital fashion ecosystem (Periyasami, S., & Periyasamy, A. P., 2022)

The goal of this paper is the development of a Metaverse NFT fashion marketplace, where the whole methodology will be presented. The technologies used for the development of the NFT marketplace are Ethereum Blockchain, Solidity, Pinata, MetaMask, Hardhat and ReactJS. Lastly, the integration of this NFT marketplace with the Metaverse will be showcased.

## 2. METHODOLOGY OF CREATING AN NFT MARKETPLACE FOR THE FASHION INDUSTRY

This part outlines all the steps needed to make an NFT marketplace for the fashion industry, including project setup, smart contract development and frontend implementation, covering views such as Homepage, Create Item, Listed Items and Purchased Items. Prerequisites and steps needed to implement this methodology are:

1. Creating 3D models that will represent the NFTs
2. Development of the NFT Marketplace
3. Minting the NFTs
4. Connection to the MetaMask wallet
5. Integration with the Metaverse

### 2.1. Setting Up the Project

The project setup involves configuring Node.js (version 17 or higher), Hardhat (^2.8.4) and MetaMask browser extension for Ethereum development. These tools are essential for writing, testing and deploying smart contracts.

## 2.2. Smart Contract Development

Smart contracts are ERC721-compliant and written in Solidity. There are two smart contracts: NFT and Marketplace. Pictures 1 and 2 show parts of the NFT and Marketplace smart contracts respectively. NFT contract enables the minting of unique fashion NFTs (Dapp University, 2022).

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.4;
import "@openzeppelin/contracts/token/ERC721/extensions/ERC721URIStorage.sol";

contract NFT is ERC721URIStorage {
    uint public tokenCount;

    constructor() ERC721("DApp NFT", "DAPP") {}

    function mint(string memory _tokenURI) external returns (uint) {
        tokenCount++;
        _safeMint(msg.sender, tokenCount);
        _setTokenURI(tokenCount, _tokenURI);

        return (tokenCount);
    }
}
```

Picture 1. NFT Smart Contract

A marketplace contract facilitates the buying and selling of NFTs. It has functions for making an item and purchasing it.

```
function makeItem(
    IERC721 _nft,
    uint _tokenId,
    uint _price
) external nonReentrant {
    require(_price > 0, "Price must be greater than zero");
    // increment itemCount
    itemCount++;

    // transfer nft
    _nft.transferFrom(msg.sender, address(this), _tokenId);

    // add new item to items mapping
    items[itemCount] = Item(
        itemCount,
        _nft,
        _tokenId,
        _price,
        payable(msg.sender),
        false
    );

    // emit Offered event
    emit Offered(itemCount, address(_nft), _tokenId, _price, msg.sender);
}

function purchaseItem(uint _itemId) external payable nonReentrant {
    uint _totalPrice = getTotalPrice(_itemId);
    Item storage item = items[_itemId];
    require(_itemId > 0 && _itemId <= itemCount, "item doesn't exist");
    require(
        msg.value >= _totalPrice,
        "not enough ether to cover item price and market fee"
    );
    require(item.sold, "item is already sold");

    // pay seller and feeAccount
    item.seller.transfer(item.price);
    feeAccount.transfer(_totalPrice - item.price);

    // update item to sold
    item.sold = true;

    // transfer nft to buyer
    item.nft.transferFrom(address(this), msg.sender, item.tokenId);

    //emit bought event
    emit Bought(
        _itemId,
        address(item.nft),
        item.tokenId,
        item.price,
        item.seller,
        msg.sender
    );
}
```

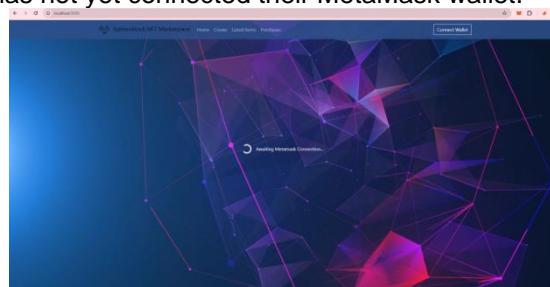
Picture 2. Marketplace Smart Contract

Then an important part is the deploy.js script for the deployment of the mentioned smart contracts onto the Ethereum blockchain. This script automates the deployment process and saves contract addresses and ABIs for front-end integration.

It is also necessary to have a test script (NFTMarketplace.test.js) to test the smart contracts before the deployment.

## 2.3. Frontend Implementation

The front end consists of several views, including the Homepage, Create Item Page, Listed Items Page and Purchased Items Page. These views allow users to browse, purchase, mint and manage NFTs seamlessly. In order for the user to use the app, they need to first connect their MetaMask wallet. In picture 3, we can see the initial view when the user has not yet connected their MetaMask wallet.

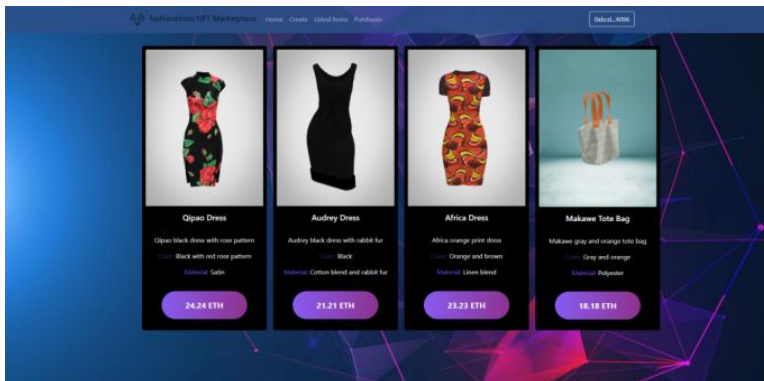


Picture 3. Initial View

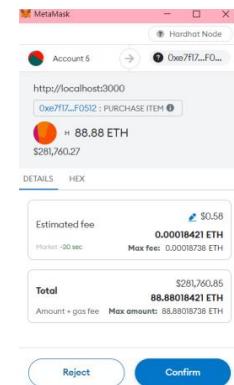
**Homepage:** The Homepage serves as the central hub for users, displaying all listed NFTs from various creators. As shown in Picture 4, users can browse through the collection and purchase NFTs by clicking on



the "BUY" buttons associated with each NFT card. NFT card also includes details such as name, description, colour, material and price of the particular NFT. Users get to buy an NFT on the Homepage by clicking on a BUY button on a card that represents the NFT. Then MetaMask wallet is open and the user is asked to confirm the PURCHASE ITEM transaction, as shown in Picture 5.

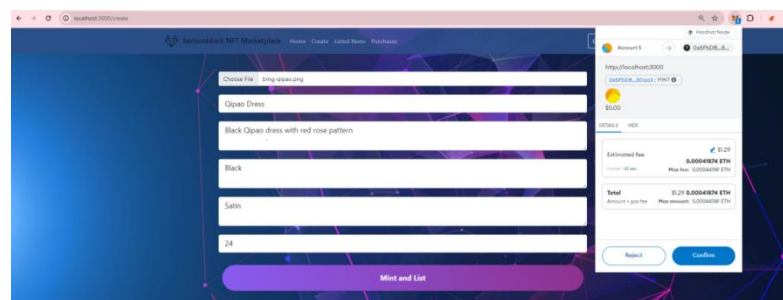


Picture 4. NFT Marketplace - Homepage



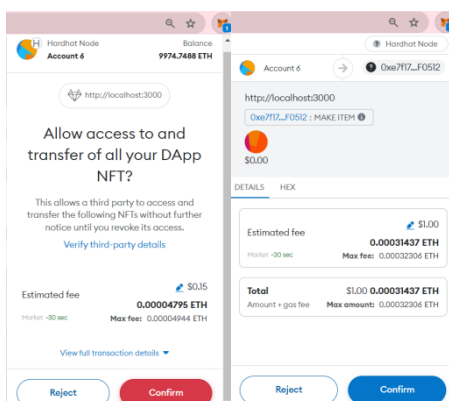
Picture 5. Purchase Item Transaction

**Create Item Page:** The Create page view allows users to mint and list their NFTs for sale. Here, users are guided through the process of minting an NFT and listing it on the marketplace. They must complete steps such as minting the NFT, approving the DApp with no spending limit and finally listing the item for sale. As shown in Picture 6, the user needs to upload an image or the animation that represents the NFT, insert name, description, colour, material and price. There we can also see the MetaMask pop-up with the details for the MINT transaction.

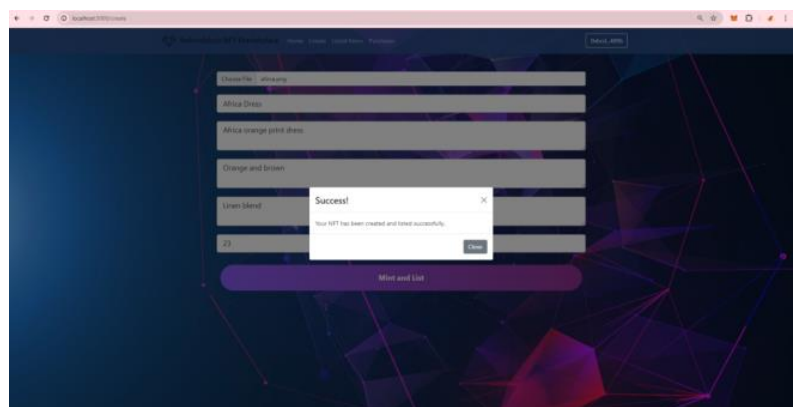


Picture 6. NFT Marketplace - Create Page 1/3

In Picture 7 we see the other two transaction details (Approve DAPP with no spending limit and MAKE ITEM). Picture 8 is the view when the transaction is successful and the NFT is minted and listed. Additionally, to further enhance the NFT Marketplace experience an auction functionality could also be added.



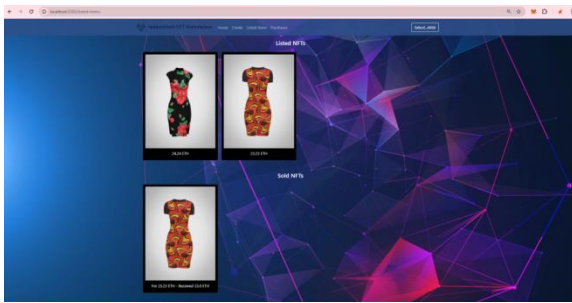
Picture 7. NFT Marketplace - Create Page 2/3



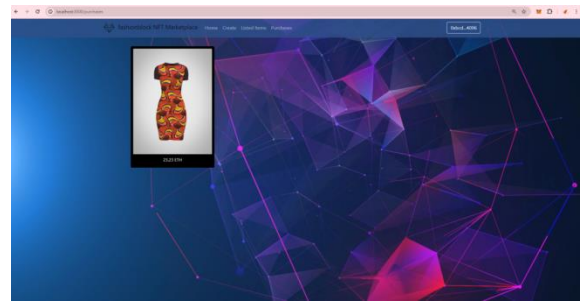
Picture 8. NFT Marketplace - Create Page 3/3

**Listed Items Page:** Provides users with a comprehensive list of NFTs they have listed for sale, as well as the ones they have sold (Picture 9). Users can manage their listed items and track their sales from this view. **Purchased Items Page:** Users can access a list of NFTs they have purchased (Picture 10). This view enables users to track their owned NFTs and view their purchase history.





**Picture 9. Listed Items Page**



**Picture 10. Purchased Items Page**

### **3. INTEGRATION WITH THE METAVERSE**

The Metaverse is a fully digital environment where users have the opportunity to create their digital identities using 3D avatars that offer them opportunities for interaction and self-expression using deep learning techniques, providing the opportunity to shape different aspects of their identity. There are three relationships between an individual and their avatar, the first relationship is identification with the avatar, then the second relationship is independence between the individual and the avatar and the third last relationship is the avatar as a projection of the individual's ideal qualities. This kind of digital self-expression has the potential to profoundly affect the way individuals see and interact in the virtual world (Wu & Zhang, 2023). When we talk about 3D digital avatars in the world of fashion and fashion design they can be used for design visualisation, customisation and sizing, for marketing and virtual stores or virtual fashion shows. Within 3D garment modelling software, fashion designers can use standard avatars to simulate and modify garment designs in real time, enabling a faster and more accurate process of creating collections and designs. Through virtual avatars in 3D clothing analysis that change and shape according to needs, quick and precise analysis of fit and style is enabled, facilitating the design process and development of clothing. A simplified collection creation process and faster design reduce the need for physical samples (MEDIA, 2021). The integration of the NFT marketplace with the Metaverse opens up exciting possibilities for immersive experiences and enhanced value for NFT owners. By leveraging platforms such as Voxels, users can showcase their NFT collections in virtual environments, interact with other users and participate in virtual events and exhibitions.

#### **3.1. Benefits of Integration**

Fashion brands face more and more the fact that it is difficult to maintain a relationship with customers as an object of sale and prolong their survival in a loyalty program, prepared if they plan to expand their business to the Metaverse. As the Metaverse involves an interactive experience between users, ads and brands become part of that experience, which can lead to deep and lasting relationships with their customers. Being able to collect data on user behaviour and preferences, fashion brands can better adapt their marketing strategies (Rathore, 2018). Fashion design in the Metaverse brings numerous benefits to fashion designers, such as creative freedom, personalization, interaction and the possibility of connecting the virtual and physical world. That is, fashion designers can use virtual models and creations as inspiration for manual or industrial creation of physical pieces. Precisely, this transformation allows the virtual fashion design to be transferred to the real world, thus achieving a correlation between the digital and the material and opening the door for innovation and experimentation (Darbinyan, 2022).

The Metaverse also affects the way and experience of shopping. By analyzing the data collected in the virtual environment, brands can tailor their recommendations, offers and experiences to best suit the needs of each consumer. Based on this, a personalized shopping experience is created, resulting in the fashion brand understanding and valuing each customer. This approach leads to greater customer loyalty (Ismail, 2023). Shopping in the Metaverse opens up new possibilities for an experience that is not limited by space and time. Customers can explore virtual stores, try on clothes in 3D space, i.e. in virtual cabins and have a 360-degree view of the appearance of the clothes (Darbinyan, 2022).

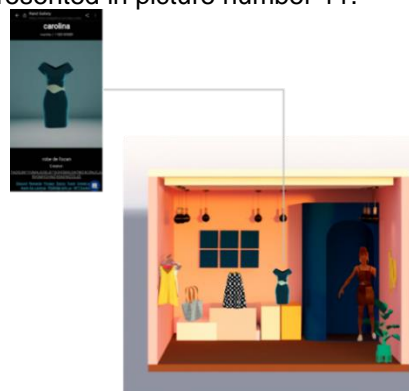
The market for fashion clothing in the Metaverse is still small, but it has attracted the attention of major fashion brands, which indicates that there is room for further realization and improvement in terms of fashion non-fungible tokens based on the Metaverse and the Metaverse itself. The question arises, what advantages do fashion brands have from entering the Metaverse. Reasons why entering the Metaverse can prove to be a very successful business strategy for fashion brands. Massive margins creating digital collections, allow fashion brands to save time and costs when sourcing raw materials, finding factories, skilled workers, stocking and the like, secondary market profits, no inventory or oversupply means that digital environments allow companies to keep their products in virtual form, meaning that physical versions do not have to be

produced as long as there is no order, then engagement and accessibility (Breia, 2022). Integrating the NFT marketplace with the Metaverse offers also virtual exhibitions where artists and creators can host virtual exhibitions and showcases, reaching a global audience without the limitations of physical location. In social interaction, users can socialize with other collectors, attend live events and participate in community-driven activities, creating a dynamic and immersive ecosystem. The brand collaboration includes that fashion brands can collaborate with virtual influencers and creators to promote their NFT collections, tapping into new audiences and markets within the Metaverse.

Among other things, there are several significant challenges. The technological complexity required by the Metaverse can lead to a very poor user experience. Also, the technology is still young, so it requires more time to develop in order to offer perfect services to a large user base. The three-dimensional representation of a million clothing items and their verisimilitude requires significant effort and investment. There are also problems with data security and privacy, the emergence of black markets or inadequate sellers. These are just some of the problems facing the shopping experience in the Metaverse (Bourlakis & Papagiannidis, 2008).

### 3.2. Potential Applications in the Metaverse

It is clear that the basic concept of the Metaverse is based on digital twins, i.e. physical objects from the real world are presented as virtual duplicates in the Metaverse to allow users to experience the movement and behaviour of the original objects. Users will be able to experience the real product in a digital format and be informed about the details (Jeong, Yi, & Kim, 2022). Based on this, fashion brands should approach the creation of business models from that perspective. From creating their games to fashion collections in the Metaverse, fashion brands are establishing a new kind of communication with consumers, which is supported by a digital experience. In this way, they expand the creative possibility and create a unique product, achieving greater loyalty and a more permanent relationship with customers (Mantilla, 2022). Before the actual creation of business models and as the idea of the work is to present a collection of virtual fashion designs as non-fungible tokens in the Metaverse, it is necessary to mint a non-fungible token. An example of the idea of a showroom or store is presented in picture number 11.



Picture 11. An example of an exhibition space idea

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Customers Fashion designer Platforms for selling NFTs Companies that sell the video games Decentraland	Creation of exhibition space Display of the collection in the exhibition space Metaverse store Safety and security Processing the entire buying and selling process	Innovations in the virtual fashion experience Encouraging creative collaborations Connecting with fashion designers and enthusiasts around the world Sustainability education Interactive elements for visitors	The social network Personalization of avatars and costumes for video games Decentraland Fashion Week	NFT collectors Video game players
	<b>Key Resources</b>  Technological infrastructure (servers, high-quality computers, AR, VR and etc.) Fashion collection Knowledge of the metaverse Financial capital Marketing and PR skills		<b>Channels</b>  NFT marketplaces Virtual stores Integration in video games Virtual events and fashion shows	
<b>Cost Structure</b>		<b>Revenue Streams</b>		
Development of technological infrastructure Costs of a fashion collection The costs of metaverse development Marketing expenses Technical support and maintenance		Sale of NFT fashion collection Transaction reimbursements Commerce commission Selling virtual fashion clothes Partnerships and sponsorships		

Picture 12. Business Model Canvas

## 4. CONCLUSION

This paper has detailed the development of a Metaverse NFT fashion marketplace, highlighting its significance in blending fashion with digital innovation. Utilizing technologies like Ethereum Blockchain, Solidity, Pinata, MetaMask, Hardhat and ReactJS, the marketplace enables secure creation, minting and trading of NFTs. The methodology includes project setup, smart contract development, frontend creation and integration with the Metaverse, offering users immersive experiences to showcase and trade their NFTs.

The marketplace opens new avenues for fashion designers and brands to explore digital fashion, engage with consumers innovatively and create sustainable designs. It supports cultural expression, social interaction and market expansion. Future research will focus on incorporating augmented reality, virtual reality and artificial intelligence to enhance the marketplace further.

In conclusion, the Metaverse NFT fashion marketplace marks a significant advancement, fostering creativity and engagement. Its potential integration with platforms like Voxels and Decentraland highlights the evolving impact of digital fashion in the Metaverse.

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# DECENTRALIZED PHR APPLICATION

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**Abstract:** *Patients face challenges such as a lack of trust in the healthcare system, difficulties in securely storing and accessing their data, as well as fragmentation of health records across multiple providers. This paper presents a detailed overview of the design of a decentralized Personal Health Record (PHR) application. Additionally, the paper includes a detailed description of creating B2C smart contracts using the Solidity programming language. Through a review of existing PHR applications based on blockchain, we introduce our innovative decentralized PHR application, highlighting its ability to effectively integrate patient data from various sources while preserving privacy and data security. Furthermore, we discuss the business model of our application and its contribution to enhancing the healthcare ecosystem, emphasizing the benefits it provides to both users and healthcare providers.*

**Keywords:** *Healthcare, PHR, Blockchain, Immutable ledger*

## 1. INTRODUCTION

Health Information Technology (HIT) hasn't yet achieved a unified view of patients' complete health histories. Patients often have fragmented records across different providers, causing inefficiencies and inaccuracies. During emergencies, accessing medical history can be difficult. Additionally, various health data standards complicate consistency and Electronic Health Records (EHRs) lack information on patient lifestyle habits, such as exercise, diet, and vital signs. Personal Health Records (PHRs) solve this by allowing patients to manage their information from various sources, empowering them to take control of their health (Li et al., 2022).

The main subject of this paper is the development of personal healthcare records for patients that will improve healthcare by addressing challenges like fragmented healthcare records, data sharing and interoperability. We use blockchain technology to allow users to consolidate their medical records from various sources into one, assuring data integrity and data security. In this paper, you will have the opportunity to see a detailed overview of the design of a decentralized Personal Health Record (PHR) application. Additionally, the paper will include a description of smart B2C contracts programmed in the Solidity programming language. The transactions of these smart B2C contracts have been tested on the Sepolia testnet, aiming to address the challenges faced by patients as mentioned above. This holistic approach not only enhances the accuracy of medical records but also streamlines the healthcare experience for both patients and providers. We empower users with unparalleled control over their health data. Users can selectively share their health metrics with chosen individuals or healthcare providers, thereby maintaining their privacy while facilitating a collaborative healthcare environment (Kormiltsyn et al., 2023).

Additionally, the application extends its utility by incorporating information on donations and insurance, providing a complete overview of the user's health profile. By offering a centralized platform for all medical data, we aim to revolutionize the way patients interact with their health records, engage with the healthcare system, and control their data.

## 2. BLOCKCHAIN IN HEALTHCARE

Blockchain-based platforms enable the exchange of digital information among a network of users. As an emerging technology, blockchain has the potential to significantly transform how people transact, collaborate, organize, and identify themselves. The platform offers several advantages, such as immutability, transparency, data verifiability, security, control, convenience, and efficiency through a decentralized ledger on a peer-to-peer network. This means that users can verify transactions without the need for a central certifying authority. Users recognize the advantages of a digital personal health record (PHR) in terms of eliminating repetition and providing necessary information for comprehensive care. They also want to avoid delays and minimize wait times for healthcare services, which was found to be the second most important

factor. Users also want control over their health records to improve access and sharing of their health information (O'Dell, 2023).

Patients are worried about the security of their data and consider blockchain-based PHRs as a new way to securely store and share their medical information. Blockchain is a revolutionary technology that ensures transparency, decentralization, and immutability to address the challenges of data loss and manipulation. PHR has several benefits, such as reducing duplicate tests and prescriptions, improving quality of life through personalized health management services, and facilitating the secure exchange of medical information between different healthcare providers (Kim et al., 2022).

By leveraging blockchain, researchers can track every piece of data, with each transaction cryptographically validated. This ensures the authenticity and integrity of the data. One of the biggest advantages of using blockchain technology in healthcare is its ability to provide a secure and tamper-proof way of storing medical records, which minimizes data breaches and unauthorized access. Also, the use of a single, unified system for accessing patient records can greatly improve communication between providers and reduce errors caused by incomplete data. Blockchain can be used to track drugs and supplies throughout the supply chain, ensuring their authenticity, quality, and combating counterfeiting. By securely storing and managing vast genetic data on the blockchain, we can accelerate the research for personalized medicine and the development of new treatments. Furthermore, each data point is recorded in chronological order. This transparency allows anyone to verify that all data was recorded in the correct sequence and that each event transpired as the authors claimed (Jafri & Singh, 2022).

Some of the drawbacks of using blockchain technology in healthcare are as follows. Firstly, storing a large amount of medical data on the blockchain can be challenging and expensive. It requires specialized knowledge and expertise to implement blockchain technology in healthcare. Secondly, there are no established standards for using blockchain technology in healthcare, which can create compatibility issues and hinder its adoption. Thirdly, the size of medical data, especially imaging scans, can be a limitation for blockchain storage. Additionally, integrating blockchain technology with existing healthcare systems can be complex and time-consuming. Lastly, regulations surrounding data privacy and ownership need to be addressed before the widespread adoption of blockchain in healthcare (Faisal et al., 2022).

## **2.1 EXAMPLES OF PHR APPLICATIONS BASED ON BLOCKCHAIN**

Blockchain-based Personal Health Record (PHR) apps are indeed a relatively new concept, and while there aren't many developed applications for commercial use, here are a few examples:

- MedRec is a blockchain-based platform that manages health records securely while giving patients control over their private data. It ties together disparate health provider data sets to provide a unified access management system for medical data. MedRec is noncommercial, free, and open to make it widely used and developed. Its primary focus is to provide patients with secure and user-controlled management of health data (Nchinda, 2018).
- Health Wizz is an innovative mobile application that uses blockchain technology and Fast Healthcare Interoperability Resources (FHIR) standards to tokenize data and provide patients with a secure platform to aggregate, organize, share, donate, or even trade their personal medical records. By enhancing communication between healthcare organizations and caregivers, the app aims to improve the quality of care and health outcomes for individuals (Dimitrov, 2019).
- Medicalchain is a blockchain company that aims to empower healthcare professionals, such as doctors, hospitals, laboratories, pharmacists, and insurers, to request permission to access and interact with patients' medical records. Each interaction is trackable, transparent, and secure, and is recorded as a transaction on Medicalchain's distributed ledger (Dimitrov, 2019).
- MediLinker is a blockchain-based identity management solution to facilitate patient autonomy and interoperability among clinics. This solution utilizes a custom web and mobile application through which patients can manage their medical information, including current medications and doses, for sharing with healthcare providers. To ensure security and legitimacy, patients are required to present a valid physical identity card to the receptionist at participating clinics before accessing MediLinker. However, since data entry is manual, there's a risk of errors in the credentials created, which could lead to issues in the system's functionality (Harrell et al., 2022).
- Solve.Care's smart contract system, based on blockchain technology, aims to synchronize all healthcare stakeholders, including patients, doctors, insurers, pharmacists, and other care providers. Patients utilize Care.Cards to securely share information and communicate with healthcare providers, pharmacists, nurses, or family members, maintaining full control over their data. They must grant explicit permission for data sharing and retain authority over access privileges. When patients join a healthcare network, safeguards ensure data isn't shared inadvertently with unauthorized parties. Solve.Care's solution prioritizes patient data privacy; while it tracks consent



processes in real-time, patient data and medical records remain exclusively with the patient (Nadendla & Buckanavage, 2023).

- Longenesi is a platform for trading health data where users contribute their data, including photos, test results, and scans. They create "smart contracts" to lease this data to companies, determining who can access it, for how long, and at what price. Companies, like pharmaceutical companies, pay to access this data for drug development or disease understanding. Users retain control over their data, choosing to decline requests or lease it to different companies after the contract expires (Gammon, 2018).

### 3. BUSINESS MODEL FOR HEALTHCARE BASED ON BLOCKCHAIN

Our business model canvas focuses on utilizing blockchain for secure storage and sharing of patient medical data in a single application. The goal is to create a PHR application that empowers patients with control over their health information, facilitating better health management and well-being. Table 1 displays the Business Model Canvas (BMC) for the application of blockchain technology in the healthcare ecosystem.

**Table 1:** Business Model for healthcare based on blockchain

<b>Business idea:</b> A secure and user-friendly platform for patients to store, manage, and share their health data, including medical histories, laboratory results, prescriptions, and more.				
<b>Products and services:</b> Personal Health Care platform, data sharing and consent management, integration with healthcare systems				
<b>Partners</b> -Healthcare providers -Hospitals, clinics -Medical laboratories -Research institutes -Pharmacies -Insurance companies -IoT device manufacturers -Data processing and analytics companies -IT infrastructure partners -Blockchain providers -Government -Patients	<b>Key activities</b> -Researching patient's needs -Software development for PHR -Integration with IoT devices -Partnerships with key partners -Maintaining data security and privacy -Data integration and interoperability -Marketing and user acquisition -Patient engagement and education -Training healthcare workers	<b>Value propositions</b> -Secure storage of patient medical records -Easy data sharing with doctors, hospitals and other stakeholders -The patient always has access to all their records regardless of the healthcare institution where the examination was conducted -Option to sell data for medical research -Data integration and review for enhanced health management -Facilitate interactions between donors and users in need -Easy medication tracking -Automatically tracking various health parameters using wearable devices	<b>Relationship with users</b> -Personalized access to health information -Customer support -Education on the importance and use of the PHR application	<b>Customer segments</b> -Individuals wanting to manage their health data -Medical practitioners and staff -Medical researchers -Insurance companies -The government wants to modernize healthcare in the country
	<b>Key resources</b> -the IT platform for the PHR application -Blockchain platform -Technological infrastructure (servers, cloud services) -Software development and support teams -Legal teams for contracts and data protection -Patient data -Healthcare provider data		<b>Channels</b> -Online platforms and applications -Hospitals and clinics as distribution partners -Partnerships with insurance companies -Direct marketing -Regulatory Support	
<b>Cost structure</b> -Development and maintenance of the application and blockchain -Hosting and maintaining infrastructure		<b>Revenue Streams</b> -Subsidies and Grants -Subscriptions for premium users -Commission from users giving access to their data for		

<ul style="list-style-type: none"> <li>-IT security and data protection</li> <li>-Training users and healthcare providers</li> <li>-Marketing</li> <li>-Partnerships, licensing, and integration</li> </ul>	<ul style="list-style-type: none"> <li>research</li> <li>-Revenue from advertising healthcare products or services</li> <li>-Integration fees</li> <li>-Telemedicine services</li> <li>-Blockchain services</li> </ul>
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In the ecosystem for Personal Health Records (PHR), patients are empowered to own and control their health data through PHR applications. Healthcare providers integrate these applications into their workflows to access comprehensive patient records, enhancing decision-making and care. Laboratories and pharmacies contribute critical data, while research institutes leverage anonymized patient data for medical research. Insurance companies streamline processes by transferring policy data directly into PHRs. IoT device manufacturers ensure compatibility for real-time health monitoring, and IT infrastructure partners provide technological support. Blockchain technology secures and decentralizes health records, while government agencies enforce regulatory compliance (Betrand et al., 2024).

The PHR application is developed using React for an intuitive interface, while Ethereum's smart contracts ensure secure data storage. A dedicated team handles ongoing functionality, maintenance, and support, covering programming, UI design, testing, and customer service. Patient and healthcare provider data are crucial for personalized care and coordination, while legal teams ensure compliance with data protection regulations, safeguarding system integrity.

We conduct original research to understand patients' needs and challenges in managing health information. Our software development includes creating a user-friendly front-end PHR system with features for data entry, storage, and access control, integrating with EHRs and IoT devices. Backend development involves Solidity smart contracts on the blockchain for immutable storage. Partnerships with healthcare providers, employers, and government entities facilitate PHR adoption. Data security and GDPR compliance are prioritized. Interoperability ensures seamless integration with healthcare systems. Marketing strategies focus on awareness and user acquisition, while patient engagement and education support effective system usage. Healthcare worker training emphasizes blockchain understanding and data recording procedures (Cernian et al., 2020).

The application securely stores patient records on the blockchain and enables easy data sharing with healthcare providers, fostering collaboration and improving treatment decisions. Patients can opt to sell anonymized health data for research while maintaining privacy. Access to medical records is comprehensive regardless of where care was received. Data integration aggregates diverse sources for efficient decision-making and personalized treatment. Smart contracts ensure data integrity and automate sharing processes. Patients can track medication adherence and integrate wearable devices for continuous monitoring (Haleem et al., 2021) (Zakari et al., 2022).

The PHR application ensures personalized access to health records, empowering patients to make informed decisions about their health. Responsive customer support services are provided via multiple channels to address any queries or technical issues. Continuing education efforts, including user guides and workshops, emphasize the importance of proactive health management and how the application facilitates it.

The PHR application enables individuals to track their health data, including medical histories, prescriptions, and conditions, in one centralized location on the blockchain. Medical practitioners can access patient data for diagnosis and treatment, while researchers can analyze trends and improve disease understanding. Insurance companies benefit from streamlined claims processing, and governments can modernize healthcare infrastructure by implementing PHR systems (Lee et al., 2020).

Online channels, hospitals, and clinics serve as distribution partners, while healthcare providers introduce the application to patients during appointments. Partnerships with insurance companies include incorporating information about the application in communications with insured individuals. Regulatory support may include mandates for healthcare facilities to offer PHR applications or insurers to cover PHR subscription costs. Direct marketing via social media, emails, radio, and TV is employed for wider audience reach.

Significant expenses for the PHR application project include development and maintenance costs for both the application and blockchain, infrastructure expenses for hardware, software, and network support, and integration costs with other healthcare IT systems. Training users and healthcare providers, marketing efforts, and partnership and licensing expenses are also key components of the project's financial considerations.

The project may receive financial support through subsidies and grants, aiding in initial development and ongoing maintenance. Revenue streams include subscriptions for premium features, commissions from user data sharing for research, and advertising within the application. Additional income may be generated through telemedicine services, integration fees, and offering blockchain-as-a-service solutions to other healthcare entities (Taherdoost & Madanchian, 2023).

5. DEVELOPMENT OF A DECENTRALIZED PHR APPLICATION

Developed decentralized PHR application aims to enable patients to electronically store and manage their health data and access it whenever needed. This application provides functionalities such as storing health reports and viewing basic information like date of birth, blood type, weight, and height with the ability to update and track medications and vaccinations. Users can add primary care physicians, doctors, and pharmacists for different access levels. Importantly, the app promotes interoperability, allowing connection with healthcare systems for seamless data sharing among patients and providers, thus enhancing care coordination.

Upon logging in and accessing the home page, users can click on their avatar to view essential information, including their name, blood type, date of birth, and unique identifier. Additionally, users can update their height and weight by entering new values and clicking on the "Update" button. Furthermore, if a user has indicated their willingness to donate organs, this information is displayed as being an organ donor, as depicted in Figure 1.

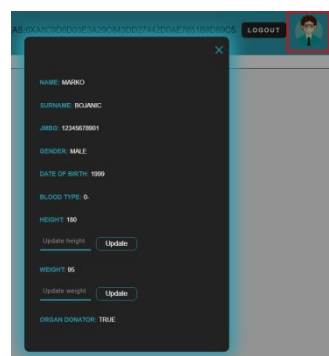


Figure 1: Patient's informations

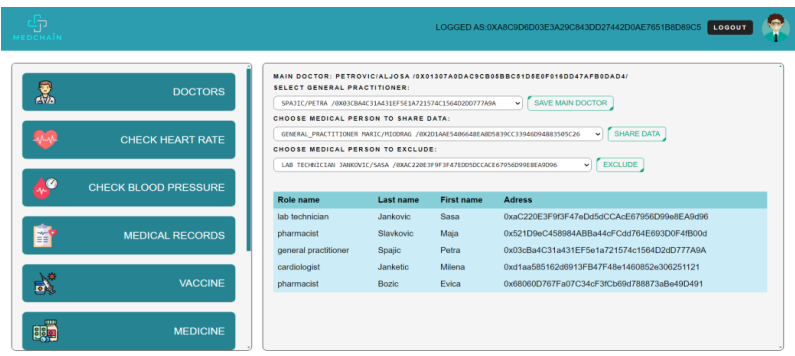


Figure 2: Doctors' tab

Figure 2 displays the doctor's panel, which shows the patient's primary doctor and a list of medical personnel with access to the patient's medical records. Users can select their new primary physician by choosing from the dropdown list of all general practitioners, and then saving their selection. There's a table displaying all healthcare professionals who have access to the patient's medical records. Users have the option to choose from a list of healthcare professionals to grant them access to their medical records by clicking on the "add" button or revoke access if needed by clicking on the "exclude" button. In Figure 3, the patient's medical reports panel is shown, featuring three buttons that enable the display of the patient's medical reports table. Users can refine their search by selecting specific diagnoses or dates, allowing medical reports to be displayed according to the chosen criteria.

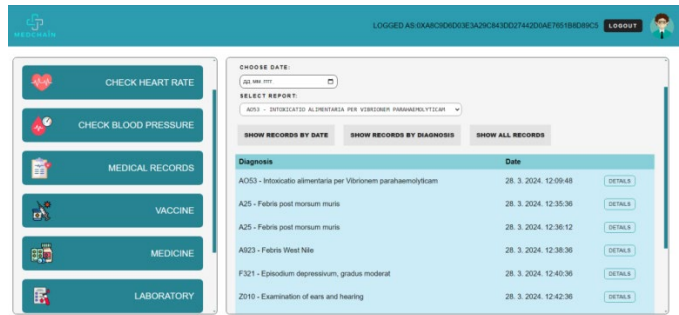


Figure 3: Patient's medical reports

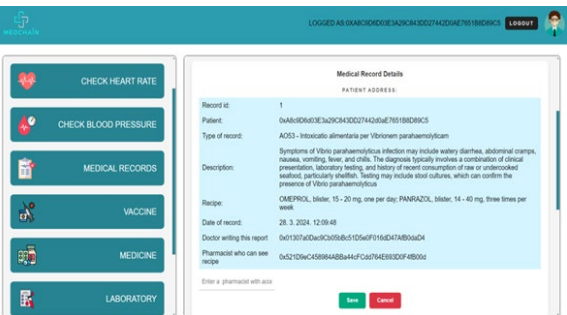
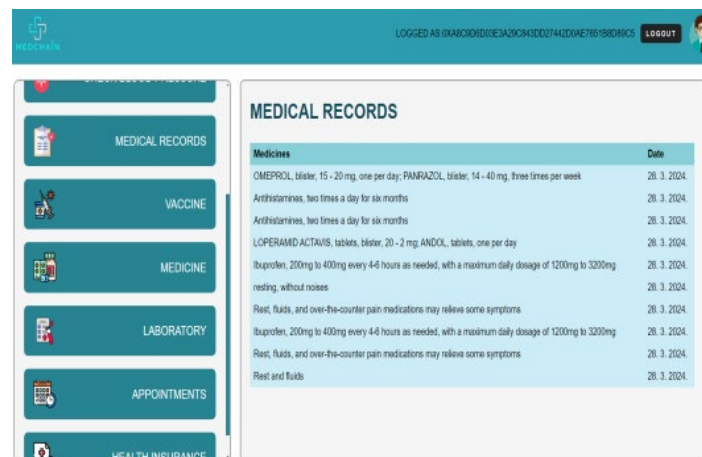


Figure 4: Detail view of patient's record

By selecting the 'Details' button for a specific report, users gain access to comprehensive details of that report. Additionally, they can designate a pharmacist who is authorized to view the prescription linked to that report, as illustrated in Figure 4.



The tab labeled "Immunizations" shows the user's vaccination history, allowing them to view their complete immunization records. Figure 5 shows the tab labeled "Medications" that grants users access to their medication history, facilitating the tracking of their prescriptions.



Medicines	Date
OMEPROL, blister, 15 - 20 mg, one per day; PANAZOL, blister, 14 - 40 mg, three times per week	28. 3. 2024.
Antihistamines, two times a day for six months	28. 3. 2024.
Antihistamines, two times a day for six months	28. 3. 2024.
LOPERAMID ACTAVIS, tablets, blister, 20 - 2 mg ANDOL, tablets, one per day	28. 3. 2024.
Ibuprofen, 200mg to 400mg every 4-6 hours as needed, with a maximum daily dosage of 1200mg to 3200mg	28. 3. 2024.
resting, without noises	28. 3. 2024.
Rest, fluids, and over-the-counter pain medications may relieve some symptoms	28. 3. 2024.
Ibuprofen, 200mg to 400mg every 4-6 hours as needed, with a maximum daily dosage of 1200mg to 3200mg	28. 3. 2024.
Rest, fluids, and over-the-counter pain medications may relieve some symptoms	28. 3. 2024.
Rest and fluids	28. 3. 2024.

Figure 5: Patient's medications

These functionalities are implemented with the help of the following functions within the several smart contracts written in Solidity programming language (Figure 6). Key features include setting pharmacists to view prescriptions, returning all prescriptions for a patient, returning all vaccinations, returning all medical reports, setting a new primary physician for a patient, and setting medical personnel to view patient medical records.

```
function getMedicalRecordsForPatient()
public
view
returns (MedicalRecord[] memory)
{
    uint256 arrayLength = medicalRecords.length;
    MedicalRecord[] memory patientMedicalRecords = new MedicalRecord[](
        arrayLength
    );
    uint256 count = 0;
    for (uint256 i = 0; i < arrayLength; i++) {
        if (medicalRecords[i].getPatient() == msg.sender) {
            patientMedicalRecords[count] = medicalRecords[i];
            count++;
        }
    }
    assembly {
        mstore(patientMedicalRecords, count)
    }
    return patientMedicalRecords;
}

function setMainDoctor(address mainDoc) public {
    mainDoctor = mainDoc;
}

function addMedicalPersonWithAccess(address medicalPerson) public {
    if (IdDocMedicalPersonWithAccessExistInTheList(medicalPerson)) {
        medical_persons_with_access.push(medicalPerson);
    }
}

function setDoctorWhoCanSeeRecipe(
    string memory _recipe,
    address _doctorWhoCanSeeRecipe
) public {
    uint256 arrayLength = medicalRecords.length;
    for (uint256 i = 0; i < arrayLength; i++) {
        if (
            keccak256(abi.encodePacked(medicalRecords[i].getRecipe())) ==
            keccak256(abi.encodePacked(_recipe)) &&
            medicalRecords[i].getPatient() == msg.sender
        ) {
            medicalRecords[i].setDoctorWhoCanSeeRecipe(
                _doctorWhoCanSeeRecipe
            );
        }
    }
}

function returnAllRecipesOfPatient() public view returns (string[] memory) {
    uint256 arrayLength = medicalRecords.length;
    string[] memory listOfRecipes = new string[](arrayLength);
    uint256 count = 0;
    for (uint256 i = 0; i < arrayLength; i++) {
        if (medicalRecords[i].getPatient() == msg.sender) {
            listOfRecipes[count] = medicalRecords[i].getRecipe();
            count++;
        }
    }
    assembly {
        mstore(listOfRecipes, count)
    }
    return listOfRecipes;
}

function getImmunizationList() public view returns (Immunization[] memory) {
    return immunizations;
}
```

Figure 6: Smart contracts

## 6. CONCLUSION

Our proposed work is focused on blockchain technology in the healthcare field. Therefore, we analyze the current existing problems in the healthcare domain from the patient's perspective. Current healthcare systems must address the lingering security and privacy concerns that patients must enhance their trust in medical professionals and clinics. As a solution to these problems, academics are turning to blockchains, a technology that offers several advantages. Blockchain can serve as a digital ledger facilitating communication among patients, caregivers, and insurance companies due to their irreversible, transparent, distributed, and decentralized nature (Panwar et al., 2022). Moreover, they enable the consolidation of patient information into a single file, providing caregivers with a comprehensive perspective of the patient's health history. The patient plays a central role in controlling consent and sharing their PHR records with third parties (Dong et al., 2023).

In this research study, we have outlined the benefits of implementing blockchain in healthcare with a focus on the patient. We have identified existing PHR or similar platforms, developed a business model for the healthcare ecosystem based on blockchain, and built a new platform for patients' personal health records (PHR) so they can have all their data in one place and better control over it.

Further research could concentrate on introducing new functionalities, such as integrating with IoT devices for measuring health parameters and enhancing interoperability with Electronic Health Records (EHRs). Additionally, to achieve interoperability across the entire healthcare system within a country, consideration could be given to establishing a private blockchain network utilized by both patients and the entire healthcare system. This would ensure data consistency and facilitate the storage and sharing of patient information.

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# APPLICATION OF BLOCKCHAIN TECHNOLOGY IN THE PREVENTION OF MONEY LAUNDERING

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**Abstract:** *This article considers the problem of money laundering and the possible applications of blockchain technologies in preventing money laundering. The goal is to make a comprehensive analysis of the possibilities and current applications of blockchain technologies in money laundering and discuss directions for further development. The main focus is on the analysis of the application of blockchain in monitoring audit trails and enhancing the current know-your-customer and anti-money laundering processes. The results indicate that the main stakeholders have recognized the potential of blockchain in this context and already started with activities in this direction. It is evident that successful implementation of blockchain solutions requires careful consideration of technological compatibility, regulatory compliance, and stakeholder collaboration.*

**Keywords:** *blockchain, money laundering, fintech*

## 1. INTRODUCTION

Money laundering is a global problem with profound economic, political and social implications. Money laundering activities have existed in society for a long time, and factors such as the globalization of business and the widespread use of information technologies have caused their scale to expand significantly. Although these same factors can contribute to the suppression of money laundering and terrorist financing - through strengthened international cooperation and more straightforward and more accurate monitoring of money movements - the practice of combating money laundering remains an open possibility. As the technology used against money laundering and terrorist financing advances, so do the ways to enforce it. Today, these illegal activities are carried out more sophisticatedly and are becoming more difficult to trace.

The banking sector is the primary route for illegal money laundering due to access to banking mechanisms and legal powers that banks have. Anti-money laundering laws have become more stringent in the recent past, causing financial institutions to undertake expensive compliance processes. Emerging technologies such as blockchain are seen as solutions to mitigate financial crimes. These technologies can transform various processes in financial services, including peer-to-peer payments, trade agreements and supply chain tracking. Customer identification and verification, often called "Know Your Customer" (KYC), is fundamental to building transaction trust.

## 2. LITERATURE REVIEW

The digitalization of various sectors, particularly the financial industry and specifically banking, has been notable over the past years. Advancements in internet connectivity, particularly with 4G and 5G technologies, alongside the growth of the IT industry, have

transformed the internet, impacting the global financial sector (Ekinci, 2021). While this technological advancement brings positive changes, it has also given rise to new money laundering schemes, primarily targeting mobile devices, leading to a surge in criminal activities (Ozili, 2022). This increase in crime was enabled by some of the characteristics of the digital environment: anonymity, depersonalization of financial transactions, and increased speed of cyber laundering activities (Wronka, 2022). Today, traditional detection methods face obstacles due to technological advancements like internet protocol spoofing and encryption. Consequently, there has been a noticeable increase in financial regulations globally in response to the growing threats of money laundering and terrorist financing over the years (Kirimhan, 2023).

In recent times, blockchain technology has transitioned from being primarily associated with *Bitcoin* to being recognized as a potentially revolutionary innovation with numerous transformative benefits. While some described cryptocurrencies as “heaven for money laundering activity” (Lorenz et al., 2020, p. 1), many believe that blockchain technology holds significant promise, particularly in applications such as bank transfers and anti-money laundering (AML) efforts. In 2017, New York Law Journal used an expression *white collar crime* to address the phenomenon of how the same technology that once appealed to criminals for its ability to facilitate illicit money transfers through Bitcoin may now assist financial institutions in combating such activities (Everdell & Mandell, 2017).

If the blockchain's history was unclear, authors claim that its future appears promising. Advocates of blockchain technology believe that distributed ledger technologies (DTL) have the potential to transform entire industries, spanning banking, financial services, securities, and insurance (Van Oerle & Lemmens, 2016; Mills, et al., 2016; Wenke et al., 2022). In the banking sector, there is optimism that DTL will greatly enhance AML compliance. However, the question arises: *how can a technology initially associated with facilitating money laundering now offer a solution to the problem?* Banks have sought to address this by creating private or "permissioned" blockchains (Huang & Trangle, 2020).<sup>\*</sup> In these private networks, only trusted banks are permitted to join, functioning as nodes that maintain a shared ledger using the hash value process of the original Bitcoin blockchain. While the ledger is distributed among member banks, the system is not decentralized, and banks remain trusted intermediaries that verify and record transactions (Thommandru & Chakka, 2023).

The explicit phases of the money laundering process play a pivotal role in the efficacy AML strategies. These well-defined stages enable regulatory and law enforcement agencies to track illicit funds back to their unlawful origins effectively (Al-Tawil, 2023). Financial institutions typically scrutinize each stage for warning signs, employing a risk-based approach (RBA) endorsed by the Financial Action Task Force (FATF). FATF, an international body setting global standards for combating money laundering and terrorist financing, advocates for using risk categories or indicators, known as *red flags*, to assess the likelihood of money laundering and terrorist financing (De Koker, 2022). These red flags often encompass transactions associated with geographical/country risk, customer risk, and product/service risk. Identifying these risk categories informs decisions on documenting the transaction through a suspicious activity report, prompting further inquiry or disregarding it altogether. However, some authors suggest that the decentralized nature of cryptocurrencies poses challenges in implementing FATF RBA regulations and identifying red flags (Al-Tawil, 2023).

The blockchain infrastructure operates as an open and transparent system, accessible to anyone with Internet connectivity, enabling the tracking of transaction histories. This

<sup>\*</sup> NB: unlike the open or "permissionless" blockchain of Bitcoin

transparency presents a challenge for concealing illicit financial activities, as transactions within the blockchain network are constantly observable (Al Mamun et al., 2020). Consequently, individuals engaging in money laundering via the network face the risk of surveillance, akin to the concept of a *panopticon* in philosophical discourse, as described by Foucault. The presence of such panoptic surveillance fosters regulatory acceptance and compliance, similar to the monitoring tower in a prison. Consequently, the transparency afforded by blockchain technology deters money launderers, who must anticipate being monitored and held accountable for their actions. This deterrent effect on money laundering has secondary implications for AML and transaction monitoring efforts (Daugaard et al., 2024). With reduced incentives for laundering money through traditional financial institutions, banks may require less stringent transaction monitoring, potentially lowering costs for commercial banks. Alternatively, they may outsource transaction monitoring to specialized third-party analytics firms like *Chainalysis*, which possess expertise in blockchain technology, transaction analysis, and financial regulations. However, the concentration of such specialized knowledge among a few industry players could act as a barrier to the full realization of the *panopticon* effect (Daugaard et al., 2024).

The widespread awareness of blockchain transparency, coupled with the fallout from the 2008 financial crisis and instances of money laundering, has underscored the need for stronger regulation of financial activities. This has led to increased demand for technological solutions, such as those within the regulatory technology (regtech) subsector of the Fintech Revolution, aimed at enhancing compliance (Teichmann et al., 2023). Consequently, technology-driven solutions geared towards easing AML processes have gained traction, albeit at significant human and economic costs associated with research and development in this domain (Kurum, 2023).

These private networks are still in the testing phase, but if successfully implemented, they offer numerous AML benefits. Above all, the KYC documentation could be integrated into the private ledger and shared among member banks, reducing the need for redundant KYC due diligence and transfers could be easily traced using blockchain information. Also, regulators could receive real-time reports of suspicious activity at lower costs (Pocher et al., 2023).

However, private blockchains are not expected to completely eliminate money laundering. Despite efficient KYC processes, sophisticated criminals may still provide false information. Additionally, money launderers who seek to evade regulated financial institutions may turn to digital currencies offering complete anonymity. Nonetheless, for entities prioritizing AML compliance, blockchain technology could represent a significant advancement (Huang & Trangle, 2020).

### **3. ANALYSIS OF THE APPLICATION OF BLOCKCHAIN TECHNOLOGY IN THE PREVENTION OF MONEY LAUNDERING**

Technological advancements and globalization have facilitated corporate operations but have also provided opportunities for money laundering and digital financial crimes. According to some estimations, maintaining and upgrading AML and KYC systems at banks can cost between \$900 million to \$1.3 billion annually (Parra Moyano & Ross, 2017). Financial institutions face pressure from clients to handle transactions efficiently while grappling with the significant expenses and complexities of KYC/AML compliance. Often, compliance systems are burdensome, manual, and slow, straining client relationships and hindering business processes.

Therefore, blockchain technology arises as a possible solution for addressing these challenges in the financial industry. It enables secure and transparent ledger systems, automates compliance checks through smart contracts, and facilitates collaboration among institutions through consortium blockchains. Asset tokenization enhances traceability, while data analytics and machine learning aid in detecting money laundering patterns. Sovereign identities and immutable audit trails enhance KYC/AML processes, while smart contracts automate compliance procedures. Enhanced due diligence leverages blockchain for transparent verification, and secure data sharing ensures privacy and data integrity. Successful implementation requires stakeholder cooperation, regulatory compliance, and careful consideration of privacy concerns (Malhotra, Saini, & Singh, 2022). In the table below, the typical challenges in terms of traditional KYC/AML are shown.

*Table 1: Problems in traditional KYC/AML procedures*

<b>Problem</b>	<b>Description</b>
Identification of fraudulent data Customers providing fake and bogus data Verification of integrity of customer documents Tracing and tracking customer	KYC requires rigorous procedures for verifying customers' identity; KYC frauds typically include synthetic identity fraud, deep fake technology, biometric data theft, SIM card swapping and insider threats. All of the mentioned can make tracing and tracking customers misleading, but an in-depth analysis that is enabled by blockchain should actually help in this step.
Analysing customer risk based on information provided	The data entered provides an initial step for customer risk assessment. Therefore, wrong data leads to wrong risk assessment and does not alarm the entity about the potential danger. However, blockchain technology is supposed to allow banks to assess the risks more precisely and prevent fraud.
Processing time delays	Traditional KYC procedures are time-consuming, which gives an advantage to those who aim to conduct an illicit activity. Blockchain technology has the potential to significantly improve the speed of these procedures and draw attention to suspicious activities in real-time.
Expenses related to the process	Traditional KYC/AML procedures are not only time-consuming but also costly. They require a lot of manpower and the use of various software and databases. Blockchain technology would reduce these costs and make the process automated and simple.

Source: (ET, 2024; Malhotra et al., 2022; Martens et al., 2017)

Numerous well-established financial institutions, such as Barclays, UBS, Deutsche Bank, Santander, and Bank of America, are investigating avenues to incorporate blockchain technology. This may involve either developing their proprietary technology or collaborating with firms operating in the blockchain space (Huang & Trangle, 2020). For instance, J.P. Morgan uses Liink, which is a blockchain application that is used to enable financial institutions and corporate users to make secure peer-to-peer data transfers at greater speed and with more control. The primary advantage of utilizing Liink lies in its seamless integration into any platform via the accessible API. This feature serves as a strong foundation for reimagining how institutions engage in communication and exchange important data. HSBC uses R3's blockchain platform for its custody services. HSBC utilizes R3's blockchain platform to power its Digital Vault, a custody blockchain platform designed to securely store digital assets. Recognizing the potential of blockchain technology, HSBC aims to enhance the security of digital asset storage while simultaneously reducing the costs associated with its custody services. With Corda's blockchain technology, HSBC envisions the possibility of shifting more of the transaction lifecycle onto the ledger in the future. This would enable the bank to issue digital tokens in place of traditional paper certificates. R3's Corda platform facilitates direct and private transactions using smart contracts, thereby minimizing transaction costs, record-keeping expenses, and optimizing business operations. Launched in 2019, the Digital Vault service digitizes transaction records for various private placement assets such as equity, debt, and real estate. This innovation allows global custody clients to access real-time details of their private assets directly, eliminating the need to rely on cumbersome paper-based records. Through blockchain technology, transaction records become readily auditable, providing a swift and efficient means of verification for stakeholders. Goldman Sachs, a leading U.S. investment bank, has launched an educational microsite to explain the benefits of blockchain technology, emphasizing its security and transparency. The bank believes proprietary software development for blockchain is unnecessary due to its inherent transparency. However, global adoption is necessary, although legislative frameworks addressing liability issues are required. Goldman Sachs is a major investor in Circle's USDC stablecoin, which is pegged to the U.S. Dollar, providing a secure means for global money transfer without exposure to cryptocurrency volatility.

A coalition of European banks currently utilizes a KYC blockchain solution, developed with *Catalyst Blockchain Manager*, to significantly enhance the efficiency of customer verification processes. Catalyst Blockchain Manager facilitates the development, deployment, and ongoing management of next-generation KYC solutions by providing a comprehensive blockchain solutions operating system. It simplifies management and automates processes, enabling enterprises to overcome technical challenges associated with blockchain technology and achieve significant cost savings, reduced complexity, and rapid implementation times in developing KYC blockchain solutions. This enables network institutions to share verified KYC datasets and data updates, while clients retain control over their data. This streamlined approach saves time for both financial institutions, which can now procure verified KYC data, and clients, who only need to provide their data once to the system. Additionally, the solution standardizes the collection of KYC data and verification rules. Blockchain technology ensures that all participants have access to the same dataset with the latest client information, know which institutions can share a client's dataset, and maintains a transparent and tamper-proof audit trail of updates and verifications. Moreover, this is achieved without the need for a central authority controlling all data, protecting business privacy and compliance with competition laws (IntellectEU, 2024).

In the case of using blockchain forensic and analytic tools, Srivasthav, et al. (2021) provided a comparison of the various tools using three practical parameters – number of cryptocurrencies supported, number of features provided, and ease of accessing services, and gave an overview of their theoretical effectiveness in general with some open challenges identified. The main challenges include substantial hardware demands necessary to parse and handle extensive blockchain data, as well as the complexities of real-time analytics, particularly concerning speed and precision due to the expanding size of blockchains. Additionally, cross-ledger analytics present a complex obstacle, as tracing monetary movements and connecting multiple transactions/addresses across disparate ledgers becomes particularly challenging.

#### 4. DISCUSSION

Each approach to integrating blockchain technology in banking presents its own set of advantages and challenges. While proprietary solutions like J.P. Morgan's Liink offer control and customization, they may require significant investment and expertise. Collaborative efforts, such as the European Banks Coalition, leverage shared resources and standards to achieve efficiency and interoperability but may face challenges in governance and coordination. HSBC's adoption of R3's Corda platform showcases the potential for blockchain to enhance specific banking functions like custody services, with a focus on security and cost reduction. Goldman Sachs' investment-centric approach highlights the importance of collaboration and investment in blockchain infrastructure and ecosystem development. The integration of blockchain technology in the banking sector presents diverse approaches and strategies, each with its own set of advantages and challenges. While some banks opt for proprietary solutions like J.P. Morgan's Liink to gain control and customization, others like HSBC leverage partnerships with blockchain platforms such as R3's Corda to enhance specific functions like custody services. Additionally, collaborative efforts like the European Banks Coalition focus on shared resources and standardized processes to achieve efficiency in areas such as KYC verification.

Despite these differences, several key conclusions can be drawn from the comparative analysis:

1. Blockchain technology offers significant potential for enhancing security, transparency, and efficiency in banking operations, particularly in areas like AML/KYC compliance and transaction processing.
2. The choice between proprietary solutions and collaborative efforts depends on factors such as resource availability, expertise, and strategic objectives.
3. Successful implementation of blockchain solutions requires careful consideration of technological compatibility, regulatory compliance, and stakeholder collaboration.
4. Education and investment in blockchain infrastructure and ecosystem development are essential for driving global adoption and overcoming challenges related to scalability, interoperability, and regulatory uncertainty.

Ultimately, it is important to highlight that there are numerous stakeholders interested in the application of *blockchain*-based solutions in preventing money laundering whose interests should be taken into account. Above all, the ministries of finance and the central bank of one country, as well as international financial institutions can significantly benefit from these improvements. The banks can also improve their trustworthiness and credibility, as well as other financial institutions that would implement this technology. Citizens and enterprises as banks' clients are also interested in maintaining the financial system transparent and stable, meaning that they are another group of stakeholders.



The central bank plays a crucial role in maintaining the financial system of one territory stable and transparent. Since this institution has significant influence over the operations of commercial and other banks, it can foster the transition towards more technologically advanced banking. Especially in the times when digital currency presents an important question in this field, central banks are the rule-setters that can - and should - lead the future of the financial systems.

## 5. CONCLUSION

The digital era has shifted from traditional to cyber laundering methods, posing challenges for law enforcement and financial regulators. Blockchain technology is anticipated to hold significant promise in mitigating the risks associated with money laundering and terrorism financing within the banking system. Furthermore, research suggests that blockchain technology has considerable potential to enhance the efficiency of "Know Your Customer" procedures. Currently, banks are encountering substantial challenges in this regard. However, the questions regarding the efficiency of these solutions remain open, as there could be more challenges with the blockchain-based solutions related to energy consumption, costs and implementation processes that can be too complex and demanding, as well as security issues. Since only a handful of big global banks currently implement blockchain-based solutions, further research should assess the possibility of a more significant number of banks implementing them, as well as the concrete financial impact by comparing the investment and costs on the one hand and the benefits on the other.

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# THE INTRODUCTION OF 5G ECOSYSTEM IN BIH AND POTENTIAL USE CASES

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**Abstract:** *The subject of this article is to analyze the prerequisites for the introduction of 5G mobile communication networks in Bosnia and Herzegovina and its potential applications. The goal is to create a roadmap for 5G introduction with precisely defined steps considering the current state and to identify some of the most important application scenarios. To clearly define the necessary steps, an analysis of the current situation in the country was made, based on the data available from the Communication Regulatory Agency. This data was collected by surveying license holders and using certain measuring tools that the Agency owns. Research was also done on some of the most significant applications of 5G in Europe and the world, which would contribute to economic progress in our country. The presented roadmap can be used during the multi-year process of introducing 5G mobile networks in Bosnia and Herzegovina, at the level of decision-makers and relevant institutions.*

**Keywords:** 5G technology, mobile networks, Internet of Thing (IoT), vertical industry

## 1. INTRODUCTION

5G mobile networks are expected to enable ultra-fast connectivity with low latency, not only for individual users, but also for a large number of connected objects, as well as to create an environment for the expansion of technological and business innovations in vertical industry sectors. Moreover, unlike previous generations of mobile communication networks, 5G is not conditioned by any single technology. As a "network of all networks" it is intended to connect existing and future standards, including currently implemented advanced LTE (4G) technologies. [1]

The aim of this paper is to present the current situation in Bosnia and Herzegovina from the aspect of introducing 5G mobile networks and identify a road map for successful implementation and development and point out some of the potentially most interesting applications in vertical industries.

## 2. 5G SERVICES

The information and communication (ICT - Information and Communications Technology) sector was created by the convergence of telecommunications and the Internet, with a completely new approach in the way they are processed and transmitted information. The massive and widespread use of mobile devices is an additional catalyst for economic, cultural and technological changes in society, which has become highly "networked" and connected, following the "communication anywhere, with anyone, at any time" paradigm. [2]

5G technology, as the fifth generation of fast mobile networks, represents a new phase of development in mobile communications. The main difference compared to previous generations of mobile networks is higher data transfer speeds and a larger number of connected devices on this network. Services based on this technology are key to a wide range of innovative applications and have the power to reshape various sectors of the economy and improve the daily lives of citizens. [3]

In the development and implementation of any mobile network, one of the key processes is standardization. 3GPP (Third Generation Partnership Project) plays an extremely important role in this standardization process. The 3GPP worked on the specifications that led to the definition of the 5G system during 2017. The idea of 5G was introduced back in 2012 when the ITU-R launched the IMT development program for 2020 and beyond. An overview of the ITU IMT-2020 request categories is given in the following table. [4]

**Table 1:** Key technical capabilities for 5G

Capability	Value
Maximum data transfer rate	1 – 20 Gb/s
Data transfer rate experienced by end user	10 – 100 Mb/s
Spectar efficiency	15 – 30 bit/s/Hz
Maximum mobility	350 – 500 km/h
Latency	1 – 10 ms
Link density	10.000 – 1 million devices/km <sup>2</sup>
Energy efficiency of the network	90% more efficient than in IMT-Advanced
Traffic capacity of the area	0,1 – 10 Mb/s/m <sup>2</sup>

When it comes to the architecture of the 5G network, it can be said that there has been a significant turn compared to the network architectures of previous generations and can be characterized as a service-based architecture. The 5G core network architecture is specified in 3GPP Technical Specification 23.501. [5]

The trend of increasing video traffic, interest in augmented and virtual reality, UHD video streaming, condition the need for data transfer speeds of several Gb/s. In principle, 5G networks should enable the following categories of services: [6]

- Enhanced mobile broadband access (eMBB - Enhanced Mobile Broadband): The first phase of the implementation of 5G networks will mean transmission data to mobile devices at significantly higher speeds. The smart one's terminals will be able to download or stream HD content for several seconds, browse web pages and upload different ones much faster.
- Ultra-reliable low-latency communication (URLLC - Ultra- Reliable Low-Latency Communications): Data will be exchanged with extremely low delay, which is of particular importance for functionally critical applications, such as those related to public safety. Other examples of use include smart factories, autonomous driving, remote surgery or medical diagnostics and smart grid.
- Use of radio waves in the millimeter range (mmWave): 5G will use spectrum advantages (between 24GHz and 100GHz) with shortwave lengths. In this way, conditions are created for reliable data transmission at high speed, which is of particular importance in densely populated areas - urban areas. [7]
- Massive Internet of Things (IoT) - mMTC (Massive Machine Type Communication): Although the development of communication platforms is between devices (machines) intensified in the last few years, 5G technology aims to provide communication between so far an unimaginable number of devices and things. In order to provide connectivity, maintenance and overall costs at a reasonable level, 5G will connect networks of sensors embedded in smart devices accomplishing little delay, giving the ability to adjust data transfer rates and engaged energy, with unlimited mobility.
- Using Massive MIMO: Implementing a MIMO system of high order will mean a network architecture that will enable significantly larger capacity, i.e. a large number of users will be able to connect within it areas without reducing the data transfer rate.

Improved connectivity through 5G networks will enable a more comfortable life for people, as well as several secondary benefits for the economy, in areas such as: agriculture, automotive industry, construction industry, energy, communication services, finance, health, public administration trade, transport and others.

### 3. CURRENT STATE OF MOBILE NETWORKS IN BOSNIA AND HERZEGOVINA

According to the degree and dynamics of technological development and the availability of advanced services, as well as according to the degree of market competition, mobile communications represent the most developed segment of the telecommunications market in Bosnia and Herzegovina. Three licensed mobile operators are present in Bosnia and Herzegovina: BH Telecom d.d. Sarajevo (BH Telecom), Telekomunikacije RS a.d. Banja Luka (MTEL) and JP Hrvatske Telekomunikacije d.d. Mostar (HT Eronet). [8]

In accordance with the Decision on Permits for the use of radio frequency spectrum for the provision of services via mobile access systems [9], the Regulatory Agency for Communications is granted to mobile operators Licenses for the use of radio frequency spectrum for the provision of services via mobile access systems to existing licensed mobile operators in Bosnia and Herzegovina on 8<sup>th</sup> April 2019. The license allocated blocks of frequencies within the 800 MHz and 2600 MHz radio frequency bands for the provision of broadband services via mobile access networks on a technologically neutral basis. The license holder is given the right to provide a public electronic communication service in the assigned bands in accordance

with the GSM/GPRS/EDGE standards and the reference standard - IMT (International Mobile Telecommunications) which includes IMT-2000 and IMT-Advanced, on a technologically neutral basis. [10]

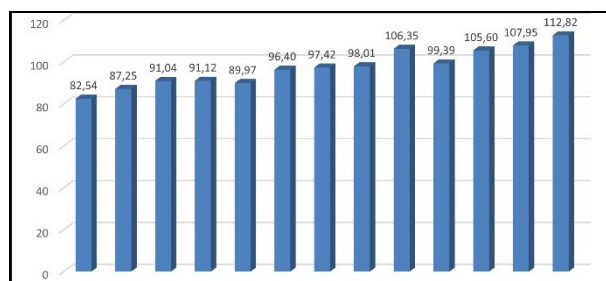
For mobile service providers (SP) in Bosnia and Herzegovina, there is the possibility of operating through commercial contracts with licensed mobile network operators (MNO), i.e. license holders for the use of radio frequency spectrum for the provision of services through mobile access systems. At the end of 2023, four mobile service providers existed regarding concluded commercial contracts on network access: DASTO-SEMTEL d.o.o. Bijeljina, LOGOSOFT d.o.o. Sarajevo, NOVOTEL d.o.o. Sarajevo and HALOO d.o.o. Sarajevo. [11]

Table 2 shows an overview of the total allocated numbering space, number of prepaid and postpaid subscribers, as well as the total number of subscribers in the networks of mobile operators (MNO) and mobile service providers (SP) for the period from 2020 to 2023.

**Table 2:** Installed capacities and number of subscribers of licensed mobile operators in Bosnia and Herzegovina (2020-2023) [12]

Mobile operators		BH Telecom	MTEL	HT Eronet	Logosoft	DASTO-SEMTEL	Novo tel	BiH
2020.	Numbering space	3.000.000	2.200.000	1.650.000				6.850.000
	Post-paid	384.484	408.846	231.890	1.322	106		1.026.648
	Pre-paid	1.142.475	857.328	483.223				2.483.026
	Total subscribers	1.526.959	1.266.174	715.113	1.322	106		3.509.674
2021.	Numbering space	3.000.000	2.400.000	1.650.000				7.050.000
	Post-paid	410.353	376.380	239.087	1.403	86	800	1.028.109
	Pre-paid	1.220.087	961.154	553.266			5.149	2.739.701
	Total subscribers	1.630.440	1.337.534	792.353	1.403	86	5.149	3.767.810
2022.	Numbering space	3.000.000	2.400.000	1.650.000				7.050.000
	Post-paid	415.196	396.627	247.229	1.467	84	3.020	1.063.623
	Pre-paid	1.200.304	983.481	557.371			7.152	2.748.308
	Total subscribers	1.615.500	1.380.108	804.600	1.467	84	10.172	3.811.931
2023.	Numbering space	3.000.000	2.450.000	1.650.000				7.050.000
	Post-paid	466.338	437.957	251.602	1.591	85	12.637	1.170.210
	Pre-paid	1.186.911	876.356	615.871			24.929	2.704.067
	Total subscribers	1.653.249	1.314.313	867.473	1.591	85	37.566	3.874.277

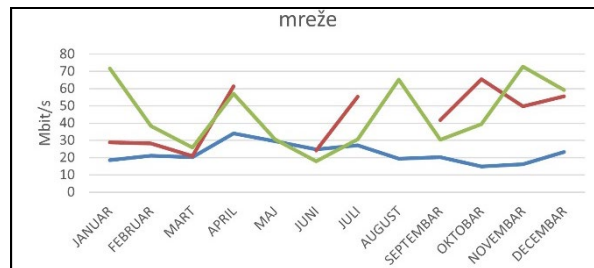
The degree of technological development of modern mobile communication networks is assessed based on the ability of the network to support, above all, broadband data transmission services. Users' constant need for higher data transmission speeds and service quality has forced mobile operators in Bosnia and Herzegovina to constantly improve their networks and thus keep pace with technological development with operators in developed European countries.



**Figure 1:** Penetration of mobile telephony in the period 2011 - 2023

The penetration level (number of mobile subscribers per 100 inhabitants) of mobile telephony in BiH at the end of 2023 was 112.82%. Figure 1 picture shows the penetration of mobile telephony in the period 2011 - 2023. In 2023, penetration was calculated based on the estimate of the population of the Agency for Statistics (3,434,000 inhabitants). [13]

In order to monitor the speed and quality of the broadband Internet access service, the Communications Regulatory Agency (CRA) has implemented the CRA NetTest measurement system, which allows users to test the speed and quality of the broadband Internet access service and monitor the results of other users who have performed measurements. The CRA NetTest application provides the ability to measure speeds in mobile and WLAN networks with all the expected parameters. [14] Figure 2 shows the average download speed by mobile network name in 2023, and the data refers to all 4G measurements by individual mobile networks in the observed period.



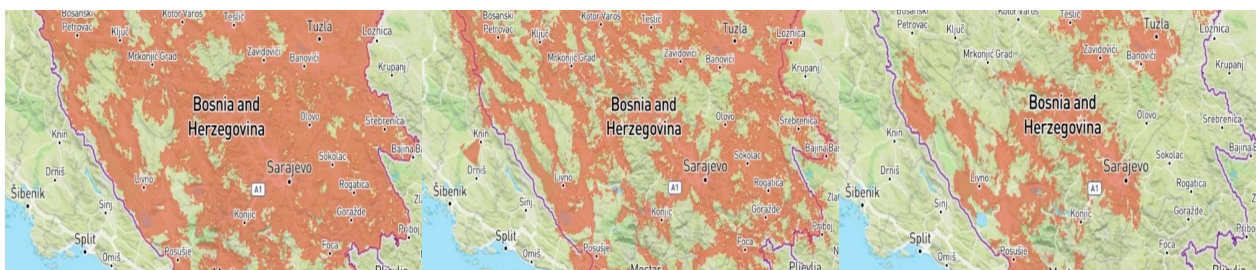
**Figure 2:** Average DL speed over time by network name [15]

Table 3 illustrates data on the total number of mobile telephony base stations that mobile operators have installed and in use, on the basis of licenses issued by the Communication Regulatory Agency. [16]

**Table 3:** Number of mobile base stations

Mobile operators	Cells	Locations	LTE BS
BH Telecom	12359	1500	1443
MTEL	19233	1709	1397
HT Eronet	10696	2185	895

The following image shows the coverage of the territory of Bosnia and Herzegovina by LTE networks of each mobile operator. [17]



**Figure 3:** BH Telecom, MTEL and HT ERONET coverage of BiH territory

Table 4 shows in what percentage mobile operators achieved coverage of roads and territory in BiH with the LTE network. Considering that the 5 years from the issuance of the license will soon expire, they are obliged to achieve coverage of road routes of at least 95%, territory coverage of at least 75% and a minimum average internet access speed of 4 Mbit/s.

**Table 4:** Number of mobile base stations [18]

Criteria	BH Telecom	MTEL	HT ERONET
Coverage of roads in BiH with MBB signal (%)	98,60	97,10	93,50
Minimum average Internet access speed (Mbit/s)	7,68	15,40	-
Voice service territory coverage (%)	91,94	90,20	69,52
Coverage of travel routes by voice service (%)	99,61	98,10	93,25

As for LTE mobile networks in BiH, mobile operators are continuously focused on increasing the capacity of the radio access network. By increasing the density of base stations, an increase in total capacity is generally achieved, but in this way the total interference in the network also increases, so this option, apart from the high costs of building a new infrastructure, also has its own technological limitations.

Another direction of development implies the implementation of 5G mobile networks. Regardless of the dynamics of their introduction, it is realistic to expect that in the first phase they will be available only in urban areas, i.e. in areas where there is a need for services that this technology enables.

#### **4. 5G APPLICATION SCENARIO**

The introduction of new technologies never has the same effect on the transformation and growth of production possibilities of various sectors of the economy, and it is the same with 5G technology. While in some sectors a complete transformation of the way production activities take place and the development of completely new products and technologies can be expected, in some other, predominantly traditionally service industries, the availability of the 5G network will not have such a big impact. Two significant application scenarios are identified below.

##### **4.1. Logistics and transport**

The use of IoT technology based on the use of the 5G network enables real-time tracking of shipments, assets and people throughout the value-added logistics chain, from warehouses, long-distance transport to delivery to end customers. A prerequisite for tracking shipments in real time is the installation of sensors on means of transport and the transported goods themselves. [19] The availability of real-time information also enables a better connection between transport companies and the network of buyers and suppliers, and in this way the distance that transport means travel without a load can be minimized. Increased visibility for logistics company owners directly translates to reduced delays and losses, which ultimately saves time and money. In logistics, every time saving and tracking improvement brings significant cost efficiency. For example, good fleet planning that results in a reduction in empty kilometers has a direct impact on fuel consumption and, therefore, on direct operating costs.

In Bosnia and Herzegovina, logistics and transport services are not at a satisfactory level, especially when we talk about express post services. There are frequent cases of delays and replacement of shipments, damaged ones, and it is very difficult to get timely information about the status of the shipment. The lack of labor force in the country further complicates this situation. "POŠTE SRPSKA", as a public postal operator, may benefit from usage of 5G and IoT, especially in product storage. For example, IoT sensors can be attached to individual items to precisely identify and locate them, significantly improve shelf storage, manage inventory and picking operations (the process of removing goods from storage locations based on customer requests) and packaging, with a detailed understanding of exactly where the specific product is located at any time. In this way, the logistics process can be much more precise, and with a smaller number of staff.

By using 5G technology, certain benefits are realized also for the end user. With more detailed product tracking, logistics service providers will be able to ensure the exact position of the products, help manage the safety of products that could be at risk, such as chemicals or raw materials, and deliver the quality of the item the customer expects. The end user would have the ability to manage its shipments in such a way as to schedule the date and time of delivery, to combine the delivery if (s)he expects two or more shipments and so on. All these possibilities contribute to efficiency, cost reduction and customer satisfaction.

##### **4.2. Sensor Networks**

In 2022, the Communications Regulatory Agency implemented a sensor network to cover urban areas to measure radio frequency spectrum occupancy, interference detection and geolocation. The purpose of this sensor network is to continuously monitor the spectrum in the given RF bands, identify and determine sources of interference for licensed users of the spectrum, without the radio-monitoring team going out into the field. The tasks of the monitoring station are:

- Monitoring of emissions to check compliance with the frequency license,
- Observation of the frequency range and measurement of channel frequency occupancy,
- Search for cases of disturbances/interference,
- Identification of unauthorized emissions,
- Locating, evaluating and identifying unknown emitters and comparing measured data with the database of issued licenses,
- Geolocation estimation using TDOA stations,
- Measurement of radio coverage zone. [20]

This sensor network was implemented using TCI solutions for spectrum monitoring CSMS 709, which were installed on antenna towers throughout Bosnia and Herzegovina. A Cisco C1121-4P network router was also

installed at each location to achieve the sending of data from each sensor station to CRA. Since optical fiber Internet access was not available at each of the locations where the sensor stations were installed, as well as the annual rental price being very high, the TOTAL DATA package option was chosen, i.e. data transmission via GPRS, and where available via EDGE and 3G network. [21] Unfortunately, this method of data transmission has proven to be very inefficient and unreliable, with frequent interruptions and the unavailability of sensor stations that require physical intervention at the location, which represents a waste of time and human resources of the Agency. The mentioned sensor network is one of the first scenarios through which the Agency will be able to test the benefits of 5G networks, especially in the test phase of implementation, which will be discussed in more detail in the next chapter.

## **5. ROADMAP FOR THE INTRODUCTION OF 5G MOBILE COMMUNICATION NETWORKS IN BOSNIA AND HERZEGOVINA**

This chapter presents the sequence of steps that need to be implemented to enable the introduction of 5G mobile communication networks in Bosnia and Herzegovina. Some steps are mutually conditioned, but most can be done in parallel.

Step 1 refers to the harmonization of the regulatory framework in the field of electronic communications with EU regulations, which implies the amendment of the existing Law on Communications or the adoption of a new one to harmonize it with Directive (EU) 2018/1972 on the European Electronic Communications Code (EECC) and the adoption of the Sector Policy of electronic communications of Bosnia and Herzegovina for the period 2023-2027. [22] Further to step 1, it is necessary to harmonize Rule 86/2018 – Plan of Allocation and Utilization of Radiofrequency Spectrum in Bosnia and Herzegovina with international regulations related to the implementation of 5G networks, to adopt a Decision defining the deadline for granting licenses for the use of RF spectrum for the provision of services via the 5G network, conditions for the granting of permits, and the price, method and procedure of payment. [23]

Step 2 entails ensuring the unhindered use of radio frequencies from the range for the implementation of 5G mobile networks on the entire territory of BiH and requires the release of the 3400-3800 MHz range. Previously, this band was intended for fixed access networks and accordingly, in the national territory of Bosnia and Herzegovina, frequency blocks from this band were assigned to the Ministry of Security and the Agency for Identification Documents (IDDEEA). [24] Studies of the compatibility of 5G and fixed access networks have shown that these networks cannot coexist in the same geographical area and in the same frequency blocks, therefore it is necessary to free up the spectrum for the implementation of 5G.

Step 3 represents the implementation of a pilot project in order to enable testing of 5G technologies on a non-commercial basis and must be carried out in coordination with mobile operators. This phase includes not only setting up test locations of base stations and testing the system and its key performances, but also implementing pilot projects with the aim of proving the applicability of the 5G network in vertical industries. [25]

Step 4 refers to the allocation of radio frequencies for the early implementation of 5G mobile communication networks and should be implemented in coordination with step 2.

Step 5 is aimed at removing barriers to the construction of telecommunications infrastructure and the installation of elements of broadband networks. [26] Implementation of Directive 2014/61/EU on measures to reduce the costs of setting up high-speed electronic communication networks into national legislation, while simplifying and increasing the efficiency of the implementation of procedures for approving the construction of telecommunications infrastructure, as well as standardizing the application of regulations by all entity and local self-governments, and defining more efficient procedures for access to land owned by the state and local governments for the construction of base stations, represent the key activities that should be implemented in this step. [27] In BiH, unfortunately, these activities have not even begun and are closely related to the adoption of the BiH Electronic Communications Sector Policy for the period 2023-2027.

Step 6 is about raising awareness of the benefits and communicating the risks of introducing 5G mobile communication networks. This step should include three types of activities. The first activity should take place in parallel with all the previously mentioned steps and is related to the promotion of 5G technology and the advantages it provides. The target groups are vertical industrial sectors, public administration, but also end users of the 5G network. [28] Within the second activities, it is necessary to gather representatives of mobile operators, ICT companies, the academic community, public administration and interested subjects from vertical industrial sectors through special workshops and/or round tables, to consider the possibilities of joint action to use the opportunities that new technology provides as efficiently as possible for overall



economic growth in BiH. [29] It is extremely important to adequately respond to identified public concerns related to issues of the impact of electromagnetic emissions on the environment and the security of 5G networks, which represents the third activity. [30]

Bearing in mind that the above-mentioned activities are highly multidisciplinary, as well as the need for a high level of coordination in their implementation, the involvement and cooperation of all relevant institutions at the BiH level is necessary.

## 6. CONCLUSION

This article gives an overview of the current situation in Bosnia and Herzegovina from the aspect of the state of mobile networks and services. Key advantages of 5G technology were identified, as well as specific application scenarios, where the benefits could be used to improve logistics and transport services, as well as the functionality of the sensor network for measuring radio frequency spectrum occupancy, interference detection and geolocation.

To accelerate the deployment of 5G in Bosnia and Herzegovina, strong collaboration is required between stakeholders, namely regulators, industry associations, network operators, service/technology providers and public-private partnership organizations, who need to engage in continuous dialogue to respond to the challenges we face when introducing 5G networks and to maximize the opportunities it will bring in all economic spheres. This is one of the conclusions of roadmap for the introduction of 5G mobile communication networks in Bosnia and Herzegovina, which is the result of an analysis of both technical and legal aspects.

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# DIGITAL TWINS OF ROAD SIGNAGE: LEVERAGING AI AND RFID FOR IMPROVED ROAD SAFETY

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**Abstract:** *This paper explores ways to enhance road safety using advanced technology. The main idea is to apply RFID technology and AI to improve driver behavior and address potential hazards caused by drivers ignoring traffic signs, which can lead to dangerous incidents. We propose a digital twin model of road signage that processes data received through In-Vehicle Monitoring Systems (IVMS) and Radio-Frequency Identification (RFID) tags. This data, analyzed with AI, provides final estimates and predictions in the form of instructions to drivers, as well as to Road Maintenance and Road Design departments. In conclusion, this model can synchronize and improve all road safety pillars: driver, vehicle, and road. Drivers, through warning messages about potential incidents, become safer drivers. Vehicles, applying these IVMS improvements, become safer vehicles. Roads, applying RFID tags, creating Digital twins of road signage and the ability to change infrastructure based on AI data, become safer roads.*

**Keywords:** *digital twins, IVMS, RFID, road safety, AI*

## 1. INTRODUCTION

Safe roads are the foundation for a safe driving experience. The global picture of road infrastructure, however, paints a concerning story. Reporting countries collectively account for nearly 68 million kilometers of roads. Of this vast network, only 4.5 million kilometers are paved expressways, with the remaining majority consisting of paved interurban roads (47 million km) and unpaved interurban roads (10 million km). Furthermore, there is a dominant focus on vehicle-centric infrastructure. A survey revealed that most countries prioritize building roads for motor vehicles. Many new roads fail to meet recognized safety standards, emphasizing the need for a shift towards designing and maintaining roads with the safety of all modes of transportation in consideration. (World Health Organization (WHO), 2023)

Vehicle road assessment emerges as a crucial tool to address these challenges. By systematically evaluating the condition and design of existing road networks, potential hazards can be identified and improvements prioritized to minimize risks for all types of transportation. This proactive approach, informed by data-driven insights, is essential for ensuring a safe and efficient transportation system in a world with unequal infrastructure. Traffic signage inventory is an important part of transportation asset management, which is a systematic process of operating, maintaining, upgrading, and expanding physical transportation assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making.

Managing traffic signage inventory presents unique challenges due to its distribution along roadways across expansive regions. This necessitates an efficient method for identification and information retrieval. Recent years have seen active exploration into computer-based automated systems for traffic signage inventory management. One such approach involves employing vehicles equipped with video cameras to detect and recognize traffic signs. However, the effectiveness and precision of this visual inspection method heavily rely on factors such as viewpoint clearance and camera lighting conditions. Consequently, performance may suffer in areas with dense vegetation where the camera's view of the traffic signs is obstructed. Another limitation is the difficulty in handling multiple signs clustered on the same structures, as computer vision algorithms often struggle to differentiate between closely situated signs. Additionally, the intensive processing of image data and computation means that most camera-based approaches conduct offline traffic sign recognition after image collection, posing a critical constraint on real-time traffic signage inventory management. (Chen et al., 2022)

Traffic sign recognition systems (TSR) are integral components in modern vehicles, provided by leading auto manufacturers including Audi, BMW, Ford, Mercedes-Benz, Opel, Volkswagen, and Volvo. Typically, these systems consist of a video camera, a control block, and a data output medium, often located behind the rear-view mirror. The second generation of TSR is capable of recognizing various signs such as "Stop at Intersection," "Road Up," and "Priority to Oncoming Traffic." These systems may also integrate with navigation systems to utilize speed limit information from navigation charts when sign identification via the camera is challenging. Functionally, TSR operates by comparing captured traffic signs with database entries, enabling the identification of common traffic symbols. However, challenges arise when unconventional signs, such as maximum speed limit signs on vehicle tanks, are encountered. (Byshov et al., 2017).

Instances of drivers failing to adhere to traffic signs at junctions pose significant risks to road safety. Traditional interventions have often focused on singular aspects, neglecting the complex interactions between drivers, road conditions, and vehicle characteristics. This paper underscores the necessity of addressing these three elements in tandem to effectively mitigate the prevalence of disobedience towards traffic signs. Furthermore, it delves into the potential of modern technologies such as IVMS and RFID to complement existing strategies and enhance overall road safety.

Radio frequency identification (RFID) is widely recognized as a method for identification, tracking, and tracing, serving as a fundamental technology within the industrial internet of things (IIoT). However, IIoT systems necessitate the integration of complex sensor networks to enable pervasive monitoring, presenting ongoing challenges concerning the sensing and recording of data at the item level (Song & Wu, 2024). RFID presents a more effective alternative that addresses the limitations associated with camera-based solutions. Unlike camera-based systems that rely on visual observation, RFID solutions utilize ultra high frequency (UHF) signals to remotely interact with RFID tags affixed to or integrated within objects. These tags respond by transmitting stored data, including a unique tag ID (EPC) and other object attributes. Consequently, RFID technology eliminates the need for visual clearance or high-quality visibility and can be deployed on-site in real-time scenarios. Moreover, RFID solutions demonstrate superior performance in environments with densely clustered assets compared to camera-based alternatives. Recent advancements in RFID-based road applications include the in-motion detection of traffic signs, showcasing rapid processing times for RFID tag identification (Chen et al., 2022).

## 2. RELATED WORK

In the system formulated by Sato & Makanae (2006), fixed operating frequencies are utilized. Unlike the method proposed by Oya et al. (2018), which involves a complex tag encoding scheme leading to increased processing overhead during tag interrogation, Chen et al.'s (2022) system opts to store traffic sign attribute data in a cloud server database instead of directly encoding it into the tag's Electronic Product Code (EPC).

**Table 1:** Comparative view of related works

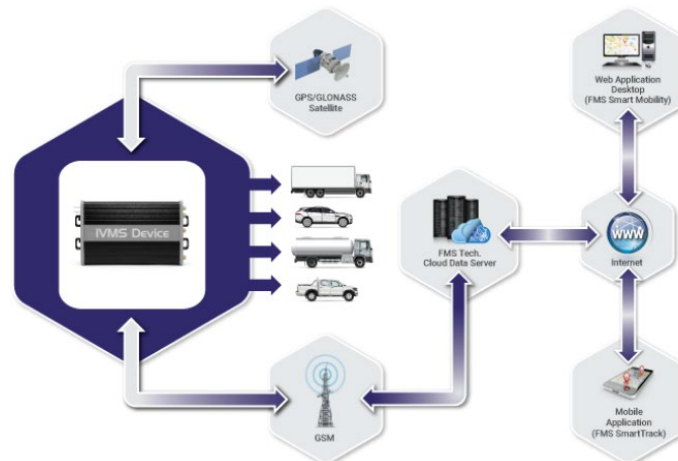
Specification	Oya et al.	Sato et al.	Mariut et al.	Chen et al.
Tag type	Passive	Passive	Active	Passive
Operating frequency (MHz)	886.5	13.56	2400-2483	865-956
Maximum reading distance (m)	4	0.4	30	4.8
Maximum vehicle speed (km/h)	80	32	100	90
EPC storage (bits)	96	64	24	96
Tag price (USD)	3.3	1.31	20	0.75
Tag size (mm x mm)	51.5 x 47.5	76 x 45	Not specified.	75 x 25

While Mariut et al. (2012), utilize active tags for extended tag interrogation distances, up to 30 m, these tags come with a high cost and necessitate battery charging, making them economically unfeasible for large-scale deployment in road sign management, but most stable in detection of traffic signs. The authors aim to achieve good results at a lower cost, so they often use passive tags with a reading range of up to 5m. However, road safety cannot rely on this approach. We assume vehicles will pass close to traffic signs, but in cases of overtaking or avoiding roadwork barriers, the traffic sign might not be read. Additionally, using active tags allows us to capture signals from tags even at vehicle speeds exceeding 100km/h (Masud et al., 2010).

## 3. IN-VEHICLE MONITORING SYSTEMS (IVMS)

In-vehicle monitoring systems (IVMS) track and analyze vehicle activity to improve road safety and efficiency (Chepuru et al., 2020). These systems are becoming increasingly common, even mandatory in some areas. Available for both private and commercial use, IVMS can help young drivers identify areas for improvement.

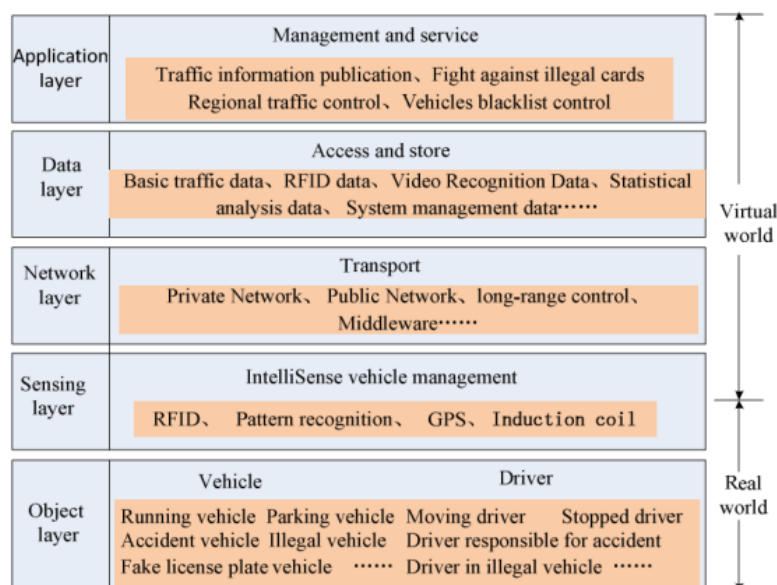
Studies show significant benefits from IVMS, including a 60% reduction in speeding and a major drop in accidents. The system also encourages safer habits like seat belt use and discourages harsh driving behaviors. Beyond safety, IVMS offers cost savings through reduced fuel consumption, less wear and tear on vehicles, and potentially lower insurance premiums (Shell, 2024).



**Figure 1:** IVMS infrastructure (FMS Tech, 2023)

In-vehicle monitoring systems (IVMS) consist of five essential layers: the object layer, the sensing layer, the network layer, the data layer, and the application layer. These layers work together to provide comprehensive monitoring and management capabilities within vehicles (Hu et al., 2011).

- **Object layer:** This layer moves beyond traditional license plates by creating a digital information source for each vehicle and driver. This source acts like a digital ID card, containing identification and regulatory data for both machine and human use (think barcode vs. readable text).
- **Sensing layer:** This layer uses advanced technologies like RFID, GPS, and cameras to collect real-world data about vehicles and drivers. It essentially translates the physical world into a digital one, creating a rich pool of information for analysis.
- **Network layer:** This layer ensures data collected from various sensors gets transmitted across different regions. It acts like a digital highway, carrying information through wired networks, wireless connections, or even satellites.
- **Data layer:** This layer acts as the information hub. It stores sensor data, manages system information, and provides tools to analyze and extract insights from the collected data. It can also control sensor devices and provide basic functions like data retrieval to the application layer.
- **Application layer:** This layer puts the collected information to use. It offers functionalities through various interfaces (large screens, mobile apps, etc.) to manage vehicles and drivers in the real world. This layer essentially builds the foundation for a modern and intelligent transportation system.



**Figure 2:** IVMS 5-layers model (Hu et al., 2011)

The data gathered by IVMS (In-Vehicle Monitoring System) technology can be relayed back to the driver in real-time or retrospectively through various mechanisms. These include in-cab warning lights, auditory alerts, detailed reports, and video playback, all designed to assist drivers in avoiding or correcting risky driving behaviors. By providing immediate feedback, IVMS helps improve driver awareness and promotes safer driving practices. Additionally, retrospective analysis of driving patterns and behaviors allows for targeted training and interventions, ultimately enhancing overall road safety (Bell et al., 2017).

#### 4. DIGITAL TWINS OF ROAD SIGNAGE

The role of the DT extends beyond mere simulation as it actively interacts with the physical system and adjusts to evolving external circumstances. DT technology heavily relies on data intake and correlation analysis, closely intertwined with data-intensive modeling driven by advanced Machine Learning and Deep Learning, as well as big data analytics (Durković et al., 2023).

Our digital twin model is based on enhancing IVMS using RFID technology and artificial intelligence. Essentially, the digital twin would incorporate IVMS that collects data on speed, geolocation, and RPM, crucial for sudden braking of each vehicle.



**Figure 3:** Visualizing digital twins of road signage collecting data

The RFID existing in the vehicle would be unlocked and modified for reading RFID tags on traffic signs. Active tags would be used for the signs to ensure secure data reading, especially in real-time traffic situations such as overtaking and passing, where the distance from the traffic sign could exceed 10m in some cases, making direct reading impossible. The sign readings would be stored in the existing database, which can be exported to a CSV file. It is necessary to initially determine the geolocation of each traffic sign and attach the appropriate active RFID tag to it. It is suggested that this tag be made of PVC plastic shell, that is high-tension, waterproof and is capable of operating in temperatures ranging from -40°C to +85°C, with a range of over 100m and a battery life of 3 to 5 years.



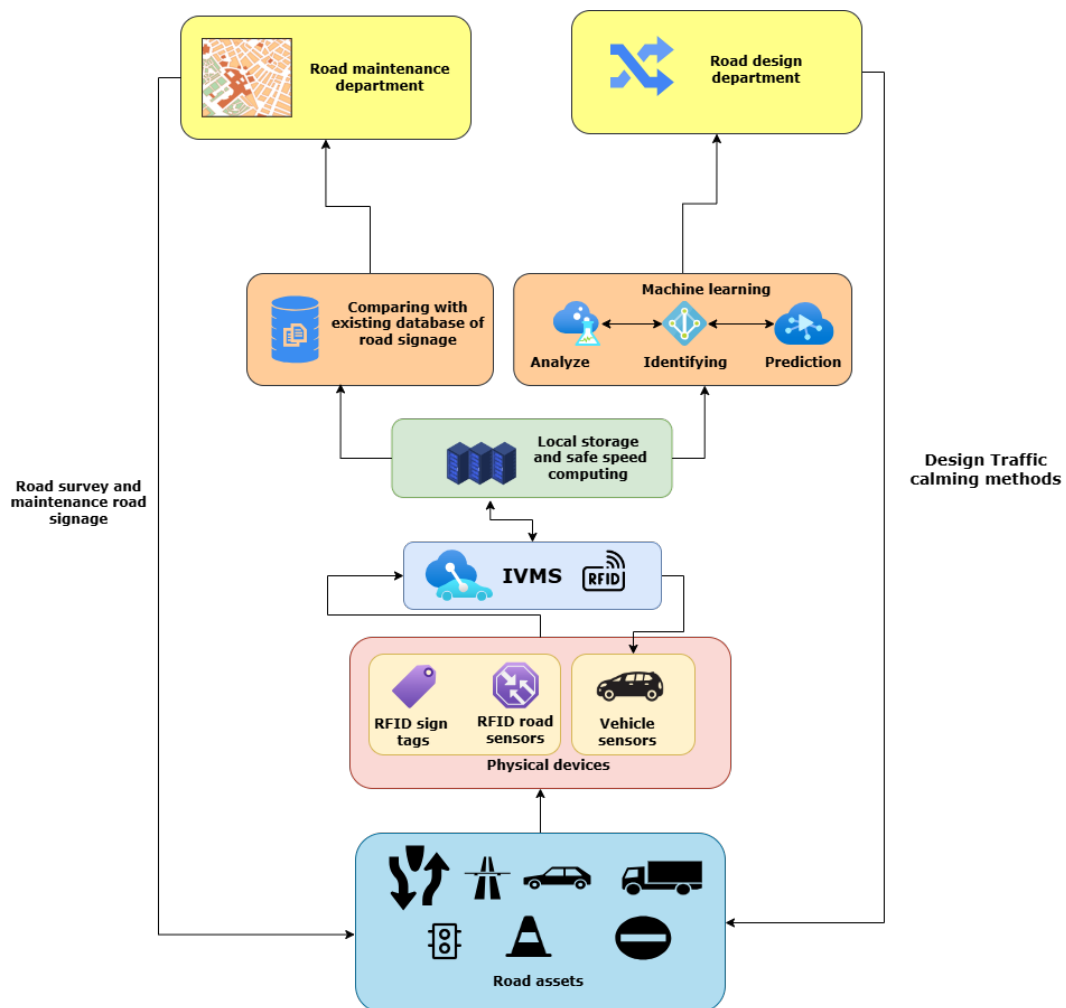
**Figure 4:** RFID active tag (ID TECH, 2024)

The database with the determined geolocation data of all speed limit signs and stop signs (technically, this is a sign limiting the speed to 0 km/h) will be used to predict the speed based on computing and inform the driver to reduce speed. The IVMS itself has a system and a formula for harsh brake - deceleration exceeding 10 - 16km/h/s while driving at speed higher than 30km/h, which is one of the outputs in the report (International Association of Oil & Gas Producers (IOGP), 2024). For example, if the driver is driving at a speed of 100km/h, which is usually the maximum speed for company vehicles, safe braking to a speed of, 60km/h defined at the intersection at a distance of 150m, the speed calculation would be made at 100m, to determine if the driver can reduce the speed to 60km/h safely. If not, a voice message is sent to reduce speed; if yes, the next calculation is made to the sign, to ensure the driver actually slows down, or respects the traffic sign. If the driver exceeds the allowed speed, a message is sent to the system indicating a violation.

**Table 2:** The IVMS report and database contain relevant data for the digital twin of road signage.

Date	Time	Asset	Driver	GPS Position	GPS Direction	Odometer	Speed	Panic Button	Speed limit sign	Sign coordinate	Warning message
23 04 2024	08:16:44	FON Toyota 1206 FO	Milos	22.54348 41.875628	N	42756.801	56	0			
23 04 2024	08:16:45	FON Toyota 1206 FO	Milos	22.54348 41.875628	N	42756.801	65	0			
23 04 2024	08:18:50	FON Toyota 1206 FO	Milos	22.543493 41.875958	NE	42756.85	64	0			
23 04 2024	08:18:59	FON Toyota 1206 FO	Milos	22.543706 41.876175	NE	42756.883	68	0	70	22.544036 41.87689	NO
23 04 2024	08:19:01	FON Toyota 1206 FO	Milos	22.543706 41.876284	NE	42756.89	66	0		22.544036 41.87689	NO
23 04 2024	08:19:07	FON Toyota 1206 FO	Milos	22.543814 41.876384	NE	42756.905	69	0		22.544036 41.87689	NO
23 04 2024	08:19:09	FON Toyota 1206 FO	Milos	22.543814 41.876384	NE	42756.908	72	0		22.544036 41.87689	YES
23 04 2024	08:19:11	FON Toyota 1206 FO	Milos	22.543814 41.876384	E	42756.911	75	0		22.544036 41.87689	YES
23 04 2024	08:19:19	FON Toyota 1206 FO	Milos	22.543814 41.876612	NE	42756.935	74	0		22.544036 41.87689	YES
23 04 2024	08:19:25	FON Toyota 1206 FO	Milos	22.544036 41.87689	NE	42756.959	76	0		22.544036 41.87689	VIOLATION
23 04 2024	08:19:28	FON Toyota 1206 FO	Milos	22.544115 41.876986	NE	42756.975	74	0		22.544036 41.87689	VIOLATION
23 04 2024	08:19:31	FON Toyota 1206 FO	Milos	22.544175 41.877075	NE	42756.986	73	0		22.544036 41.87689	VIOLATION
23 04 2024	08:19:34	FON Toyota 1206 FO	Milos	22.544212 41.877142	NE	42756.994	68	0		22.544036 41.87689	NO
23 04 2024	08:19:37	FON Toyota 1206 FO	Milos	22.544262 41.877215	NE	42757.003	64	0		22.544036 41.87689	NO
23 04 2024	08:19:39	FON Toyota 1206 FO	Milos	22.544285 41.877253	NE	42757.007	65	0		22.544036 41.87689	NO

The RFID reading of signs would act as a trigger for calculations, enabling the retrieval of sign data in instances where the vehicle cannot connect to the GPS or GSM server to confirm their status. Additionally, the RFID reader plays a vital role in gathering data about traffic signs and transmitting it to the digital twin of road signage, thereby informing us of the presence of traffic sign assets on the roads



**Figure 5:** The model of the digital twin of road signage

The primary concept is to utilize data from IVMS to address and enhance our traffic signage, prioritizing deficiencies in traffic signaling and conducting a road survey immediately upon detecting a missing traffic sign tag during scanning. IVMS data will also indicate areas where drivers are most frequently alerted to potential speed limit violations, signaling the need to implement traffic calming measures such as speed bumps, speed indicator signs, and rumble strips at those locations.

Synchronizing Driver, Road, and Vehicle Elements through harnessing technology for enhanced safety (Hadzic & Al Balushi, 2019):

- **Driver Factors:** Understanding the psychological and behavioral aspects influencing driver compliance with traffic signs is paramount. Factors such as distraction, fatigue, or lack of awareness can contribute to disobedience. Educational campaigns and targeted interventions can play a pivotal role in fostering a culture of adherence to traffic regulations.
- **Road Infrastructure:** The design and layout of roads and junctions significantly impact driver behavior. Clear signage, proper visibility, and intuitive road markings are essential for facilitating safe navigation. Moreover, periodic assessments and upgrades to infrastructure should be conducted to address evolving traffic patterns and emerging safety concerns.
- **Vehicle Technology:** Modern vehicles are equipped with an array of advanced safety features that can aid in promoting adherence to traffic signs. IVMS, for instance, enables real-time monitoring of driver behavior, providing feedback and alerts in case of non-compliance. Integration with RFID technology can further enhance situational awareness by providing contextual information about the surrounding environment.

The utilization of IVMS and RFID represents a promising avenue for bolstering road safety. IVMS offers insights into driver performance, enabling proactive measures to mitigate risks associated with disobedience. Concurrently, RFID technology facilitates seamless communication between vehicles and infrastructure, enhancing the efficacy of traffic management systems. By leveraging these technological innovations in conjunction with traditional approaches, a comprehensive framework can be established to address the multifaceted nature of traffic sign compliance on roads, especially at junctions.

#### 4. CONCLUSIONS AND FURTHER RESEARCH

In conclusion, mitigating incidents arising from traffic sign disobedience necessitates a multifaceted approach that considers the synergistic relationship between drivers, roads, and vehicles. By synchronizing these elements and leveraging advancements in technology, substantial strides can be made towards enhancing road safety. The integration of IVMS and RFID presents a compelling opportunity to augment traditional strategies and foster a safer and more efficient transportation ecosystem.

This research explores a digital twin model for road signage, combining existing In-vehicle Monitoring Systems (IVMS) with RFID tags and machine learning. The model offers a comprehensive approach to traffic safety by collecting detailed vehicle data and enabling real-time traffic sign reading. By analyzing this data, the system can predict speed limits and warn drivers in advance, promoting adherence to traffic regulations. Additionally, the model efficiently manages traffic sign information, facilitating informed decision-making for improved traffic management. Additionally, exploring the effectiveness of integrating other sensor technologies, such as LiDAR and camera systems, alongside RFID technology, could enhance the accuracy and reliability of traffic sign detection and data collection.

Moreover, evaluating the impact of the proposed model on road safety outcomes, such as the reduction of traffic accidents and violations, would provide valuable insights into its effectiveness in real-world applications. Additionally, investigating the scalability and cost-effectiveness of deploying the model across different road networks and geographical regions would be beneficial for widespread adoption.

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# THE ROLE OF DIGITAL TWINS IN VERTICAL E-BUSINESS APPLICATIONS

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**Abstract:** *This paper presents a review of digital twins (DT) application in e-business, with a focus on vertical applications in healthcare, agriculture, and smart cities. Digital twins serve as advanced digital replicas that enhance decision-making and operational efficiencies. The main value of this review is identification of different DT application in e-business, gaps in current research and potential research directions, highlighting the importance of DTs in transforming e-business practices across various domains. In healthcare, they provide realistic simulations for medical training and optimize hospital operations. Agriculture benefits from DTs through enhanced modeling and simulation of complex biological systems, driving the digitization and sustainable practices in the sector. Smart cities utilize DTs for urban planning and infrastructure management, leveraging large-scale data and cloud computing. Despite the promising advancements, gaps exist such as the integration of human factors in healthcare, the comprehensive adoption in agriculture, and the interdisciplinary approach needed in smart cities.*

**Keywords:** *digital twin, healthcare, smart cities, agriculture, vertical applications*

## 1. INTRODUCTION

Digital twins (DTs) are accurate digital replicas that integrate real-time data to enhance the efficiency and effectiveness of physical systems across industries like energy and telecommunication (Jafari et al., 2023), aerospace, automotive (Li et al., 2017), healthcare (Xames & Topcu, 2024), agriculture and urban planning and smart cities (Qi et al., 2021). Supported by IoT, AI, machine learning, and big data analytics, these models simulate and analyze physical properties and operations (Qi et al., 2021; Tao et al., 2019). They continuously update from sensor data, ensuring accurate real-time representation and operational diagnostics. While digital twins offer significant advantages, they also pose challenges related to data security, scalability, and ethical considerations, necessitating ongoing research to address these issues and expand their applications (Purcell & Neubauer, 2023).

DTs have rapidly evolved as a pivotal technology in various sectors, propelling e-business into a new era of digital integration. In healthcare, DTs are crucial for simulating both physical spaces and biological entities, significantly enhancing medical training and operational efficiency (Chen et al., 2024; Hassani et al., 2022; Xames & Topcu, 2024). In the agricultural sector, DTs facilitate complex simulations of biological systems, supporting sustainable practices and advancing digitization efforts (Liu et al., 2023; Purcell & Neubauer, 2023; Slob et al., 2023). Similarly, in urban development, DTs contribute to the optimization of city planning and infrastructure management through sophisticated data integration and simulation capabilities (Botín-Sanabria et al., 2022; Jafari et al., 2023; Lehtola et al., 2022).

While the application of DTs is advancing, several critical gaps remain underexplored. In healthcare, the integration of human factors and the transition from theoretical models to practical applications lag behind technological capabilities (Xames & Topcu, 2024). Agriculture's full potential for DTs is hindered by a lack of comprehensive adoption strategies and specific models for varied agricultural practices (Purcell & Neubauer, 2023). In the realm of smart cities, there is a need for more interdisciplinary approaches that combine technological, sociological, and environmental insights to fully leverage DT capabilities (Botín-Sanabria et al., 2022).

This paper aims to bridge these gaps by presenting an in-depth review of current DT applications and identifying unexplored areas that could benefit from further research. By analyzing existing literature and applications, the paper highlights the transformative potential of DTs in e-business and proposes pathways for their fuller integration and utilization across the highlighted sectors.

The rest of the paper is organized as follows: Section 2 shows the theoretical framework behind this research explaining DT as a concept, different architectures and underlying technologies. The third section describes

specific applications in healthcare, agriculture, and smart cities, each subsection identifying current implementations, benefits, and gaps. The conclusion synthesizes these findings, proposing future research directions and practical applications.

## 2. THEORETICAL FRAMEWORK

Digital twin (DT) technology is a key driver in the advancement of Industry 4.0, seamlessly merging cyber and physical spaces (Tao et al., 2019). As a growing field, digital twins have increasingly been used in studies focusing on lifecycle management and predictive analytics across various sectors (Botín-Sanabria et al., 2022). This technology provides comprehensive insights into system operations, interactions between system components, and the anticipated behaviors of their physical counterparts, offering practical benefits for users and stakeholders (Tao et al., 2019). While DTs are seen as innovative, they are essentially an evolution of existing technologies such as 3D modeling, system simulation, and digital prototyping, which includes geometric, functional, and behavioral aspects (Qi et al., 2021).

The origin of the Digital Twin concept can be traced back to a 2002 presentation at the University of Michigan, by dr Grieves titled “Conceptual Ideal for PLM” (Grieves & Vickers, 2016). This slide, although simple, contained all the fundamental components of a DT, including the physical space, virtual space, a connection for data transfer from physical to virtual space, a conduit for information flow from virtual to real space, and various virtual sub-spaces. All five components are critical for DT, and require full integration of data flow in both directions (physical-virtual and virtual-physical) (Fuller et al., 2020). The physical component forms the foundation for constructing the virtual counterpart. This virtual element facilitates the simulation, decision-making, and control processes of the physical component (Grieves & Vickers, 2016; Tao et al., 2019). Central to DTs is data, which is essential as it serves as the basis for generating new knowledge (Tao et al., 2019).

Digital twin is not a singular technology. It is a term encompassing various technologies working together to create a digital replica of the physical product, or a process. Technologies enabling DTs include, but are not limited to (Fuller et al., 2020) (Table 1):

**Table 1:** DT enabling technologies

Domain	Technology layer	Enabling technology
A - Application Domain	Model Architecture and Visualization Software and APIs Data collection and Pre-processing	3D modeling Business process modeling Computer Simulation Virtual and extended reality Internet of Things Cloud computing and infrastructure
		Cloud computing and infrastructure Blockchain Big data analytics Artificial intelligence Machine learning
B - Middleware Domain	Storage Technology Data Processing	Cloud computing and infrastructure Internet of Things Mobile technologies, 5G
C - Networking Domain	Communication Technology Wireless Communication	Cloud computing and infrastructure Internet of Things Mobile technologies, 5G
D - Object Domain	Hardware Platform Sensor Technology	Cloud computing and infrastructure Internet of things

The Application Domain of enabling technologies for DTs facilitates the creation, visualization, and data handling of detailed virtual models that enhance the interaction and management of their physical counterparts. The Middleware Domain provides storage and processing of data collected within the A domain, ensuring the transfer between B and C domains. The Networking Domain enables consistent communication between the domains and layers and wireless communication for data transmission. The last domain ensures the correct hardware is in place to conduct the DT analysis (Fuller et al., 2020).

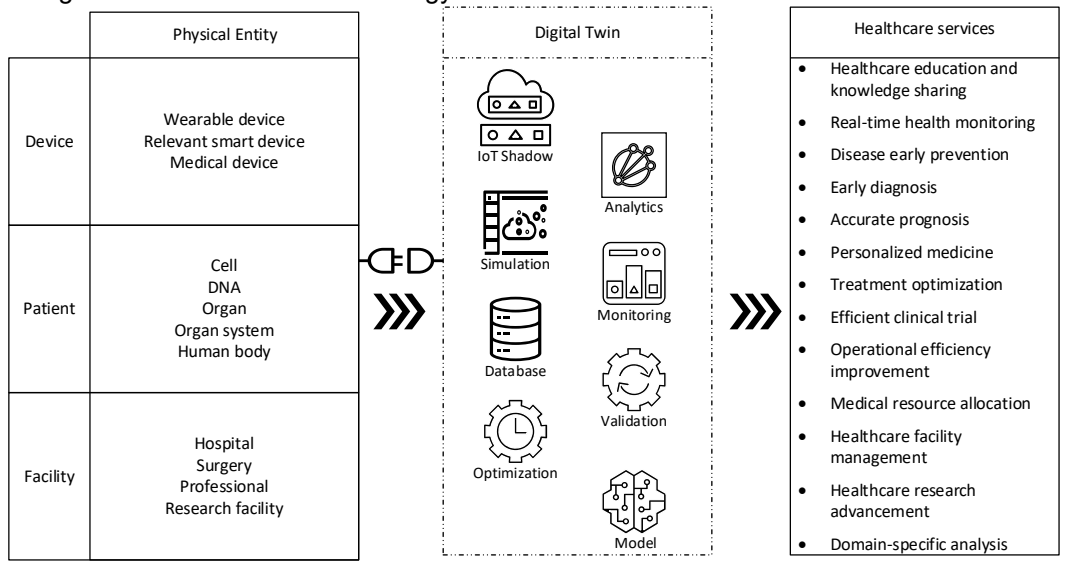
### 3. DIGITAL TWINS IN VERTICAL APPLICATIONS

Vertical applications, as mentioned in the IEEE Technology Predictions Report for 2024 (Abedi et al., 2024), refer to specialized digital solutions designed to meet the unique needs of specific industries or sectors. These applications focus on addressing the particular challenges and requirements of various sectors, enhancing efficiency, productivity, and innovation within those industries. Vertical applications refer to industry verticals, segments of an industry that focuses on a particular niche or market (*What Is an Industry Vertical?* | *Enigma*, n.d.). When talking about vertical applications, we are mostly focusing on following industry verticals (Abedi et al., 2024; *ATIS' Next G Alliance Maps the Future of 6G Vertical Applications* – ATIS, n.d.; ATIS, 2023): Agriculture; Automotive; Education, Gaming and Entertainment; eHealth; Industrial; Mining; Public Safety and Smart Cities.

While DT as a concept has been applied in various industries and domains such as energy and telecommunication, aerospace, automotive, healthcare, agriculture and urban planning and smart cities, this paper will focus on healthcare, agriculture and smart cities. These industry verticals have been identified as key beneficiaries of advancements in state-of-the-art predictions, what-if analysis and oversight, that DT technology brings (Abedi et al., 2024).

#### 3.1. DT in Healthcare

One of the main areas of DT application is medicine and healthcare. DTs have emerged as a transformative technology in healthcare, revolutionizing various aspects from clinical applications to operational management (Sun et al., n.d.). The integration of DTs enhances diagnostic accuracy, treatment personalization (Hassani et al., 2022), and healthcare facility operations, promising significant advancements in patient care and system efficiencies. Figure 1 shows how DT technology transforms healthcare services.



**Figure 1** Digital twin in Healthcare (Hassani et al., 2022)

In clinical applications, DTs have demonstrated substantial benefits across several domains. Specifically, In cardiovascular healthcare, DT technology facilitates precise heart modeling, supporting both diagnosis and interventional procedures(Sun et al., n.d.). Similarly, (Coorey et al., 2022) highlight the deployment of DTs in cardiovascular disease management, stressing their potential in improving outcomes through sophisticated simulation models that anticipate patient-specific reactions to treatments.

Beyond cardiology, DTs extend their utility to areas like surgery, where they provide detailed pre-surgical planning and simulations, and pharmacy, where they model metabolic responses to drugs, allowing for personalized medicine (Sun et al., n.d.). These applications underscore DTs' capacity to adapt treatments to individual patient needs, significantly reducing risks and enhancing therapeutic efficacy.

However, the path to integrating DTs in healthcare is full of challenges. Data integration, real-time processing capabilities, and ethical concerns about data privacy present an unsolved hindrance (Hassani et al., 2022). Moreover, the interdisciplinary nature of DT development necessitates a collaborative approach involving various stakeholders to realize its full potential (Coorey et al., 2022). Another major gap highlighted by (Xames & Topcu, 2024) is the lack of implementation research. While many studies propose theoretical models and conceptual frameworks for DTs in healthcare, there is a need for more empirical studies that move beyond conceptualization to evaluate the effectiveness, usability, and impact of DTs in live healthcare environments.

### 3.2. DT in Agriculture

The agriculture industry can benefit immensely by integrating DT. Some of the areas of enhancement are precision, sustainability, and operational efficiency. Sophisticated modeling of crop and livestock systems, enabled by DT technology, facilitates real-time monitoring and predictive analytics, leading to more informed decision-making (Ghazvini & Sharef, 2023; Purcell et al., 2023; Purcell & Neubauer, 2023). In crop management, DTs specifically aid in precise nutrient management and disease control. For example, (Ghazvini & Sharef, 2023) describe a DT model for rice that uses regression algorithms to accurately predict nutrient concentrations and compositions, thereby optimizing fertilization practices and reducing environmental impact by preventing fertilizer overuse.

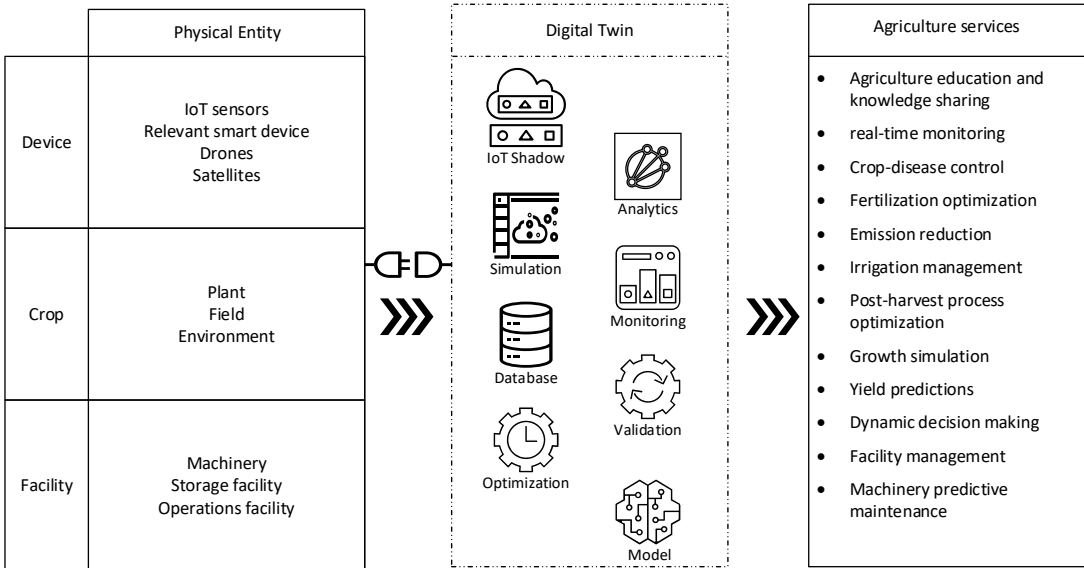


Figure 2 Digital Twin in Agriculture

Expanding the application of DTs, (Purcell & Neubauer, 2023) showcase how these technologies enhance livestock monitoring, crop input optimization, and emissions reduction (Fig 2). Similarly, (Nasirahmadi & Hensel, 2022) emphasize DTs' contributions to soil and irrigation management, as well as post-harvest processes, which collectively improve water use, crop productivity, and food quality. In the specific arena of greenhouse horticulture, (Ariesen-Verschuur et al., 2022; Slob et al., 2023) explore DTs' capabilities in growth simulation and yield prediction, integrated with greenhouse control systems for better-automated management. These studies highlight the critical role of DTs in addressing global challenges like food security and climate change, advocating for continued technological advancement and a multidisciplinary approach to ensure DTs' sustainable development in agriculture.

### 3.3. DT in Smart Cities

Digital Twins are reshaping urban landscapes by offering sophisticated solutions for city management, planning, and governance. DTs are utilized in urban management by creating dynamic, virtual replicas of cities that integrate real-time data from IoT devices, sensors, and other digital sources (Botín-Sanabria et al., 2022). This technology supports city planners in simulating and analyzing urban scenarios, enhancing decision-making, and improving public services, with systems like GIS and BIM providing high-fidelity content that accurately reflects the urban environment (Deng et al., 2021; Lehtola et al., 2022). DTs contribute to sustainable urban planning by optimizing resource use and infrastructure development, supporting public safety through efficient emergency response systems, and fostering greater public participation in planning processes, making them more inclusive and transparent (White et al., 2021).

Furthermore, DTs are vital in managing energy systems within smart cities, enhancing the efficiency of smart grids and transportation systems through capabilities like real-time monitoring, system management, fault detection, and predictive maintenance (Jafari et al., 2023). Practical implementations, such as Dublin's Docklands digital twin model, showcase DTs' ability to simulate new building developments, green spaces, and flood scenarios, enabling effective community engagement and feedback integration into urban planning and policy-making (White et al., 2021). This hands-on application highlights DTs' potential to transform urban landscapes into smarter, more responsive, and sustainable environments.

Having this in mind, (fig 3) shows how city can be transformed into a smart city utilizing devices, citizens and DT technology.

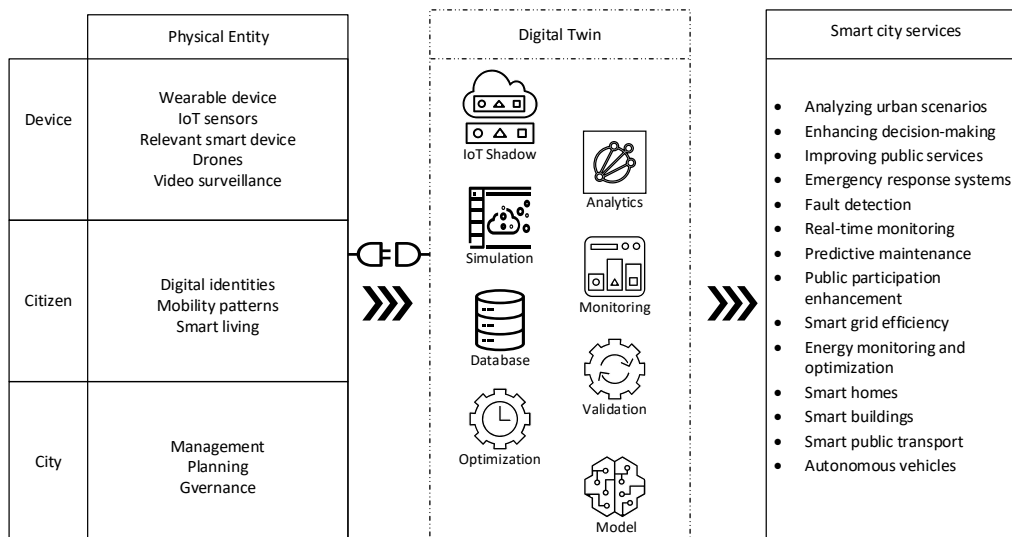


Figure 3 Digital Twin in Smart Cities

#### 4. DISCUSSION AND CONCLUSION

Digital Twins in vertical applications like healthcare, agriculture, and smart cities offer transformative potentials but also face significant challenges and limitations that must be addressed to realize their full benefits.

In healthcare, the future of DTs lies in enhancing precision in health monitoring and predictive healthcare (Hassani et al., 2022), potentially leading to earlier interventions and better health outcomes. However, challenges such as the integration of advanced technologies into clinical settings, data privacy concerns (Venkatesh et al., 2024), and the need for substantial infrastructural changes pose barriers to adoption. (Venkatesh et al., 2024) emphasize that advancing drug discovery and personalized medicine through DTs will require overcoming socioeconomic and regulatory challenges to ensure equitable access and effective implementation.

In agriculture, DTs promise to revolutionize farming practices through improved data integration and IoT technology (Nasirahmadi & Hensel, 2022). Yet, the adoption faces technological challenges such as managing data from diverse sources and ensuring real-time data processing capabilities. Socioeconomic barriers, accessibility, affordability, and the need for training reflect the multifaceted challenges in this sector. Environmental considerations are also crucial, as DT implementations must not exacerbate existing ecological issues or fail to adapt to climate change impacts. Ethical and social considerations, including data security and potential job displacement due to automation, are paramount for ensuring that DT adoption is secure and socially beneficial.

For smart cities, DTs hold the promise of making urban areas more efficient, sustainable, and responsive to citizen needs. However, similar to healthcare and agriculture, challenges such as data integration, cybersecurity, and maintaining the continuity and reliability of digital models are significant. These issues require ongoing research and interdisciplinary efforts to develop robust and secure DT frameworks capable of handling urban complexities (Botín-Sanabria et al., 2022).

Overall, while DTs present a forward-looking approach to managing complex systems across various domains, their successful integration hinges on overcoming these diverse challenges. The future of DTs will depend on continuous technological innovations, policy support, and ethical considerations, ensuring that these powerful tools enhance rather than complicate the sectors they are meant to transform.

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# **FINANCIAL INNOVATIONS AND CHALLENGES IN CHANGING BUSINESS ENVIRONMENT**



# PORTFOLIO MANAGEMENT USING MACHINE LEARNING: SCOPE OF APPLICATIONS

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**Abstract:** *The portfolio management is complex process in which financial resources are allocation to selected assets enabling the construction of a portfolio according to risk-reward preferences and cash flow requirements of the investors. After the portfolio is constructed, the process of portfolio management continues with portfolio strategy formulation and execution, portfolio evaluation against the chosen benchmark and, portfolio performance evaluation. In this regard, machine learning techniques, especially deep learning, artificial neural networks, and reinforcement learning have been used. Having in mind that in nowadays the portfolio management has to be more efficient, the machine learning could be used for portfolio management improvement. The aim of the paper is to present the scope of machine learning applications by considering the most valuable papers and studies that have emerged over the past ten years. The paper showed what machine learning techniques were used to most and why this had happened. At the same time, the paper indicated that asset selection and allocation, and portfolio strategy and portfolio performance evaluation represent the issues on which machine learning techniques could be used more and in a better way than they are used until now.*

**Keywords:** *portfolio management, machine learning, asset selection, asset allocation, portfolio performance*

## 1. INTRODUCTION

Machine learning (ML) represents a key artificial intelligence technique that focuses on data preparation and prediction, which can be invaluable for portfolio management decision-making. The types of machine learning are: supervised learning, unsupervised learning and reinforcement learning.

Supervised learning is based on data collection and tries to predict the outcome using partial least squares, principal component analysis, least absolute shrinkage and selection operator, least angle regression, ridge regression, decision trees, support vector machines, artificial neural networks and so-called deep learning techniques) (van Liebergen, 2017; Awad, 2015). All of the listed supervised learning techniques can be used in portfolio management, where some are used more often for portfolio selection and construction, while others are more often used for portfolio rebalancing, its optimization and performance improvement.

Artificial neural networks are used for predicting portfolio returns, i.e. portfolio performance. Finally, deep learning and neural networks can be considered both supervised and unsupervised machine learning because they can be applied to predict outcomes (e.g. portfolio exposure to market risk) as well as to learn from data, thereby providing a more reliable basis for making portfolio decisions.

Deep learning combines artificial neural networks with techniques that enable automatic discovery of representative data for variable detection and/or data classification. In other words, deep learning uses a hierarchical level of artificial neural networks that enables data processing using a non-linear approach. This technique represents a relatively new technique that adds the so-called "hidden layers" to input data and enables modelling the influences among them. In this way, deep learning makes it possible to solve the problem known as the so-called. black box, i.e. the problem that is inherent portfolio decision making.

Unsupervised learning enables better classification of data and cluster creation in order to obtain signal(s) that could be considered in decision-making. In general, this technique includes the learning of structured patterns observed in the data based on the rejection of the so-called Pure unstructured noise. In this regard, clustering and dimensionality reduction algorithms are usually unsupervised.

Reinforcement learning is an algorithm that helps the program understand what has been done well. This learning helps neural networks and machine learning algorithms to identify what was done well, prompting them to try to do it the same way again. Sometimes this learning pays off and sometimes it doesn't. The real goal of this learning is to help the machine or program understand the correct path so that it can be replicated later.

Having in mind, the potential machine learning techniques have and bearing in mind that the goal of portfolio management is to achieve the expected return on the portfolio with an acceptable level of risk, the aim of the

paper is to indicate what has been done in this field so far. In other words, the aim is to provide an insight into this significant area that will require more attention because of its importance to institutional investors (especially mutual and hedge funds).

The rest of the paper is structured as follows; in the section two the portfolio management process is presented. Section three considers the application of different machine learning techniques in asset selection and allocation portfolio selection and portfolio construction. In section four portfolio performance evaluation using machine learning is presented. Finally, in section five concluding remarks and directions for further research are given.

## 2. PORTFOLIO MANAGEMENT OVERVIEW

Portfolio management should be defined in a way that enables optimization of portfolio performance on the basis of risk assessment strategy definition and diversification. In other words, portfolio management process requires: definition of portfolio management goals, asset allocation and selection, portfolio construction, portfolio management strategy definition and implementation, portfolio performance monitoring, revising the portfolio strategy periodically, portfolio assessment in relation to benchmark(s), investment risk mitigation and management, portfolio optimization, and diversification strategy and, diversification strategy choice.

Portfolio management goals are defined based on the assessment of risk appetite, investment horizon and expected return on investment.

Assets can be allocated on different asset types (such as stocks, bonds and cash), which has the greatest impact on portfolio performance. Depending on risk appetite, the portfolio will consist of an approximately equal percentage of shares and debt securities (moderate risk appetite), higher percentage of debt securities (risk aversion) or higher percentage of shares (aggressive approach).

The selection of assets that will be included in the portfolio should be done in accordance to portfolio management goals, risk appetite and asset allocation. It is necessary to choose which security to invest in, i.e. whether and in what percentage to invest in shares, notes, bonds, investment funds, exchange-traded funds, real estate trusts etc.

Portfolio construction is based on asset allocation and selection and can be done by purchasing securities, opening investment accounts, executing trades, financial resources allocation and cash flow investment accounts management.

Portfolio management strategy definition requires identifying specific strategies to be implemented, such as whether passive or active portfolio management strategies will be implemented, how and to what extent diversification or market timing will be applied. After the s has been done, the chosen strategy has to be implemented, by investment decisions implementation, portfolio rebalancing, cash flow management, trade execution, tax impact and portfolio adjustment in relation to timing, costs and market conditions.

Portfolio performance monitoring is of key importance for portfolio management goals achievement. It includes monitoring the investment performance, assessing the level of risk and comparing the accomplished results with the benchmark(s). It is necessary to choose portfolio performance measures, and they can be: return on investment, volatility, Sharpe's ratio, tracking error and maximum drawdown.

Revising the portfolio strategy periodically is necessary for adapting the portfolio to changes in market conditions and the needs of investors adjustments and revisions, which can be done quarterly, semi-annually or annually.

Portfolio assessment in relation to benchmark(s) provides insight into the relative performance of the portfolio and identifies opportunities for their improvement. This includes the selection of the appropriate benchmark(s), calculation of performance measures and analysis of results. Depending on the structure of the portfolio, different indices can be used as benchmark(s). Portfolio should be evaluated against the chosen benchmark(s).

Investment risk mitigation and management is of a great importance for portfolio management. This includes identifying potential risks, defining adequate risk mitigation strategies, and monitoring and managing risks over time. Risk mitigation strategies can be: diversification, asset allocation, stop-loss orders, hedging and risk assessment.

Portfolio optimization refers to finding opportunities to increase returns and minimize risk through identifying possible improvements, analysing the impact of proposed changes and applying optimization strategies, such as: rebalancing, tactical asset allocation, tax-loss harvesting, cost reduction, etc.

Finally, diversification can be oriented to specified activities and sectors or it can be done by investing in a relatively large number of assets. Besides this, can be dynamic (based on market conditions) or global.

### **3. ASSET SELECTION, ASSET ALLOCATION, PORTFOLIO SELECTION AND PORTFOLIO CONSTRUCTION USING MACHINE LEARNING**

Asset selection can be done by the use of different machine learning techniques. Over the past ten years, a certain number of studies in this field have been conducted, whereby some studies showed relatively good results (Black and Litterman, 1991; Fu et al., 2018; Feng et al., 2020; Kaczmarek and Perez, 2021; Li et al., 2022a). Furthermore, study of Patalay and Bandlamudi (2020) proposed the prediction of stock prices, portfolio generation and model selection based on machine learning algorithms, artificial neural networks, statistical techniques and so-called unstructured learning. The results of the study are encouraging because the models showed the ability to predict share prices for at least three months in advance, which allowed for a better selection of securities in the portfolio.

Besides this, the paper of Kim et al. (2022) should be mentioned because it gives a novel portfolio management framework called ASA that combines ranking models with classification and regression models for autonomous stock selection and allocation. For stock selection, this model suggests combining the simple graph-based and hypergraph-based ranking models that enable the most profitable stock to be selected into portfolio. On the other hand, Shukla et al. (2022) have considered portfolios consisting of stocks and fixed income securities, where different machine learning techniques are used for stock selection and financial asset allocation. It is also necessary to point out to study of Patalay and Bandlamudi, (2022) which proposes the prediction of stock prices, portfolio generation and model selection based on machine learning algorithms, artificial neural networks, statistical techniques and so-called unstructured learning. The results of the study are encouraging given that the models were shown to be able to predict share prices for at least three months in advance, which allowed for a better selection of securities in the portfolio.

Assets allocation represents the specified number of securities in which the financial asset will be invested based on risk aversion of the investor. In this regard, the genetic algorithms are applied for portfolio weights calculation (Fu et al., 2013). The combination of clustering algorithm and genetic algorithm are used for asset allocation optimization and diversification and provide so-called optimal ratio of selected individual actions and so-called risk-free securities (Gupta et al., 2020). Some authors (Haddadian et al., 2022) propose the use of neural networks and technical indicators, while some others (Kim et al., 2022) propose the combination of classification and regression models

Asset allocation directly influences the portfolio selection. For portfolio selection K-means algorithms were used recently (Aithal et al., 2023). On the other hand, Talebi et al. (2022) proposed neural network model that provide optimal solution to the linear programming problems related to portfolio selection.

After the asset allocation and portfolio selection are done, portfolio can be constructed. In general, the aim is to create so-called optimal portfolio. In this regard a various machine learning techniques can be applied. Zang and Chen (2017) have constructed a portfolio based on spectral clustering that showed better performances compared to traditional methods.

For portfolio optimization supervised and reinforcement learning are commonly used. The paper of Solin et al. (2019) has used an artificial neural network and a genetic algorithm for forecasting and optimization of stock portfolios, and shows that their application gives better results compared to a model that uses only one index, both in terms of returns and risks, as well as in terms of improving portfolio management. In other research, recurrent consolidation learning has been successful in portfolio optimization by rebalancing the portfolio constantly (Aboussalah and Lee, 2020). Another paper (Wu et al., 2021) developed a Portfolio Management System using reinforcement learning with convolutional neural networks and recurrent neural networks. Moreover, a new reward function involving Sharpe ratios is proposed for system performance evaluation, which showed very good performance. Some paper represents an overview of machine learning techniques used for portfolio optimization (Santos et al., 2022; Wang, 2023). It is worth pointed out to paper that proposes a predictive auxiliary generative adversarial network classifier (PredACGAN), which uses the characteristics of an adversarial network in which the output of the generator forms a distribution. The algorithm uses risk measurements to arrive at a classifier. In the algorithm, funds that were predicted to be exposed to high risk were eliminated from investing when rebalancing was necessary. Therefore, PredACGAN considers both return and risk in order to optimize the portfolio. The proposed algorithm and PredACGAN showed that higher annual returns and higher value of Sharpe's ratio (Kim and Lee, 2023)

### **4. PORTFOLIO PERFORMANCE EVALUATION USING MACHINE LEARNING**

Portfolio performance evaluation tries to assess how the chosen portfolio has performed compared to selected benchmark(s). The portfolio evaluation can be done with application of traditional and conditional performance measures. Traditional performance measures are based on the assumption of constant risk over the entire evaluation period. These measures compare the portfolio performance with a chosen market index by measuring to what extent portfolio return deviates from the market return, i.e. whether it performs better or

worse than market. The commonly used measure tries to adjust portfolio returns taking into consideration risk levels between the chosen and market portfolio (Treynor, 1962; Sharpe, 1966; Jensen, 1968). On the other hand, conditional measures take into account the risk and return variation. The main conditional measures are conditional alpha, conditional beta and conditional market timing. Some empirical studies (Tchamyoun, 2017; Alkhazali, 2020) showed the improvement of portfolio performance measurement.

Over the past ten years a certain number of researches of performance evaluation using machine learning have been conducted. In their paper, Zhang and Chen (2017) have constructed portfolio based on spectral clustering and shows that artificial intelligence techniques contribute to achieving better performances compared to traditional methods.

Bae et al. (2018) proposes the application of rank prediction methods in portfolio management using an artificial neural network. Since this network requires large series of data, a method of data augmentation was used and then included in the neural network. The simulation study showed that the mentioned method improves performances compared to other methods. Syu et al. (2020) developed a portfolio management system with a market-neutral strategy focused on stocks in reinforced learning. In addition to this, a new return function has been created that includes the Sharpe ratio to evaluate system performance. Experimental results indicate that the system with this new function has very good performance, and that it significantly increases the yield compared to benchmark strategies. Some authors have used portfolio optimization techniques and hierarchical risk parity optimizers and showed that this combination can improve the performance of a portfolio constructed with stocks that are preselected using machine learning (Kaczmarek and Perez, 2021). In addition to the mentioned papers, it's worth pointing out to the paper of Gao et al. (2020) that introduces the strategy of the so-called "deep" Q-nets in order to optimize the weighting of the securities in the portfolio and increase the performance of the portfolio in relation to the application of traditional strategies, where it has been proven that this strategy significantly increases the return while reducing the risk.

## 5. CONCLUSION

Portfolio management has to be efficient in terms of time, return and risk, and performance. Because of that the role of portfolio manager becomes even more challenging. In this regard, the emergence and development of machine learning as key artificial intelligence technique, has directly influenced on increase in efficiency and portfolio management improvement.

Over the past ten years, the number of papers and studies that tried to apply machine learning in portfolio management is growing. Some portfolio management issues have been relatively good researched and indicated that machine learning techniques can improve portfolio management process through better asset selection and allocation based on investor's risk-return profile and enabling the portfolio construction and portfolio strategy definition in accordance to portfolio management goals. In addition, portfolio optimization has been researched quite well, providing the guide to portfolio managers in portfolio management decision-making.

The paper indicated where and how machine learning can be applied in portfolio management, i.e. it presents an overview of what has been done and, in that way, indicated the scope and ranges of machine learning use in portfolio management. At the same time, it was pointed out to issues in which machine learning techniques are rarely applied, such as the formulation and portfolio rebalancing and diversification strategies as well as the portfolio performance evaluation. The future research will be focused on exploring the possibility of better and greater application of supervised and reinforcement learning in asset allocation, evaluation of trading strategies and evaluation of portfolio performance.

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# DIRECT COSTS OF ASSISTED REPRODUCTIVE TECHNOLOGY TREATMENT: A STUDY FROM SERBIA

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**Abstract:** ART treatments are widely used as effective ways for infertility and one of the main challenges in infertility treatments is high medical costs. ART or IVF is a for-profit medical field on the world map, where it is not only the absolute amount that the government and patients spend on IVF services that matters but also the measure of profitability estimated using costs per live childbirth. Data were collected for cycles of ART treatment carried out in a private clinic in Serbia. Research shows the reduction in female fertility between age groups and that is related to age. The age group  $\geq 42$  years spent the most health care resources and therefore in this age group the utilisation of donated eggs would make a better rate of success using ART and would be more cost-effective per live childbirth.

**Keywords:** infertility, assisted reproductive technology treatment, direct costs

## 1. INTRODUCTION

According to the World Health Organization – WHO (2023a), "infertility affects millions of people – and has an impact on their families and communities. Estimates suggest that approximately one in every six people of reproductive age worldwide experience infertility in their lifetime". Many reasons could cause infertility (WHO, 2023b). Planning the number and timing of having children should be one of the essential human rights, and that right could be threatened by infertility. This is the reason why is important to address the infertility issue and give rights to individuals to create their own family.

The importance of the infertility issue has been recognized and included in the United Nations' Sustainable and Development Goals (SDG), as a crucial part of the 2030 Agenda for Sustainable Development. Out of 17 SDG, infertility has been addressed in the two goals for health and gender rights. Target 3.7. of Goal 3 – Good health and well-being, indicates that "by 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes" (United Nations, 2015).

Assisted reproductive technology (ART) treatments are widely used as effective ways for infertility. As in most other countries, infertility in Serbia is challenging regarding availability, access and quality of interventions. One of the main challenges in infertility treatments is high medical costs. ART or in vitro fertilization (IVF) is a for-profit medical field on the world map, where it is not only the absolute amount that the government and patients spend on IVF services that matters but also profitability of this process quantified as a cost per one live child born.

In the Republic of Serbia, many infertility services are covered by health insurance. Although public coverage is available for infertility treatment, the private sector predominates in the field of assisted reproduction. In 2010, the age limit for financing in vitro fertilization was moved to 40 years at the expense of the Republic fund of health insurance, couples then had two attempts of the treatment. In 2017, the age limit was moved to 42 years, and the number of attempts was increased to three procedures of treatments. The new Directive from 2023 foresees an

unlimited number of stimulated IVF procedures, as well as three cryo-embryo transfers for the first child, two stimulated procedures and one cryo-embryo transfer for the second child, and the age limit for women will also be raised to 45 age of life of women (Republic fund of health insurance, 2023). Studies show that the threshold for increased risk as well as low prognosis for achieving pregnancy is  $\geq 42$  years (Havrljenko et al., 2023). The number of live births per cycle decreases from 10% at age 40, 6.9% at age 41, to 5.4% at age 42, to 4.1% at age 43, and to 0.0% at age 44 of life of women (Health Research Bord, 2017).

This study give focus on the costs and results of ART treatment in the Republic of Serbia. Main outcome of the research would be to suggest the way ART should be financed, but also to give indication of the target clients that are acceptable for this type of treatment, since this causes a significant debate among doctors. Another important question to be answered regards weather the number of ART treatment cycles that are financed by government should be limited, grounded on the age of life of the woman, and the number of treatment cycles attempts. The aim of the study, on direct costs and outcomes borne by the government and patients, was to estimate the average costs of one ART services, as well as the average and group-specific costs per patient-year per one live childbirth for all ART treatments. A huge shortcoming of this research is the non-existence of similar researches that tackle both costs and effects for this type of services in the Republic of Serbia.

After the introduction, this paper gives a literature review on the given subject, methodology and research section as well as results and conclusion part, with a list of references at the end.

## 2. LITERATURE REVIEW

Many cultures consider human fertility as being of the highest importance for the existence and continuance of mankind (Doody, 2021). For reproductive medicine the problem of infertility has always been a primary challenge but, diagnosis and treatment of this medical condition are high-priced, with no existence of a procedure that could lead to healthy pregnancy and delivery of a live and healthy baby. (Szamatowicz & Szamatowicz, 2020). Infertility treatment and reaching fertility goals could be assisted with accurate diagnosis and effective therapy, with success rates that depend on age and diagnosis (Carson & Kallen, 2021).

Assisted reproductive technology (ART) which can be defined as process that comprises of several treatments that deal with infertility and should led to healthy pregnancy, has increased steadily in the last two decades, mainly for two reasons – raising the age limit of women in the process and raising the insurance coverage (Luke, 2017). The high cost connected with ART treatment from one side, and rising infertility on the other, has raised the ethical question of whether ART is available just to wealthy individuals or couples (Faircloth & Gürtin, 2018).

Researchers Read et al. (2014) in their study had recommended consulting people in ART treatment if they needed psychosocial support and what kind would be most useful. These recommendations came after their study revealed that during the ART treatment people appreciate understanding and sharing experiences, practical information, social engagement, or guidance from those who had finalized their ART, to better manage stress, relationship issues, etc.

There are research studies that have analyzed the costs and performances of ART treatments. Authors Crawford et al. (2016) have calculated treatment and pregnancy-related medical costs, for ART, on sequential single and double ETs (elective double embryo) and found out that sequential single ETs carry costs that would be lower, on one hand, but with increased rates of live childbirth from 57.7%–68.0%, on the other hand.

An interesting study has been performed by Njagi et al. (2023) who have researched the direct costs of (ART), but also are those costs acceptable for those patients that live in low- and middle-income countries. They found out that the “direct medical costs paid by patients for infertility treatment are significantly higher than annual average income and GDP per capita, pointing to unaffordability and the risk of catastrophic expenditure for those in need.”

Authors Kawwass et al. (2021) have paid special attention to mandatory insurance coverage of ART treatments and the human right to it. Research, conducted in the USA, has shown that “have improved coverage of fertility services, significant gaps in access to treatment still exist. The gaps in access to care are the result of an imperfect patchwork that purposely or unknowingly excludes broad groups of individuals and couples with inconsistent inclusion and exclusion criteria and, in some cases, medically illogical treatment requirements.”

Research studies that have analyzed ART treatments about international approaches to public financing mechanisms and the criteria, show that infertility treatments are paid by a combination of limited public funds and private client's money (Keane et al. 2017).

### 3. METHODOLOGY

To calculate the direct costs of ART treatment in Serbia for at least one live childbirth, according to different age categories, authors have relied on the research model of Chambers et al (2006).

For this study, data were collected for cycles of ART treatment carried out in the period from July 1, 2022. to July 31, 2023. in a private clinic in Serbia. Data were statistically analyzed, and authors have gotten information about total financial resources spent on ART treatments in Serbia. This research does not rely solely on fertility clinic fees but reflects total healthcare costs from both patients themselves and government insurance. Due to the difference in the fees of infertility clinics, the costs were nationally adjusted by taking the average value of the prices for these services in the Republic of Serbia of direct services of fresh and thawed cycles from the websites of clinics that have a price list on their website, as well as the price paid by the Serbian Republic Fund for Health Insurance (RFZO) taken as the average value of prices for these services in the Republic of Serbia.

Authors will express categorical variables as absolute and relative numbers in percentages. Depending on the data distribution, numerical data are expressed by mean and standard deviation or median and interquartile range. The normality will be checked by the Shapiro-Wilk test. Only direct healthcare ART treatment costs were taken into consideration. To obtain average ART cost per one cycle, authors have divided total cost of all ART treatments with the number of cycles that have been initiated. Further, the average costs and costs connected with specific age category per live childbirth, have been computed dividing the total ART services costs by the number of live childbirths, given for each age category separately. All analyses will be considered significant at the level of 0.05. The data analysis will be completed using IBM SPSS ver. 21 program.

### 4. RESEARCH

In the period from 1st July 2022 to 31st July 2023 a total number of 1215 non-donor ART cycles were started in a private clinic in Serbia. Of those 1215 cycles 609 were fresh IVF cycles and 606 frozen IVF cycles. Costs for those cycles were both covered by the Republic Fund for Health Insurance and patient's own financial resources. Table 1. presents the type and number of cycles and related costs. Costs associated with hormone support or drug consumption were adjusted for differences related to the length of stimulation and the number of ampoules used, and the mean values of the length of stimulation and the consumption of drugs for stimulation were taken.

The entirety of the direct price for healthcare in the non-donor ART treatment cycle performed during the study year was €1.608.965,7 million (of those €1.202.945,7 million were for fresh IVF cycles and €406.020 million for frozen IVF cycles). Research has shown that the average price of all started cycles in this period from the category of a fresh IVF cycle was €1.293,5. Similarly, the average price of a frozen IVF cycle was €607. Authors have concluded that the average direct price for health care treatment in fresh IVF cycles was up to 21 times more expensive among older (age group of 42 and above) than among younger women (age group below 30 years), €544.393,8 vs. €25.392,5 respectively, while the average direct health care treatment costs for frozen ART cycles were up to 11 times more expensive among older (age group of 42 and above) than among younger women (age group below 30 years) €126.630,0 vs. €11.390 respectively.

Table 1. Type and number of cycles and related costs

Type of cycles	Costs*	Age category (years)					
		All age categories	<30	30-33	34-37	38-41	≥42**
<b>Fresh IVF cycle</b>							
Stimulation	985,7	609	17	54	126	171	241
Failed oocyte retrieval	818,5	63	0	1	6	17	39
Fertilization, no embryo transfer	1.897,8	3	0	1	1	0	1
Finished fresh IVF cycle	2.012,5	90	1	4	15	21	49
Finished fresh ICSI cycle	2,207,7	161	2	5	31	44	79
Finished combine ICSI/IVF cycle	2,207,7	4	1	0	2	1	0
<b>Total initiated fresh IVF cycles</b>		<b>930</b>	<b>21</b>	<b>65</b>	<b>181</b>	<b>254</b>	<b>409</b>



### Frozen IVF cycles

Completed frozen embryo cycle	670	606	17	82	135	183	189
<b>Total initiated frozen embryo cycle</b>		<b>606</b>	<b>17</b>	<b>82</b>	<b>135</b>	<b>183</b>	<b>189</b>

\*Costs are expressed in euros (exchange rate as of May 2024) \*\*All ages 42 and over are combined in one age group, Acronyms: IVF – in - vitro fertilization; ICSI = intracytoplasmic sperm injection

Resource: Authors' calculations

The average price for all non-donor ART treatment cycles per live childbirth was €5.625,7 (Table 2). The cost range per live childbirth was from €876,1 for frozen IVF cycles in the age category of less than 30 years to €108.878,8 for fresh embryo cycles in the age category of 42 years and older.

Table 2. Price per live childbirth from non-donor ART cycles

ART treatment cycle	All ages categories	Price * per age category (years)				
		<30	30-33	34-37	38-41	≥42**
Fresh cycles	31	1	5	9	11	5
Frozen embryo cycles	255	13	50	73	71	48
<b>Total all cycles</b>	<b>286</b>	<b>14</b>	<b>55</b>	<b>82</b>	<b>81</b>	<b>53</b>

\* Price is given in euros, \*\* All age categories 42 and over are combined in one age group

Resource: Authors' calculations

The entire costs of non-donor ART services and price per live childbirth are presented in Figure 1. It showed the increase of both, direct costs of non-donor ART treatment cycle and price per live childbirth, from the youngest (<30 years) to the oldest (≥42 years) age groups. The greatest quantity of resources for healthcare were utilized by the ≥42 age category group (42%).

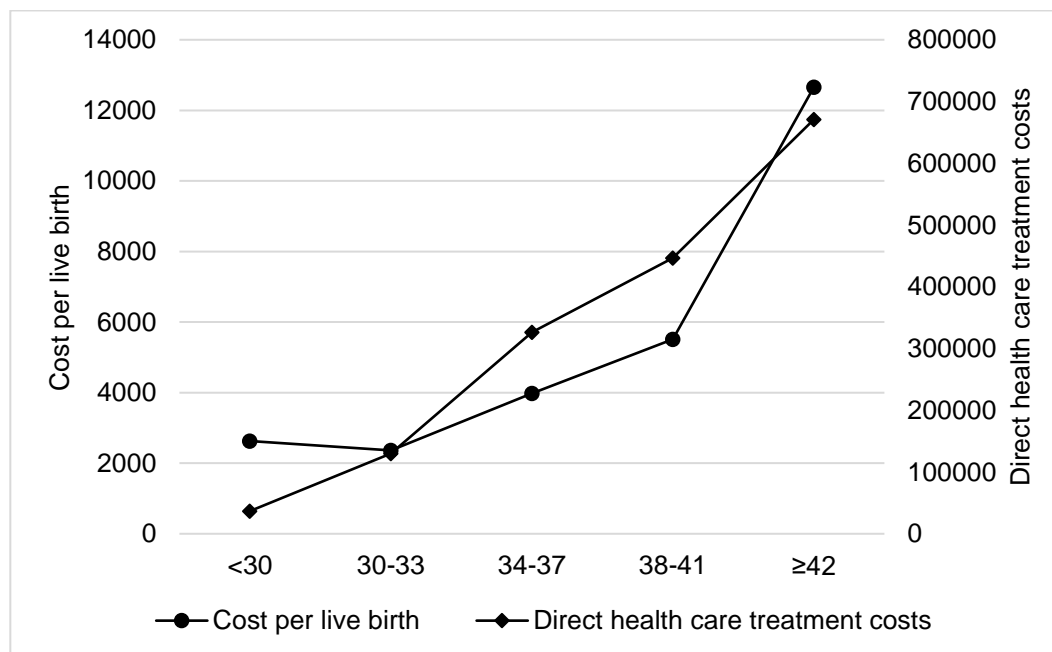


Figure 1. Total costs of non-donor ART treatment cycle and cost per live childbirth (both in euros)

Resource: From authors' calculations

## 4. CONCLUSION

The financing of ART services differs from country to country, and the Republic of Serbia is one of the few countries where ART treatments are covered without restrictions by the Republic Fund for Health Insurance and it that sense it is hardly to compare those practice in Serbia with international experience. The aim of this study, on direct

costs for an ART treatment cycle and outcomes, borne by the government and patients, was to calculate price average and group-specific cost per patient-age category per live childbirth for all types of ART treatment cycles. As specific costs per live childbirth have been examined in an insufficient number of studies, in this research we sought to show that the variation amongst age groups is alike to and directly correlated to the age-related downfall within all types of ART infertility treatment cycles. The age group  $\geq 42$  years spent the most health care resources and therefore in this age group, the utilization of donated eggs would improve outcomes in pregnancy rates with donor ART cycles. ART for women older than 42 is less profitable than in younger women, but the success rate is influenced by other factors besides age, the most important factor of possible success with ART treatment is ovarian reserve as well as many other factors.

The results of this study should encourage further thinking not only in terms of cost/benefit but also in terms of medical/ethics. When to stop? What is the upper limit for ART? Is it determined by age, ovarian reserve, the number of stimulated attempts or data on the quality of gametes that remain closed in laboratory documentation and about which so little is written? Research says that 30% of couples (Sadeghi, 2015) do not succeed in achieving pregnancy even with all today's knowledge. In the population over 42, the following questions await answers: how to improve gamete quality, embryo quality and endometrial receptivity. The growing number of elderly patients (which is seen in the first table) and the increasing costs (which is seen in the second table) give a clear "age-dependent" result and this group of patients (over 40) should be approached separately and analyzed (40-42, 43, 44 and 45). Establishing a national registry, a database on assisted reproduction that records information on all cycles of ART treatment conducted in the Republic of Serbia will allow similar economic considerations like this study to be made at the national level. In this direction goes further research on this topic that authors are planning to perform.

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# INTEGRATED STATE AUDIT: A FRAMEWORK FOR PLANNING, CONDUCTING AND REPORTING

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**Abstract:** *Integrated state audit, as a combination of the financial statements audit, the performance audit, and the information systems audit, offers numerous advantages to state auditors, enabling greater impact without necessarily increasing the number of employees. Integration can help state auditors remain relevant and up-to-date in fulfilling their dynamic roles as advisors and confidants in a rapidly changing environment, particularly following the COVID-19 pandemic. The strength of integrated auditing is that it shows not only where money is spent, but also how it is spent, which is very important knowledge in the public sector. Citizens of a country, as taxpayers and key stakeholders, want government bodies and state-owned enterprises to spend their money wisely, efficiently, and effectively. This is why public sector auditors exist, and integrated auditing can provide this assurance. Such concern is completely different from that of private sector stakeholders, who are focused on making a profit. Therefore, the aim of this paper is to analyze the concept of integrated state audit by elucidating its elements, and presenting a framework for its planning, conducting, and reporting phases, thereby offering practical guidance to enhance audit efficiency and effectiveness. The main conclusion is that the process of integration, combining the financial statements audit, the performance audit, and the information systems audit into a single audit concept that would be applied in supreme audit institutions to individual audit engagements, can represent a significant challenge for numerous state auditors, yet the overall benefits can be substantial.*

**Keywords:** *integrated audit, state audit, auditors, engagement flow audit*

## 1. INTRODUCTION

The integrated state audit, as a unique combination of financial statement audit, business expediency audit, and information systems audit, offers numerous advantages to state auditors, enabling greater impact without necessarily increasing the number of employees. Integration can help state auditors remain relevant and up-to-date in fulfilling their dynamic role as advisors and confidants in a rapidly changing environment following the Covid19 pandemic (Jakovljevic& Dmitrovic, 2023). The strength of integrated auditing is that it shows not only where money is spent but also how it is spent, which should be very important knowledge in the public sector. The citizens of a country, as taxpayers and key stakeholders, which is why public sector auditors exist, probably want government authorities and state-owned enterprises to spend their money wisely, efficiently, and effectively, and integrated auditing can provide this assurance, which is completely a different kind of concern compared to private sector stakeholders, which are focused on making a profit. Historically, government audits have been associated with obtaining information about an organization's financial transactions and financial reporting. However, audits now include non-financial areas, such as security, information systems, and environmental issues (Zaharco&Petreanu, 2023). There is a growing need for expediency audits in government agencies and state-owned enterprises, and as a result, supreme audit institutions that have recognized global trends have hired audit practitioners who specialize in security audits and information systems audits (Hegazy et al., 2022). Risk assessment decisions require an increased focus on auditors to broaden their perspectives and think outside the box.

A more holistic view of an integrated audit requires the auditor to modify his perspective and think outside the traditional scope of the audit (Amdanata& Mansor, 2020). A key role in the success of an integrated audit is played by the chief auditor due to higher requirements in terms of qualifications and ability to manage the audit project (Sembiyeva et al., 2024). The lead auditor should have a full understanding of the potential risk of the audit activity in all aspects of the scope of the audit (Flasher et al., 2022). The lead auditor will be

required to have sufficient soft skills to ensure effective teamwork between audit staff and others who will provide expertise to the engagement (Jakovljevic, 2021). When planning an integrated audit, the initial step is always to define the topic for the business feasibility audit, which includes the subject of the audit necessary resources, and more (Wellalage et al., 2023). Determining the entities for the audit of expediency, the entities for the audit of financial statements, and the list of information systems they use, which should be reviewed, together with the applied techniques and processes of information security and IT controls, are automatically obtained (Candra et al., 2022). Thus, as part of one audit engagement, a package of individual audit reports would be issued in the areas of financial statement audits, business expediency audits, and information systems audits, which explain individual positions or areas in more detail, and an integrated audit report would be issued with them, which would summarize audit findings within the examined topic and which would provide integrated recommendations for the systematic improvement of deficiencies from the topic of overall importance for a society, that is, for a country (Huynh et al., 2022). The subject of the paper is the analysis of the concept of integrated state audit through the presentation of its elements and the flow of engagement.

2. PLANNING THE INTEGRATED STATE AUDIT

Information regarding the processes, systems, and issues in that area should be gathered and examined to comprehend the audit topic and the issues in the audit area (Jeremić et al., 2021). The audit team should create summaries of the actions that were audited as well as first conclusions about the operational issues that were encountered, their root causes, and, if applicable, their effects. Auditors ought to search for recurring issues or themes that are mentioned or supported by various sources (Jakovljevic & Dmitrovic, 2024). The easiest way to convey observations is usually to arrange them into broad areas of preliminary findings, identifying the sources of different observations and providing clues about potential operational issues (Flasher et al., 2022). Knowing how various issues or signs of issues in that area relate to one another is also crucial. Initial results should be adequately described in terms of performance concerns and the information's underlying sources. However, there are no hard and fast rules on the type of data that must be provided or the standards that must be met for the initial evaluation at this planning stage. To guarantee that the conclusions of the primary study may be based on appropriate audit evidence, the auditors should, however, define the right criteria as well as the sources and pertinent types of data for the questions to be addressed in the study (Jakovljević & Jakovljević, 2021). The team must create a work plan for the primary research after discussing the audit problem with management in the preliminary stages. Top management should review and approve a draft audit engagement plan. The work plan's goal is to organize and specify how the audit problem review will be carried out during the primary investigation. The team will be guided through the audit process by the work plan, which will assist them in organizing their objectives and providing analytical justifications. To conduct a high-quality audit that adheres to good governance principles and is timely, inexpensive, and efficient, auditors should design the audit in a way that supports these goals (Huang et al., 2024).

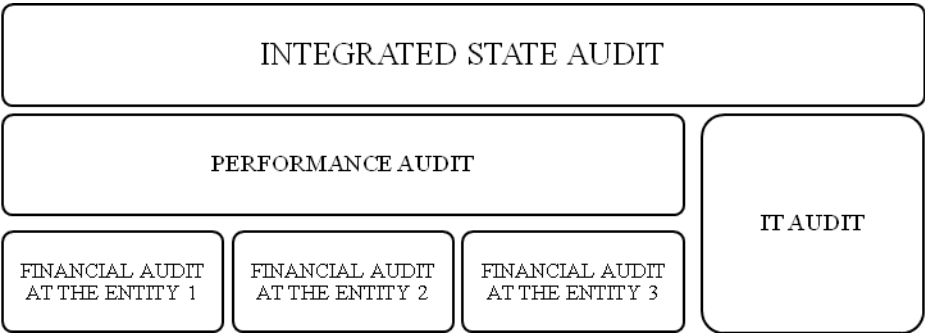


Fig.1. Integrated state audit  
Source: Authors

When senior management selects an audit topic that is unconnected to signs or perceptions of issues in a specific area, the audit problem selection method might not be applicable. In these kinds of situations, auditors can employ a results-oriented approach to determine whether specific goals are accomplished, or a system-oriented approach to see whether a certain system is operating as planned. Auditors should use previous study observations and performance problem indicators as a starting point for their investigation of alternative audit difficulties (Efimova et al., 2021). Occasionally, a subject selected by upper management can be sufficiently detailed to serve as an audit challenge (Candra et al., 2022). Under such circumstances, auditors ought to seek out observations that either validate or invalidate the initial notions' plausibility. In addition, auditors want to think about whether there are any other audit problems in this field that would be a

better option than the particular issue that management selected (Viana et al., 2022). The goal of the integrated audit topic selection process should be to optimize the anticipated audit impact while accounting for audit capacity, particularly in terms of professional and human resources, and the degree to which financial, business, and information systems audits can be integrated.

### 3. CONDUCTING THE INTEGRATED STATE AUDIT

When it comes to the process of putting an integrated state audit into practice, all entities that are being audited can offer feedback on the draft audit criteria in writing, at a special meeting, or during the introduction meeting. Meetings should be recorded, especially if there are remarks and discussions about the criteria. If required, the audit team should independently modify the audit criteria to reflect those changes. It is critical to work on a shared understanding of the audit. To the extent deemed relevant, further auditee opinions on the audit design and plan should also be taken into consideration. Following the initial meeting, the audit team, the assigned contact person, and other pertinent officials may get together to talk about more operational issues of the audit. The contact person is supposed to help the audit team with contacts and information needed for the audit, including relevant documents, and help set up interviews, among other things. On the other hand, the contact person must be informed of the audit's progress by the audit team leader. Prior to the audit team visiting the auditee's regional or local offices, they must speak with the contact person. Selecting an appropriate data-collecting method is essential to an integrated state audit since it allows auditors to verify information from written documents or field studies in specific circumstances, as well as to obtain enough expertise about the subject from the parties concerned (Melnik & Shot, 2021).

To obtain a balanced assessment of the situation, interviews with operational personnel, managers at various levels, and other stakeholders should typically be done. Interviews must be well organized and structured, and the one conducting them ought to be knowledgeable about the subjects and topics to be covered. The interview's format is determined by its goal (Dionisijev & BozhinovskaLazarevska, 2022). The purpose of the integrated state audit team development is to discover and partially verify the existence of flaws, issues, and unfulfilled goals. As such, the inquiries may be more open-ended and wider in nature. However, when the primary study is carried out, the emphasis will change to examine the gaps more thoroughly and determine their causes as well as potential remedies. Typically, an interview happens during a meeting. When the questions are common and relatively easy, telephone interviews might occasionally offer a more cost- and time-effective option. The questionnaire can be used on a sample of population units and offers a methodical way to get data from a specified population. Questionnaires are mostly used to gather information that cannot be found in any document and are crucial for providing context for the results. They can also be used to gather viewpoints (Abutabenjeh & Rendon, 2023). It is crucial that the questions are clearly stated and simple to comprehend. Before the finalized version is distributed to every responder, it is strongly advised that a draft of the questionnaire be delivered to the pilot respondents. For your pilot, use genuine test subjects and specialists. Simultaneously, the audit team must consider a variety of document types, such as regulatory framework and internal policy statements, audit entity budget reports, management reports, applied information systems reviews and documents, file reviews, financial reports, and more. Ministerial instructions, delegating decisions, operational guidelines, manuals, and policy papers should all be gathered by the audit team (Song et al., 2015).

Auditors should also consider modifications made to laws and other records, such as speeches, press announcements, lawsuits, appeals, and case histories, that were instrumental in requiring the modification. Audit entity budget reports include a summary of the entity and include financial data together with details about the objectives and performance of the entity. Organizations usually draft several internal papers outlining current problems and/or recommended lines of action for top management. Such documents should be found and examined by auditors. Interviews and a review of the minutes of management meetings are two ways to find reports. An inspection of the files is a useful source of proof (Huy, 2015). When gathering evidence, auditors should get a list of files from the register of audited subjects to have a general idea of what files are already out there. Working papers provide an organized and concise summary of information file reviews in the auditor's own words. It is imperative that the audit team comprehends that the registered files may not contain all pertinent papers (Bui et al., 2023).

The team might be unaware of further pertinent papers. Auditors should review earlier assessments and reports that are available in the audit area before beginning an audit. Occasionally, their data can be utilized for an audit. It is important to use these supplementary data carefully (Reynolds, 2018). It is advisable to refer to scholarly studies and additional publications that are pertinent to the auditing domain (Dionisijev & Tosev, 2023). While this kind of data might not be sufficient on its own to produce audit evidence, it might offer the theoretical foundation, or points of reference needed to produce more audit evidence. An increasingly significant information source is the Internet. Since more and more government agencies are posting their documents and data online, it is now simple to search through many of the data sources via the Internet

(Yaroshchuk et al., 2022). The audit team can gain insight into the reality underlying inspection reports and other official documents through observation. It can offer a more lucid bottom-up perspective of the main problems, which can be contrasted with the image presented in official reports or at the organization's executive level. One of the fundamental risks of people-watching is that the presence of auditors may cause people to behave differently, which will reduce the validity of the data gathered (Grytsyshen et al., 2020). Physical object inspection can yield a wealth of information. The camera is helpful for recording and taking pictures of inspections (Datsii et al., 2021). The primary goal of an inspection is to closely examine a small number of things to provide specific instances of what is seen. It should be verified when the physical state observation is essential to achieving the audit's goals. This can be accomplished by having an observation from two or more auditors, ideally with an auditee representative present as well. To create audit proof, it is also possible to conduct methodical, documented physical inspections of several sites. Rational arguments, computations, comparisons, and dissection of data are examples of analytical evidence (Song et al., 2015). Auditors create fresh evidence that is pertinent to the audit objectives and audit questions by combining data from several sources and conducting both quantitative and qualitative analyses.

#### **4. INTEGRATED STATE AUDIT REPORTING**

Every integrated state audit has a written report that shares the findings with the government, the Parliament, the audit subject, and any other interested parties. The reports that have been published serve as the basis for its actors' assessments of the integrated state audit's efficacy. It is imperative to carefully review the report's veracity, reasoning, and clarity. Writing reports is mostly an analytical process, and an ongoing report-writing process will make auditing easier. The preparation of a report summary should come first when producing a report. The specific evidence that the audit team has obtained in order to achieve the audit goals is referred to as findings. To address the audit questions and fulfill the audit objective, conclusions are developed. The criteria state that every audit finding needs to be backed up by adequate and relevant evidence. Findings must be supported by logical reasoning and pertinent facts at the same time. Before making any decisions, one must consider the surrounding circumstances, apposite reasons, advantages and disadvantages, and many points of view (Dionisijev & Tocev, 2023).

It is important to balance the demand for accuracy against what is practical, affordable, and useful. Perspective and a clear conclusion regarding audit matters should be included in the audit findings. It is important to make sure that the audit's aim, questions, findings, and conclusions are all consistent. The results of the audit should address the audit questions and be in line with the audit's objectives and conclusions. The factual scenario and the audit criteria are compared to produce the audit findings. Discrepancies are conclusions that can indicate possible non-conformances. When there is no disagreement, the auditee has essentially fulfilled the criteria-based expectations. Determining the significance of the discovery and its underlying reasons is crucial for the audit team to accomplish (Jakovljević & J. Jakovljević, 2022). It is important for auditors to establish their own standards for assessing every root cause, so they may offer various causes as distinct conclusions. The audit's primary issue is, by definition, the results of the causes it examined. Occasionally, it might be suitable to carry out further analyses of the implications of some findings (Jakovljević, 2022b).

During an audit, it is typical for auditors to note several things that might be used as criteria to assess performance. Since the integrated state audit essentially involves direct reporting, auditors must try to document the actual activities of the examined subjects and assess them based on predetermined standards. It is usually preferable to expand the primary findings at a higher level, conclusions that are supported by several deficiencies discovered, rather than presenting shortcomings one by one (Jakovljević & Petrović, 2023). Additionally, readers will find the report more engaging and find it simpler to retain the key points because of its increased material concentration. Rather than just reflecting on the flaws noted in detail, presenting the key findings at a higher level can also serve as the foundation for recommendations that are likely to make a substantial contribution toward resolving issues or weaknesses found by the audit (Jakovljević, 2022a). When conducting financial statement, performance, and information systems audits, audit teams must make every effort to establish a connection between the results and measure the impact. The team can provide examples of the consequences of poor decision-making, a lack of control, or a lack of concern for the service when the effects cannot be measured. Only essential terms should be included in the matrix, even though the report should include a detailed narrative text outlining the findings (Jakovljević et al., 2022).

The findings matrix aids in the clarification of the findings and enables the team and reviewers to assess if each finding is supported by adequate audit evidence and meets the criteria, all while disclosing the sources of the evidence. Audit findings, on the level of the financial statements, do not typically include an overall assessment of the economy, efficiency, and effectiveness achieved at the auditee level in performance audit

reports. Conclusions can be supported by quantitative data gathered through sampling or scientific procedures. As audit data might be compelling, formulating conclusions to address audit problems may involve a substantial amount of judgment and interpretation (Jakovljević & S. Jakovljević, 2022). Before making any findings, it is necessary to weigh the context, pertinent reasons, advantages and disadvantages, and various viewpoints. These conclusions should also be directly related to the audit's goal.

## 5. CONCLUSION

One of the key organizational advantages of applying the integrated audit concept is efficiency and effectiveness. This exposure helps auditors to develop an understanding of the various business processes of their organization, to become more efficient decision-makers and therefore more complete individuals, to a greater extent qualified to be leaders and bearers of audits in the public sector, and above all state audits. Integrated auditing simultaneously provides organizations with a broader reach and depth in auditing, as well as a powerful tool for looking at complex issues. International standards for public sector auditing require data to be reliable, emphasizing the importance of auditing information systems. Despite its advantages, integrated state audit is not easy to implement. Many supreme audit institutions are insufficiently skilled and lack the staff and skill sets, especially for auditing information systems. The widespread presence of risk aversion, as well as a mindset echoing *we've always done things one way, why should we change now when we're doing so well*, can be a significant limitation to organizational evolution and transition to integrated auditing. Having adequate and competent personnel resources is a primary concern in the process of establishing the application of integrated audit, and it is often followed by establishing effective communication between members of the audit team and accepting the concept of integrated audit. In the current environment, organizations need to use every resource to become current, so it is advantageous to utilize the skills of auditors.

The transition to an integrated audit certainly represents the evolution of the state audit. Many state audit institutions today conduct separate audits of financial statements, audits of the expediency of operations, and audits of information systems, and the auditors, whether it is about expediency, finances, or information systems, are separated from each other, each in their own field, so they often lose contact with each other, which is a key segment in the process of evolving a professional organization. Through an integrated state audit, everyone will be able to gain greater knowledge about the others' fields. It is a unique, very good opportunity for the internal exchange of knowledge and cross-training, not only in the field of technical skills but also in the field of teamwork, mutual communication, interpersonal relations, trust, and organizational culture, primarily in the context of breaking rivalry between state auditors and team members, as well as developing mutual understanding. Persons engaged in audit work in state audit institutions possess different sets of skills and work with different legal requirements and standards. However, they do not work for personal gain, but for the state interest, which should always be equated with the interest of the community. This means that everyone works to achieve the same ultimate goal, which is to determine whether audit subjects fulfill their responsibilities in accordance with legal authorizations, i.e. whether state bodies and state enterprises spend taxpayers' money efficiently and effectively and to the best of their ability. The main conclusion is that integrating the audit of financial statements, business expediency, and information systems into a single audit concept, which will be applied in supreme audit institutions to individual audit engagements, can pose a significant challenge for many state auditors, yet the overall benefits can be substantial.

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# STRATEGIC PLANNING IN THE ROLE OF FINANCING OF SCIENTIFIC RESEARCH PROJECTS AT THE UNIVERSITY OF DEFENSE

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**Abstract:** *Financing scientific research projects at the University of Defense, in addition to the legal obligation, also represents a vital function in developing and improving scientific and teaching staff. In addition to direct incentives through the payment of "fees" for participation in scientific research projects, trips and exchanges of experience are financed both in the country and abroad, as well as the equipping of modern laboratories and cabinets and the procurement of reagents and other materials for the implementation of approved projects. Financing scientific research projects is realised from several sources and places but with a common goal: improving military education and scientific research activities.*

*The paper aims to point out the importance of "proper" planning of financial resources for the development of military training and military scientific research activities. Of course, spending the given funds is very important and crucial for the quality of military education and military scientific research activities. It is essential to emphasise that designated financial resources' legal and purposeful spending is understood. However, not knowing the procedures for spending financial resources and many other factors can cause the selected financial resources not to be paid even though the University of Defense really needs them. Accordingly, the primary hypothesis is that knowledge of procedures and regulations, and primarily of the chart of accounts, directly affects the realisation of financial resources planned and determined for the scientific research projects of the University of Defense and, ultimately, its work results. In addition to general scientific methods, considering the subject and goal of the research, a comparative method was mainly used to analyse the financing of expenditures and expenditures of the University of Defense in the period from 2016 to 2022, by funding sources, as well as the way of content, i.e. sources of funding in the same period.*

**Keywords:** *financing, sources of funding, scientific research projects.*

## 1. INTRODUCTION

Technological development and geopolitical changes in this century require changes and implementation of strategic orientation of the institutions and organizations (Mihic & Obradović, 2012). Changes in the geopolitics and economic environment, security risks and threats, and current business conditions require constant and continuous monitoring by the appropriate services and institutions to create conditions for unhindered functioning and development of the society of each state. With the development of society, the environment has changed to become increasingly more complex forms and phenomena required from participants at all levels an increasing level of knowledge and training. Today it is almost inconceivable that one does not learn and improve in any profession. Even with the emergence of artificial intelligence and many other modern societies, there is a tendency to expect the extinction of many centuries-old disciplines (Vuksa et al. 2020).

In addition, new and previously non-existing businesses are emerging. With the complexity and the conditionality of connecting many pre-existing professions and eventually functions into one, there is a need for interdisciplinarity in all spheres of society.

The Armed Forces are one of the segments of society with clearly defined missions and tasks. Most of them have not changed since the emergence of the need for the military to ensure the state's security. They are facing new challenges and threats as a society in general, globally and in the immediate environment. Modern forms of warfare and the use of state-of-the-art weaponry and sophisticated techniques, up to now, with unimaginable consequences, demand from the decision-makers at the highest level that our Armed Forces have to be equipped, trained and prepared to respond to any potential challenges. For this purpose, a planning model was developed in the Ministry of Defense and the Serbian Armed Forces, which ensures that, even under restrictive financing conditions, the maintenance of existing capabilities and capacity of the Armed Forces, but also the development of new ones, remains in effect. This model is also compatible with programme budgeting in the Republic of Serbia, introduced monitoring by performance and results work, which further increases decision-makers responsibility in the Ministry of Defense and the Serbian Armed Forces for the funds. One of the main problems for Knowledge Management in the project environment is a poor analysis of the success of the project and a lack of appropriate documentation of the results of previous projects. Therefore, a form involving analysis approached the success of the project through the definition of critical success factors, key performance indicators and the process of measuring the performance brought about by the project (Todorović et al. 2015). It is actively worked on the concept of Knowledge Management in the Ministry of Defense and the Serbian Armed Forces, which is considered a priority in management (Mitrović et al. 2018).

Funding for non-prospective projects remains a distant past, and only funded projects are funded; if they give results in the present and future. The unpredictability of the future and the current environment inevitably demand scientific research projects in all areas of life, especially in each state's Defence and Security field.

## **2. MODEL OF PLANNING IN THE MINISTRY OF DEFENCE AND THE ARMY OF SERBIA**

At the beginning of the 21st century, the Ministry of Defense and the Serbian Armed Forces decided to develop a model of planning that could respond to the then-current environmental challenges and threats and would be compatible with the program budgeting introduced by the state and the situation in military terms. A decade-long hiatus in Defense planning, the absence of long-term and medium-term planning documents has failed to provide the minimum amount of funding available. Namely, decision-makers in the Ministry of Defense and the Serbian Armed Forces could not reach a consensus on how to spend the available financial resources for equipment and infrastructure (Knežević et al. 2009). A non-profit organization, where the number of employees is a staggering 75% of total defence expenditures, operational about 20%, and investments only 5% of total spending, could not ensure the development of new capabilities and capabilities of Defense (Figure 1).

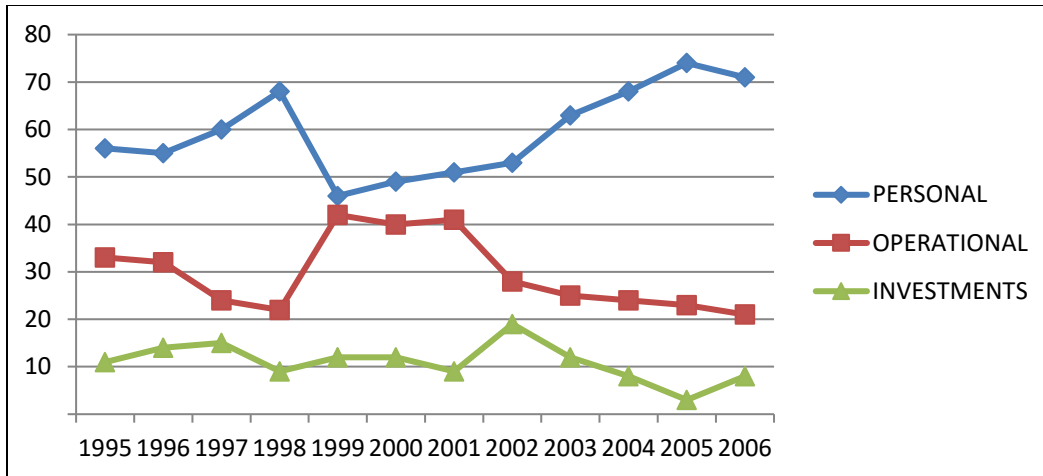


Figure 1. Structure of military budget expenditure (Knežević, M., 2021)

Lack of guidelines or criteria for priority funding in the form of long-term or mid-term planning documents ended with the return of funds to the budget. At the same time, the procurement of food items, energy and other operating costs were realized, and the remaining outstanding and transferred as liabilities to the next budget year. The Planning Model has been developed and introduced since 2008. As the years have passed, it has been set and re-designed so that today it can be said that it is compatible with the model of planning in the Republic of Serbia, but also with the most modern armed forces of the world, to be able to respond to contemporary challenges in Society and beyond (Figure 2).

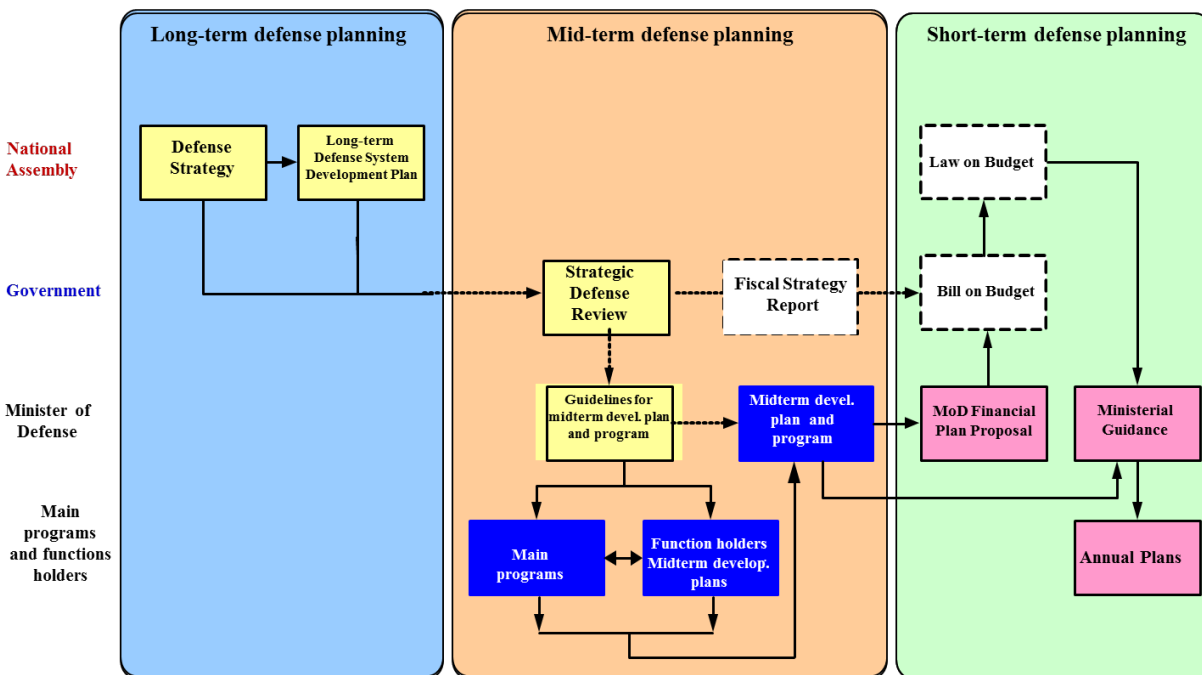


Figure 2. Planning Model (Regulations, 2010)

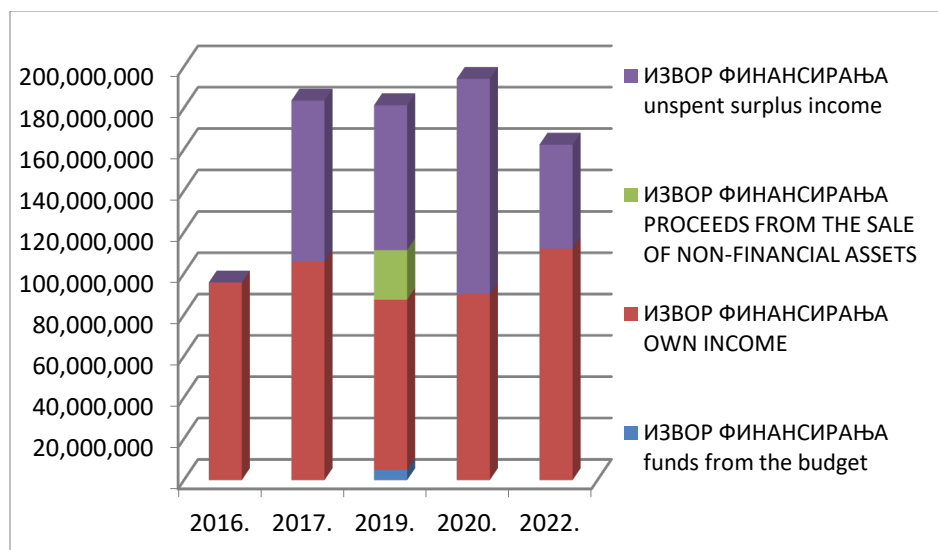
Strategic planning (Borocki et al. 2009) is defined by guidelines and directions development of the Ministry of Defense and the Serbian Armed Forces, and is implemented through several medium-term plans and programs. Project funding with the Project budgeting is only part of the medium-term planning of the Ministry of Defense and the Serbian Armed Forces. Defining and implementing all programs and projects is carried out through more short-term, i.e., the Ministry of Defense and the Serbian Armed

Forces annual plans. Deficiency of financial resources generally requires that they be managed rationally (Avakumović et al. 2021) and economically to plan and fund priority projects and programs following strategic orientations.

### **3. FUNDING OF SCIENTIFIC RESEARCH PROJECTS IN THE MINISTRY OF DEFENCE AND THE SERBIAN ARMED FORCES**

The complex security situation at the global and regional levels requires continuous strengthening and development of the Armed Forces' new capabilities. The most recent wars are being fought on the interdisciplinary defence approach in safeguarding security in the modern world. In such circumstances, the project's financing must be able to provide funding for multidisciplinary projects that can respond to these challenges (Benković et al. 2010). The financing of such projects is carried out under applicable legal and regulatory regulations but is primarily intended. I.e., by the established activities of the project and according to the accounts of the economic classification.

Financing of projects of the Ministry of Defense of The Republic of Serbia, which develop weapons and military equipment, is regulated through the budget fund for armaments and military equipment. However, scientific research projects at the University of Defense since 2016. the years are funded by Budget funds to develop military education and military scientific research activities. As of 2023. there is no budget for the year, but there is a program for developing military education and scientific research activities (Mihajlović et al. 2020). Talking about about sources of funding for scientific and research work, it is important to mention that in addition to the University's budget, there are also available revenues which the University earns operating on the basis of education and scientific research activities, as well as the unspent revenues from previous years. The complex security situation at the global and regional levels requires continuous strengthening and development of the Armed Forces' new capabilities. In such circumstances, the project's financing must be able to provide funding for interdisciplinary projects (Milojević et al. 2019) that can respond to these challenges. The most recent wars are being fought on the multidisciplinary defence approach in safeguarding security in the modern world. The financing of such projects is carried out under applicable legal and regulatory regulations but is primarily intended. I.e., following the established activities of the project and according to the accounts of the economic classification. Financing of projects of the Ministry of Defense Of The Republic of Serbia, which develop weapons and military equipment, is regulated through the budget fund for armaments and military equipment. However, scientific research projects at the University of Defense since 2016. Budget funds fund the years to develop military education and scientific research activities. As of 2023. there is no budget for the year, but there is a program for developing military education and scientific research activities. Sources of funding for scientific research in addition to the University's budget. There are also revenues from the University activities based on education and scientific research activities and income from previous years.



**Figure 3.** Sources of funding of the budget fund for the development of education and military NID

Based on the data in Figure 3, it is possible to see an increase in financial resources for scientific research needs since 2016. until 2018. year, then a smaller decline until 2022. year. In 2016. in the past, the fund has only available funds from its income. As of 2017. years, in addition to its revenue, it comes with an unallocated income. While 2019. year because it is next to these two funding sources and received payment from the sale of non-financial assets and funds from the budget.

All the activities related to military development are financed from this budget fund for military education and military scientific research activities (Pantić et al. 2020). Projects approved by the Ministry of Defence, especially interdisciplinary, are financed mainly by funds from the Ministry's defence budget. Scientific research projects supported by the Ministry of Science, technological development and Innovation are funded by that Ministry. The funding sources are diverse, projects and their purpose varies, and interdisciplinarity is increasingly represented.

Examples of interdisciplinary defence projects are "The development of the ability to defend against terrorism" and "Management model defence system capabilities development". The most successful implementation of this project requires the participation and synergistic action of several Sciences and disciplines., of each state's ministries, departments, and services (Savić, 2022). Today, terrorism has many forms and different phenomena. It doesn't show up like it did ten years ago. Modern technology and technology have made it possible to terrorists to act in the most treacherous, covert and diverse ways much faster and more precisely. Developing the defence system's capabilities implies an interdisciplinary approach. Therefore, this project at the University of Defense includes researchers from various scientific fields with knowledge essential to the military.

#### 4. CONCLUSION

The complex security situation at the global and regional levels requires continuous strengthening and development of the Armed Forces' new capabilities. In such circumstances, the project's financing must be able to provide funding for interdisciplinary projects that can respond to these challenges. The latest conflicts of war are evidenced by the multidisciplinary approach of Defense in the construction of the new ability of the military to defend and preserve security in the modern world. At the beginning of the 21st century, the Ministry of Defense and the Serbian Armed Forces developed a model of planning that could respond to the current environmental challenges and threats. The planning model that was introduced was compatible with the models of the most modern armies of the world but also with programs implemented by the Republic of Serbia.

Strategic planning of the mission and the objectives of the Serbian Armed Forces are implemented through all stages of planning and are executed explicitly by the program budgeting. Program budgeting involves managing performance, work results, and project funding. Project funding is focused on the work's results and, in a very efficient way, allows measuring the effects. Based on the author, it is necessary to continue with strategic planning and financing focus on S and R projects. The authors also point to the need for funding interdisciplinary projects from multiple funds and opening up opportunities for connecting scientists and researchers in areas prioritized for the Armed Forces' missions and tasks.

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# BIBLIOMETRIC ANALYSIS OF PRIMARY RESEARCH ON FINTECH

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**Abstract:** *Financial technologies have been disrupting financial industries for decades now. The growth of scholarly studies dealing with FinTech is exponential. The aim of this paper is to analyze scholarly studies on FinTech based solely on primary data (using either questionnaires or interviews). This paper provides the summary statistics on frequency of academic output in the FinTech research field, productivity of journals and authors, spatial distribution and cross-country cooperation and the main subtopics in the field. In total, 264 papers were extracted from Web of Science database and analyzed in a bibliometric manner.*

**Keywords:** *FinTech, bibliometric analysis, interview, questionnaire*

## 1. INTRODUCTION

Modern technology has been revolutionizing financial services in the last few decades. Innovation in the provision of financial services has been disrupting the landscape of previously very traditional industry (Benkovic et al., 2023). Financial technologies (FinTech) development has passed three key historical phases— emergence (to 2008), fermentation (to 2017) and take-off (ongoing) (Kou et al., 2023). Not surprisingly, both scholarly and practical attention to this blend of finance and technology has been skyrocketing lately. Such an attention to a specific scientific field and saturation in publications is usually followed by more accurate and precise definitions, and an exact way of measuring such phenomena. The later one is particularly interesting for the purpose of this study. Not only that empirical studies are not converging with each other, but it seems as if they utterly diverge.

Hitherto, a myriad of studies on FinTech were primary by nature and employed different techniques to collect data on FinTech – being questionnaires or interviews. These techniques are used in research to gather data directly from individuals or organizations and are useful for capturing qualitative and quantitative insights on various aspects of FinTech development. Primary studies on FinTech are mostly based on collecting evidence on user adoption and satisfaction (Hu et al., 2019), consumer trust (Stewart & Jürjens, 2018), service quality (Baber, 2019), entrepreneurial activity (Utami & Sitanggang, 2021), vis-à-vis performance towards the incumbent banks (Chen et al., 2021), regulatory environment (Rupeika-Apoga & Wendt, 2021), investor sentiment (Pintér et al., 2021), market research and many other fields.

The aim of this paper is to provide a literature review on empirical, primary-sources studies on FinTech. Having in mind many papers addressing FinTech by conducting primary research, this analysis is based on bibliometric principles. To the best of our knowledge, no other studies have analyzed literature on FinTech with such a goal.

The remainder of the paper is organized in the following way. Section 2 delineates the methodology used for the bibliometric analysis. Section 3 elaborates on the study findings. Section 4 contextualizes the findings and provides some implications and recommendations for both scholars and practitioners. The last part of this section is reserved for the conclusion.

## 2. METHODOLOGY

To conduct a comprehensive literature review on empirical primary-source studies on FinTech, we employed three stage methodology approach used by Spasenic et al. (2022), Vukmirovic et al. (2023) and Milosavljevic et al. (2023). The initial step is to systematically identify scholarly articles within the Web of Science (WoS) database by Clarivate Analytics. WoS is confirmed as a reliable academic database for literature reviews across various research areas such as finance (Spasenic et al. 2022; Rodriguez-Rojas et al., 2022), credit

risk management (Prado et al., 2016), management and business (Ardito et al., 2019; Torres et al., 2022), and FinTech (Li & Xu, 2021).

The search strategy is based on two specific keyword pairs, "FinTech OR Financial Technolog\*" combined with "Questionnaire\* OR Interview\*". By combining "FinTech OR Financial Technolog\*" we ensured comprehensive coverage of research examining various aspects of FinTech, such as user perceptions, industry trends, or technological innovations. The second pair of words effectively captures studies focusing on FinTech phenomenon through primary data collection methods such as questionnaires and interviews.

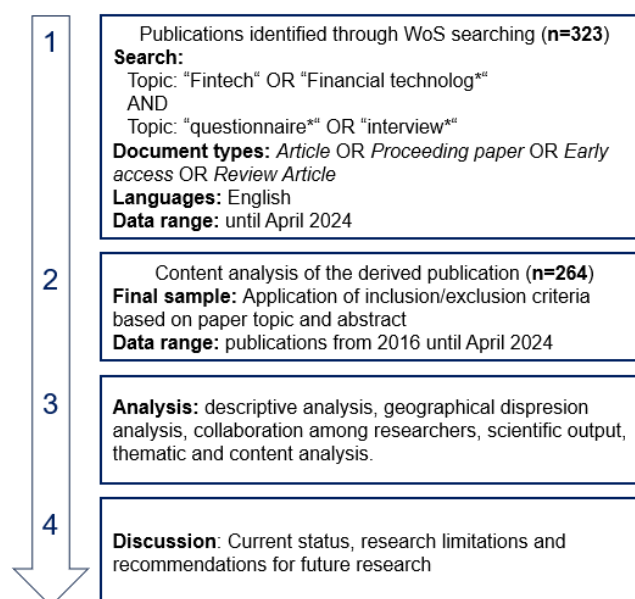
The word string is applied to WoS engine searching titles, abstracts, and keywords of indexed publications. The search parameters are additionally refined to include specific publication types (articles, review articles, and proceeding papers) and to focus exclusively on publications in English. Language filter eliminated only 3 publications confirming comprehensiveness of publications in English language. The initial search resulted with 323 potentially relevant publications spanning the period from 2006 to 2024.

In the second phase, content analysis is performed on the retrieved publications to filter the research sample to include only primary-source studies on FinTech. This involves screening of title and abstract for all publications to select those strictly related to original primary research on FinTech. The described process resulted with the final research sample consisting of 266 publications, spanning the period from 2016 to 2024, whose structure by publication types is given in table 1. The selected publications' information, including title, abstract, keywords, and document type, is extracted from WoS as text tab delimited file for further analysis in VOSviewer software.

**Table 1:** Structure of publications on FinTech primary research

No.	Document type	Number of documents	% of total
1	Article	214	81%
2	Proceeding paper	44	17%
3	Review article	6	2%
Total		264	100%

The third phase incorporates a bibliometric analysis consisting of four complementary steps. First, a descriptive analysis of the final research sample is conducted to understand the temporal evolution of publications over time. Second, a geographical dispersion analysis, collaboration among researchers, and scientific output of journals is performed. Third, the most influential publications (i.e. the most cited publications) within the field are identified. Finally, a thematic or content analysis is conducted to define the principal topics emerging from the analyzed literature.



**Figure 1:** Research design

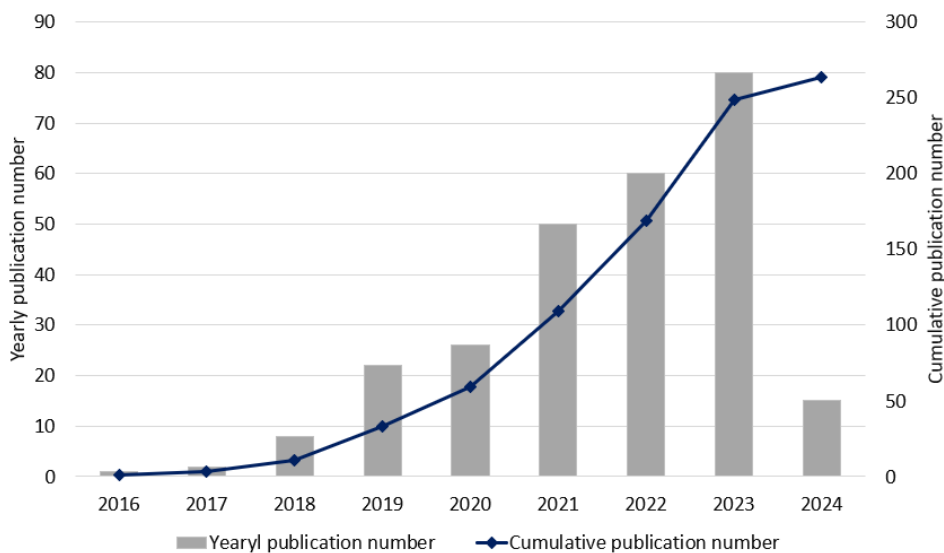
### 3. RESULTS

This section addresses the research inquiries previously outlined by examining the frequency of academic publications, the productivity of journals and authors, geographical dispersion, and inter-country collaboration, as well as the main subcategories within the FinTech research field based on the publications' keywords.

#### 3.1. Frequency of academic output in the FinTech primary research field

The trend depicted in figure 2 shows a significant growth in empirical, primary-source studies on FinTech over the years, indicating a rising interest and research activity in this field. The steady increase in the number of publications from 2016 to 2024 suggests a growing recognition of the importance of FinTech and its implications across various sectors.

This surge in academic output, particularly evident from 2019 onwards, reflects the increasing relevance of FinTech in contemporary financial systems, driven by advancements in technology, changing consumer preferences, and regulatory developments. In the next years, it's reasonable to expect continued expansion in FinTech research as scholars delve deeper into emerging trends, issues, and opportunities in this rapidly evolving landscape.



**Figure 2:** Yearly publication number

#### 3.2. Productivity of journals and authors

Leading journal is "Sustainability," which published 12 papers dedicated to FinTech-related primary research. Following closely behind are journals such as "Technological Forecasting and Social Change" with 6 papers, highlighting a substantial contribution to the exploration of technological advancements and their social implications within the FinTech area. Additionally, "Cogent Business Management," "International Journal of Bank Marketing," "Journal of Financial Services Marketing," and "Journal of Science and Technology Policy Management" each have 5 papers, indicating a diverse array of academic platforms actively engaging with FinTech research.

These findings underscore the interdisciplinary nature of FinTech research, with contributions originating from journals spanning various domains, including sustainability, technology forecasting, business management, marketing, and science policy management. The presence of FinTech-related studies in such diverse journals reflects the multifaceted impact of FinTech on society, ecology, economics, and technology advancement. Moving forward, these productive journals are likely to continue shaping the discourse around FinTech, providing platforms for scholars to disseminate their empirical findings and practical insights, thereby enhancing our understanding of the evolving FinTech landscape.

Regarding the most cited papers in the fields, the results are shown in table 2. Top 5 cited papers received cumulatively 533 citations which is above 25% of total citations in the research sample. The average citation in the research sample is 7.53 per item confirming the high interest for the research topic.

**Table 2:** An overview of the 5 most cited publications in the research field

No.	Authors	Title	Journal	Total citations
1	Chang et al. (2020)	How Blockchain can impact financial services - The overview, challenges and recommendations from expert interviewees	Technological forecasting and social change	187
2	Hu et al. (2019)	Adoption Intention of FinTech Services for Bank Users: An Empirical Examination with an Extended Technology Acceptance Model	Symmetry-Basel	156
3	Drasch et al. (2018)	Integrating the 'Troublemakers': A taxonomy for cooperation between banks and FinTechs	Journal of economics and business	77
4	Chen et al. (2021)	FinTech and commercial banks? performance in China: A leap forward or survival of the fittest?	Technological forecasting and social change	58
5	Mogaji et al. (2021)	Emerging-market consumers' interactions with banking chatbots	Telematics and informatics	55

The most influential publication is done by Chang et al. (2020) who provide an overview of the potential impact of blockchain technology on financial services, highlighting challenges and recommendations from expert interviews. The study suggests that blockchain has the capability to enhance global financial infrastructure and improve asset transfers compared to traditional systems.

Hu et al. (2019) explore the adoption intention of FinTech services among bank users by proposing an extended Technology Acceptance Model (TAM). The research includes factors such as user innovativeness, government support, brand image, and perceived risk into the TAM to investigate how users embrace FinTech services. By examining user trust as a key determinant, the study contributes to understanding the drivers behind the adoption of FinTech services in the banking sector.

Similarly, Chen et al. (2021) focus on the performance of FinTech companies and commercial banks in China, analyzing the relationship between these entities. The study examines the evolving landscape of financial technology in China and its impact on traditional banking institutions, shedding light on the dynamics between FinTech firms and established banks in the country.

Drasch et al. (2018) present a taxonomy for cooperation between banks and FinTech companies, emphasizing the need for integration and collaboration between these entities. The taxonomy offers a structured framework for understanding different forms of cooperation, highlighting the importance of synergy between traditional banks and FinTech firms. By categorizing the modes of cooperation, this paper provides insights into fostering successful partnerships in the evolving landscape of financial technology.

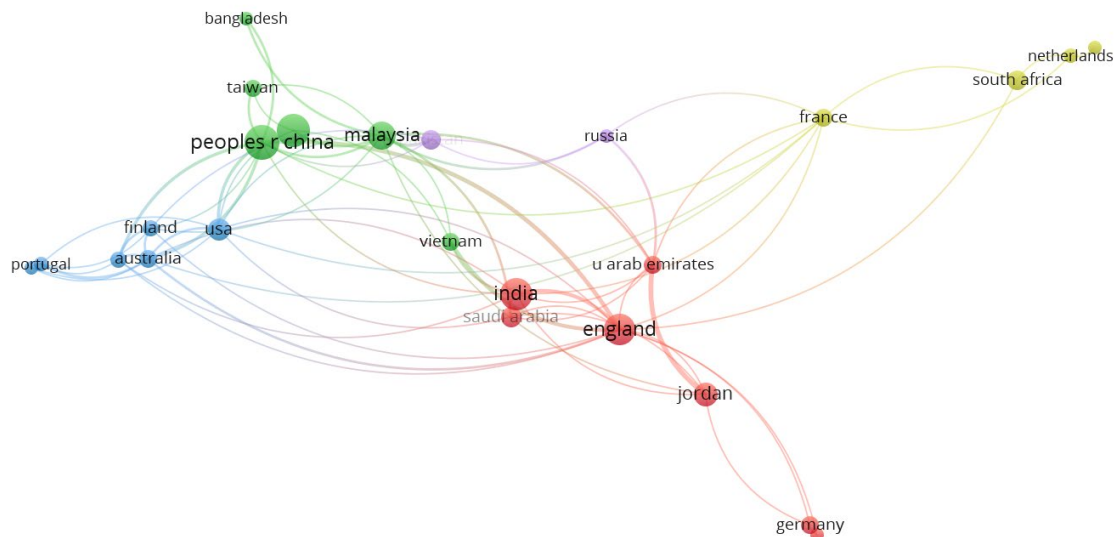
Mogaji et al. (2021) investigate the interactions of emerging-market consumers with banking chatbots. This study explores how consumers in developing economies engage with artificial intelligence-driven chatbots in the context of banking services. By examining the utilization of chatbots in enhancing customer experiences and service delivery in emerging markets, the research provides insights into the adoption and effectiveness of AI technologies in improving financial services accessibility and efficiency for consumers in these regions.

### 3.3. Spatial distribution and cross-country cooperation

Regarding the geographical origin of the publications included in this study, 33 publications originate from China, followed by Indonesia (30 papers), India (28 papers) and United Kingdom (27 papers) as the most productive country in the Europe. This is in line with the findings of Ernst & Young survey (2019) which confirms that Asia retains global leadership in FinTech adoption.

The green cluster comprising Bangladesh, Indonesia, Malaysia, China, Taiwan, and Vietnam represents a pivotal nexus in the FinTech research and development. This cluster underscores the expanding interest and significant contributions from emerging economies in Asia to the advancement of FinTech. With a combination of rapid technological adoption, robust regulatory frameworks, and a growing consumer base, these countries are witnessing a dynamic evolution in their FinTech ecosystems. Moreover, collaborations

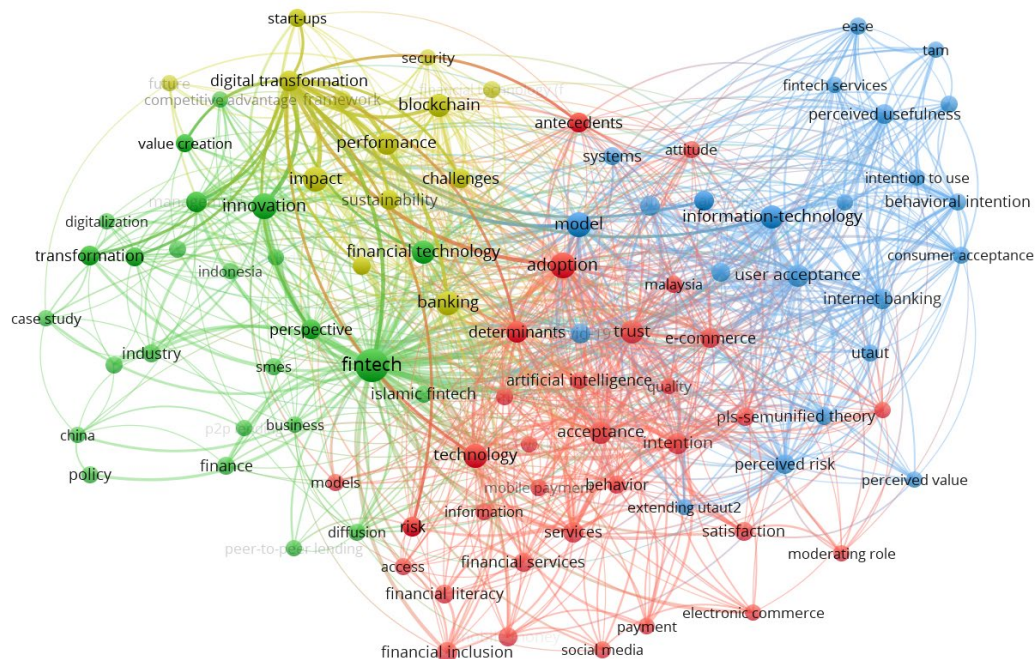
and knowledge exchange within the countries in this cluster are vital for leveraging collective expertise and addressing common challenges, thereby fueling the continued growth and sustainability of FinTech innovation in the region and beyond.



**Figure 3: Cross-country cooperation**

### 3.4. Main subtopics in the field

The analysis of the main subtopics in the field is based on all keywords with the minimum occurrence of 5 (author keywords and keywords plus generated by WoS). Using the VOSviewer software (version 1.16.17) we identified four distinct clusters. The keyword grouping is presented in figure 3 where each circle is single keyword. The frequency of keyword occurrence is in positive correlation with the circle size (i.e. more frequent keywords are represented by larger circles). Different colors represent a thematic cluster that are analyzed below.



**Figure 4: Thematic clusters**

**Acceptance and Adoption of FinTech (red cluster).** This cluster revolves around the acceptance and adoption of FinTech solutions. Keywords such as "acceptance," "adoption," "attitude," "behavior," "intention," "trust," and "satisfaction" suggest a focus on understanding the factors influencing individuals' decisions to adopt

innovative FinTech services. Additionally, terms like "artificial intelligence," "financial inclusion," and "social media" indicate an exploration of how technological advancements and social factors impact FinTech adoption and usage by end users.

*FinTech Innovation and Industry Dynamics (green cluster).* This cluster encompasses topics related to FinTech innovation, industry dynamics, and value creation. Keywords such as "business," "competitive advantage," "innovation," "digitalization," and "ecosystem" suggest a focus on how FinTech innovations and digital transformations are reshaping the financial industry landscape. Additionally, terms like "p2p lending," "Islamic FinTech," and "SMEs" indicate a consideration of specific sectors and segments within the FinTech ecosystem.

*User Behavior and Technology Acceptance (blue cluster).* This cluster centers on understanding user behavior and technology acceptance in the context of FinTech adoption. Keywords such as "behavioral intention," "consumer acceptance," "perceived ease of use," "perceived risk," and "perceived value" suggest an exploration of users' attitudes, perceptions, and intentions towards FinTech services. Additionally, terms like "covid-19" indicate a consideration of how external factors, such as the global pandemic, influence FinTech adoption and usage patterns.

*Challenges and Future Directions of FinTech (yellow cluster).* This cluster addresses challenges and future directions in the FinTech landscape. Keywords such as "banking," "blockchain," "challenges," "digital transformation," "impact," "performance," and "sustainability" suggest a focus on understanding the implications of FinTech innovations for traditional banking systems, as well as the challenges and opportunities associated with digital transformations and emerging technologies like blockchain. Additionally, terms like "start-ups" indicate a consideration of the role of FinTech start-ups in driving innovation and disruption in the financial industry.

#### 4. CONCLUSION

The research on Fintech has seen a remarkable increase in attention among scholars during the last years. The profound research productivity in this field has made a systematic literature review, where the publications are investigated manually, barely impossible to perform. This trend, along with advanced software tools, has fostered development and implementation of comprehensive literature reviews capable of analyzing large scientific paper datasets. The methodology applied in this study involves the three-stage approach that enables the comprehensive analysis of 264 publications identified by employed search strategy described in the Methodology chapter of this paper.

As the results of this study imply, the body of knowledge in the field of FinTech has been steadily growing in the last years. The findings also revealed the distinctly interdisciplinary nature of the research efforts in Fintech, spanning across a broad spectrum of domains including sustainability, technology forecasting, business and management perspectives, and science policy management. Although the FinTech publications are widely distributed around the globe, the study highlights the leading role of Asian countries in driving the attractiveness and growth of the field.

The contributions of our study are twofold. Firstly, we proposed the three-stage methodology approach to comprehensive bibliometric analysis of literature. The methodology can be replicated to any other field of research. Secondly, the proposed methodology offers the insight into the key trends and evolution of research output in the FinTech domain from a quantitative, bibliometric perspective. The results of this study can assist researchers in shaping their future studies by isolating promising research gaps and offering a valuable tool to for handling large datasets of scientific publications.

While the results of this study and its proposed methodology offer a robust foundation for bibliometric literature reviews, it is important to note its inherent limitations primarily associated with the research design. These limitations include constraints in sample construction and the quality of the chosen scientific database. Furthermore, the selection of keywords and the design of search strings may have narrowed the sample size and influenced the outcomes of the literature screenings.

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# **INTEGRATED HUMANS AND DIGITALS IN MARKETING AND COMMUNICATIONS**



# DIGITAL COMMUNICATIONS STRATEGIES FOR SOCIAL IMPACT IN NON-PROFIT ORGANIZATIONS

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**Abstract:** *Nonprofit organizations play an important role in the global economy, social welfare, and poverty reduction. Digital media simplify interactions among stakeholders, fostering relationships that can advance humanitarian efforts. Leveraging social media platforms like Facebook, Twitter, and Instagram. NPOs have enhanced their communication, networking capabilities, and stakeholder engagement, thereby minimizing their costs and increasing their impact. Effective communication is of crucial importance to non-profit organizations. This paper presents a systematic literature review of exploring the use of digital communication for social impact and its significance for accruing social capital, gaining trust, building relationships, and community support. It offers insights into fostering collaborative networks underlining the challenges NPOs face, including reliance on donor funding. The goal of this article is to analyze how digital communication strategies can enhance the effectiveness of non-profit organizations through a systematic literature review.*

**Keywords:** *non-profit organizations, digital communication, social media communication, social impact*

## 1. INTRODUCTION

Nonprofit organizations, like the Red Cross, with a focus on helping others, heavily depend on material, information and financial support for their operations (Hillig & Connell, 2018). These organizations are part of what's known as the third sector or civil society (Katz, 1999). The United Nations Department of Economic and Social Affairs has set up the integrated Civil Society Organizations (iCSO) System to provide data on NGOs. As per data around 15,049 civil society organizations have been identified, with the majority of NGOs (12,647) working in areas such as Economic and Social Development Sustainable Development Goals, Conflict Resolution in Africa Gender Equality issues and Women Empowerment initiatives (UN – Department of Economic and Social Affairs 2024). Dahie (2019) outlines that nonprofits play a role in the economy tending to enhance communities and acting as key players in fighting poverty. These organizations are known for offering humanitarian services without seeking profits and operate independently from governments. They play roles in aid efforts, development projects and charitable activities. In this case, they don't distribute profits among their members, but rather utilize them in favor of objectives (Galkina & Yang 2020).

Non-governmental organizations primarily depend on donations, for their funding, which involves distributing funds for profit purposes, which means that any extra money generated is not given to owners. While they may have paid staff, the majority of their members are volunteers (Lewis, 2001), which emphasizes the importance of building connections (Meier, 2015; Putnam, 2000). These organizations play roles in economies tackling various issues such as human rights, civil rights, poverty alleviation, support for marginalized communities (Svara, 2021) and safeguarding children (Degenaar et al., 2022). According to Fisher Preßler et al. (2023), HNGOs are vital in providing services and social value for societies worldwide as they address unmet needs that aren't covered by government or profit driven organizations.

In today's landscape, non-profit organizations face both challenges and promising opportunities to engage with their target audiences and supporters. According to Burton (2022), communication plays a role for non-profits in motivating individuals to act whether through volunteering, donating, or raising awareness about issues. Research by Funraise & Nonprofit Tech for Good (2019) reveals that a considerable number (67%) of donors are influenced to contribute by platforms like email, social media, or websites. Burton (2022) underscores the growing importance of donations highlighting the expansion of the digital sphere and its impact on fundraising efforts.

Social media are typically open, dynamic platforms that serve a variety of purposes for organizations (Schlagwein, 2017). Smith et al. (2017) argue that the use of four features of social media can help in accruing social capital in the organizational context: a digital user profile, network transparency, digital search, and digital relations.

The goal of this paper is to explore how digital communication strategies can improve the efficiency of non-profit organizations. In terms of methodology, this research utilizes a systematic literature review as its research approach to collect and synthesize information from existing case studies and academic papers. A systematic literature review implies the identification, evaluation, and combination of existing studies relevant to a particular research question. The extracted data were combined to recognize themes, strategies and results concerning the use of digital communication within non-profit organizations. Vital information from the chosen studies was included, such as the objectives, methodologies, findings, and conclusions of each study.

## 2. NON-PROFITS IN THE DIGITAL REALM

The NGO strategic development plan includes a strategy that evolves alongside societal technological changes, as noted by Bălăcescu (2021).

Effective communication is substantial for humanitarian organizations to carry out their missions, maintain independence, and effectively support victims of conflicts and emergencies.

Social media platforms have enabled humanitarian non-governmental organizations (HNGO) to enhance communication, establish connections with individuals and groups and engage effectively leading to a reduction of costs and increasing involvement and influence (Smith et al., 2017). By utilizing real-time access to social media profiles spontaneous connections can be established among stakeholders like the public, other organizations, or governmental bodies (Leong et al., 2015). The extensive use of social media platforms such as Facebook, Twitter and Instagram, as stated by Zheng & Yu (2016), has led the HNGO sector to recognize the value of using these platforms for humanitarian initiatives and relationship building. In addition, Hillig & Connell (2018) indicate that HNGOs actively engage with communities through networking to develop levels of trust and positive expectations that support their initiatives. Therefore, as observed by Fisher-Preßler et al. (2023), incorporating social media strategically can assist HNGOs build capital within their operations. As per Auger (2013), acceptance of different digital channels for the purpose of communication with diverse audiences has been largely adopted.

Social media platforms such, as Facebook, Twitter and Instagram have become a part of life for many people worldwide. According to research by Al Momani (2020) and Alodat et al. (2023), billions of individuals use these platforms to connect with friends, families and colleagues across the globe. A study by Kim et al. (2014) indicates that a vast majority of organizations (90%) engage in social media activities with Facebook and Twitter being the most used among non-profit groups. The research highlights that while these organizations are using features potential on online platforms, like Facebook and Twitter, they could benefit more from other interactive potential capabilities. It is suggested that non-profit environmental organizations develop strategies that integrate all web platforms to enhance their public relations efforts.

Similarly, Moreno-Cabanillas et al. (2024) observed that a significant number of studies indicate that the benefits and potential of the digital platform remain underutilized. The central objective of their study is to gain insight into the methods by which social organizations handle digital communication. Their findings reveal that most NGOs surveyed maintain a presence on five social media platforms, including Twitter and Facebook, which aligns with the conclusions drawn by Vu et al. (2021), Castillo et al. (2017) and Quintana (2020). Furthermore, some NGOs have also started using platforms like TikTok and Medium to connect with a younger audience (Moreno Cabanillas, 2024). Several previous studies agree that the prevalent social media channels utilized by NGOs include Facebook utilized for engaging audiences (Vu, 2021), followed by Twitter (Catillo, 2017; Quintana, 2020), and recently Instagram (Durieux, 2021).

The case study carried out by Hue (2017) has been used to highlight how the communication strategy was constructed in the CFR—a fourth-generation NGO (Council on Foreign Relations). It points out that symmetrical communication between fourth-generation NGOs and their stakeholders is crucial for successful communication strategies. Hue (2017) highlights the role of the Internet and other modern communication technologies and concludes that the construction of communication strategies in NGOs like the CFR is dynamic, involving a mix of organizational politics, culture, identity, and external factors. Therefore, an integrated framework, based on a combination of the marketing communication model and the elaboration likelihood model enables researchers to capture the process of developing a successful communication strategy in fourth-generation NGOs as the study finds.

The study conducted by Fischer- Preßler et al. (2023) delves into how social media information governance influences the accumulation of social capital. It sheds light how social media are regulated in diverse organizational contexts to connect with collaborators, improve relationships with volunteers, promote cooperation within and between organizations, and drive collective action. The research identifies eight domains that encompass three dimensions: relational, structural, and cognitive. Within the structural dimension we have the expansion and retention of networks, and the pooling of resources facilitates the development of social capital within organizations. In the relational dimension, authors recognized aspects like trust

establishment, community management and brokerage. Emotional empathy and fostering a shared identity are highlighted as factors in addressing the dimension of social capital. Moreover, the investigation additionally uncovers conflicts in the governance of information on social media platforms at various organizational hierarchies, putting forth strategic suggestions for actively managing and evolving these conflicts. Nowadays, nonprofit organizations are aware of the significance of communication management in the realm of achieving their primary goals with their diverse audiences (Moreno-Cabanillas, 2024). Noted by Fu (2019), websites and social media platforms provide a wide range of opportunities for these organizations to fulfill their humanitarian missions. Catillo et al. (2017) suggest that NGOs mainly utilize media for sharing information emphasizing one-way communication and overlooking features, whereas Lovejoy (2012) and Kim et al. (2014) argue that social media is utilized by NGOs to foster community engagement and collective initiatives while websites have limitations in this aspect.

The following table incorporates observations and analysis based on existing case studies and presents an overview of key areas, illustrating the impact of digital communication in achieving the goals of non-profit organizations, as synthesized from the provided literature. This table is the result of the author's own analysis and summarizes the effect of digital communications on non-profit organizations, portraying how strategic integration and usage of digital channels ensure mission support, stimulate widespread connectivity, and build trust. It indicates that communication strategies are moving to interactive conversations and discussions across various social media channels, and at the same time outlines the importance of promoting their activities and encouraging cooperation and collective action.

**Table 1:** Key areas of Digital Communications Impact in NPOs

Key area	Description
Strategic Development and Adaptation	Pointing out how digital strategies are integral to NGOs' strategic development, constantly evolving with changes in technology
Effective Communication for Mission Support	Demonstrating the importance of digital channels in preserving independence and ensuring humanitarian action
Enhanced Communication and Networking	Describing the role of social media in communication improvement, cost savings, enlarging participation and impact
Real-Time Relationships and Accessibility	Emphasizing the immediacy of social media profiles in facilitating voluntary connection between different stakeholders
Social Capital and Trust Building	Concentrating on the role of frequent interaction via social media in gaining trust and supporting humanitarian operations
Broad Audience Reach	Displaying broad use of social networking platforms that enables NGOs to connect with a global audience and utilize digital platforms for direct communication
Innovative Use of Emerging Platforms	Presenting the adoption of rising platforms such as TikTok and Medium to target younger audience
Symmetrical Communication Strategies	Outlining the importance of symmetrical communication between stakeholders and NGOs for successful strategies
Social Media Information Governance	Highlighting the influence of social media governance on building a network of partners and encouraging cooperation and collective action

## 2.1. Diversity of Humanitarian Digital Communication Strategies

The digital environment has made a significant contribution to the very perception of NGOs, enabling them to improve their connections with the community, ensure the flow of accurate information, encourage citizen participation and support fundraising efforts.

Dijkzeul and Moke's article (2005) divulges the public communication strategies of large humanitarian NGOs as well as UN organizations about humanitarian principles. It shows that different strategies concerning impartiality vs. solidarity and independence vs. subcontracting cause a wide diversity of humanitarian positions, which leads to different types of public communication strategies.

In their research, Dijkzeul and Moke (2005) pointed out multiple key points on the subject of humanitarian organizations and their communication strategies. Here's how each point connects with digital communications:

1. **Transparency in Communication:** Digital platforms offer non-governmental organizations the ability to communicate their strategies, actions, and outcomes transparently, enabling a wider and more engaged audience.
2. **Understanding of Humanitarian Principles:** Digital media can help disseminate and explain the core principles of humanitarian action to a broad audience, facilitating a deeper understanding among stakeholders and the general population.
3. **Diversity in Communication Policies:** Utilization of various digital channels allows organizations to adjust their communication strategies, whether they prefer autonomy or seek partnerships and collaborations.
4. **Challenges in Maintaining Independence:** Digital communication strategies can be instrumental in asserting an organization's independence by carefully managing the narratives presented to the public, especially on platforms with global reach.
5. **Significance of Local Communication Policies:** In insecure environments, digital tools can be crucial for local communication, helping to clearly distinguish humanitarian organizations from military and private entities through targeted messaging and information campaigns.
6. **Communication as a Strategic Management Function:** The strategic use of digital communication platforms is essential for managing public discourse, engaging with stakeholders, addressing security concerns, and maintaining independence amidst challenges.
7. **Influence of Donor Governments:** Digital campaigns and advocacy can enhance an organization's ability to influence government decisions, raise public awareness, and secure funding, leveraging the power of social media and online platforms to attract and stimulate supporters.

To establish a presence in the digital area, Bălăcescu (2021) affirms that it's crucial to take a proactive approach by staying updated on digital trends and adjusting the NGO's communication strategy to align with the ever-constantly changing landscape of digital platforms.

## 2.2. Barriers to digital engagement for non-profits

Considering the limitations of resources that non-profits come across, the challenges they face in enabling effective communication are completely understandable. Waters and Jamal (2011) discover that the communication approach of non-profits on social media remains predominantly one-way with minimal utilization of interactive features. The obstacles they face in maximizing social media impact, observed by Carboni and Maxwell (2015), and Seo and Vu (2020), include lack of financial resources, technical proficiency, clear organizational guidelines for platform use and assistance from management.

However, the communications firm Big Duck also identified that non-profits demonstrate "a lack of understanding of the basic principles of effective communications." This suggests that beyond resource constraints their key challenge lies in recognizing the significance of communication for their success (Durham, 2009). Bălăcescu (2021) argues that an NGO digital strategy is vital for expediting mission fulfilment optimizing resource allocation as efficiently as possible and enhancing stakeholder engagement. The lack of a digital strategy leads to overlooked opportunities for the advancement of the community, and for the investigation of new paths of community growth, engagement, and collaboration.

## 3. CONCLUSION

This paper provides a systematic review of the literature concerning the utilization of digital communication by non-profit organizations, with a focus on its role in increasing stakeholder involvement, lowering operational expenses, and broadening social impact. It was observed that through strategic use of digital platforms and social media, non-profits not only increase their reach but also foster deeper connections with their community, fundamental for accruing social capital and gaining trust. These findings contribute to the scholarly discourse by enlightening the potential of digital communication in strengthening the NGO's humanitarian activities.

This research emphasizes the importance for NGOs to continuously adapt to digital innovations in order to prosper. Future research should scrutinize the effectiveness of diverse digital platforms and the possibilities of advanced technologies in enhancing engagement. In moving forward, the responsibility falls on non-profit organizations to exploit the potential of digital media as a central element of their strategic improvement plans.

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# AI AS A SERVICE TECHNOLOGY IN HUMANITARIAN OPERATIONS: CHALLENGES AND PERSPECTIVES

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**Abstract:** *This article presents a review of existing research studies on the use of Artificial Intelligence, specifically chatbots, in both commercial and humanitarian service sectors. In this study, the integration of AI is evaluated through the Technology Acceptance Model (TAM) framework. While AI offers opportunities for improving efficiency and service provision, it also raises concerns regarding data protection and the spread of misinformation. The paper emphasizes the importance of upholding ethical principles and human values in delivering social services when the factors influencing the acceptance and effectiveness of digital technologies in humanitarian contexts are considered. By connecting AI applications to service and marketing strategies in humanitarian contexts, this study provides insights and recommendations for incorporating AI technologies to improve service outcomes. The aim is to provide a guide for future studies and suggest ways to enhance the utilization of AI solutions in different humanitarian conditions.*

**Keywords:** *Technology Acceptance Model (TAM), Artificial Intelligence, Chatbots, Humanitarian Service, Digital Marketing*

## 1. INTRODUCTION

Acting as a term for various technologies Artificial intelligence (AI) includes machine learning, deep learning, natural language processing, and computer vision, as noted by Getchell et al. (2022). As Svensson (2023) affirms, artificial Intelligence (AI) is advancing rapidly with the ability to create high-quality images and texts identical to those created by humans. This progress displays a broad range of possibilities, ethical considerations, and challenges even in the realm of Communication about Development. Witnessing the rapid development of AI technology, organizations are inevitably faced with significant challenges as well as opportunities. Also, the authors outline the increasing interest, in using AI tools for charity communications and fundraising, across media outlets, industry sources and online platforms. Based on Ziakis & Vlachopoulou's (2023) comprehensive review of artificial intelligence in digital marketing, AI has emerged as a transformative factor across different sectors. Reliance on real-time information and its changing nature characterize digital marketing, positioning it to greatly benefit from the potential that AI presents. The utilization of AI has the capability to fundamentally alter how businesses engage with their audience in the online domain, from predictive analytics to customized user experiences. Following this study, the integration of artificial intelligence (AI) in the realm of marketing has profoundly disturbed and transformed enterprise activities, labeling a modern era of alteration and advancement in business processes. Similarly, insights provided by Sabharwal et al. (2022) shed light on the mutual connection between digital advertising and Artificial Intelligence, underscoring the collaborative function in enhancing marketing approaches. This study demonstrates how AI and machine learning are reshaping the way communication channels work in marketing, underscoring the crucial purpose of AI in forming digital marketing initiatives. These data could be fundamental for strategists and corporate leaders looking to grasp the connection, among AI, advertising and formulating marketing plans. The influence of AI technologies is also evident in nonprofit sectors and commercial settings.

To raise their presence on online platforms, Philips (2022) asserts that nonprofits can utilize digital marketing strategies. As per this research, successful nonprofit digital marketing can enhance community involvement and promote brand recognition. The research suggests that nonprofit entities gain advantages from marketing by attracting donors and sponsors recruiting new volunteers and establishing a stronger online presence and reputation. Likewise, Montoya Ibarra (2023) note that nonprofit organizations have the capacity to utilize funnels, advertisements, and various digital marketing tactics in order to facilitate the advancement of their missions through the enhancement of awareness, attraction of new supporters, and stimulation of participation in their programs and services. By conducting organized campaigns, optimizing their website for enhanced conversions, and leveraging data analytics for making informed, data-centric decisions, nonprofit entities can augment the effectiveness of their marketing activities. The article also discusses the significance of establishing a robust online presence, fostering trust with contributors, and implementing an efficient communication approach in order to guarantee the efficacy of the strategy. Madianou (2021) demonstrates how AI contributes to merging service and marketing strategies in humanitarian operations. This study also

examines technology adoption rates and user involvement focusing on users' interactions with services driven by AI. The focus lies on how artificial intelligence is reshaping marketing approaches and enhancing customer service experiences. Overall, AI can be used in digital marketing to improve marketing content and enhance user engagement. Considering the variety of AI and chatbot possibilities, it is important to consider the challenges of its adoption and its effectiveness.

The methodology used in this paper includes conducting a systematic literature review focused on the investigation of existing empirical research and theoretical discussions on the integration and effects of AI in humanitarian environments. The goal of this research is to identify models in how these technologies are perceived and used in practice and to provide insights that can guide future researchers in improving the integration of AI technologies in humanitarian operations. The paper is organized to cover the methodology used for the present findings related to the acceptance and effectiveness of AI technologies, explore case studies and practical adoption of AI in humanitarian contexts, and finally, offer a conclusion and discuss implications relevant for future studies.

## **2. THE ROLE OF AI IN ENHANCING SERVICE OPERATIONS IN HUMANITARIAN AND SOCIAL WORK**

### **2.1. AI in the Context of Service**

Chatbots have become increasingly important in the sphere of marketing and information systems, especially in customer service interactions, as different authors affirm like Selamat and Windasari (2021), and Abdullah et al. (2022). These interactions have converted from being more focused on humans to being dominated using technology. Xu et al. (2020) noted that recent advancements in customer service areas have significantly improved customer communication. The use of interfaces like agents and chatbots, as observed by the same authors, allows customers to have real-time interactions with their service providers resulting in faster and better quality service. Virtual agents, such as chatbots, are progressively taking over the roles of agents and traditional customer service methods, as seen by Patil et al. (2019).

While most studies on chatbots have focused on customer's intentions, adoption and satisfaction with these systems, Zarouali et al. (2018) and Zumstein and Hundertmark (2017) argue that there is a need for an examination of customers' virtual flow experience as well.

The efficacy of chatbots in building positive customer experience largely depends on factors, like the quality of conversation content (clear communication and openness) and the overall performance of the chatbot systems (speed, customization and connectivity). Certain aspects are connected to how customers can understand and interpret the messages from chatbots, state Abdullah et al. (2022) and, therefore, clear communication is highlighted as an element that can predict customers' online interactions. Different studies have focused on customer adaptation and acceptance like Selamat and Windasaari (2021), Sheehan et al. (2020); trust in chatbots (Følstad et al., 2018; Kasilingam, 2020); chatbot features (Chung et al., 2020); customer experience with chatbots (Kushwaha et al., 2021; Verma et al., 2021).

In light of the revolution of chatbots in the customer service realm, the following section will focus on the transformative impact of AI on social work and the non-profit sector. Besides reflecting technological progress, these changes also introduce new ethical and operational challenges.

### **2.2. AI Transformations in Social Work and Non-Profits**

A case study conducted by Dey (2023) shows the transformative power of Artificial Intelligence in social work practice. By incorporating an Expert System based on AI, the NGO was able to overcome management challenges, implement remedial measures suggested by the expert, and enhance its operations. According to him, the success of this implementation demonstrates the potential of AI to support and optimize various aspects of social work and nonprofit organizations, enabling them to make a more significant impact on society. He asserts that leveraging Artificial Intelligence (AI) for research, behavior detection, and automation can enhance efficiency and effectiveness, while social media platforms can foster community participation and global understanding. However, it is essential to use AI responsibly, ensuring it aligns with ethical principles and human values in delivering social work services.

Madianou's (2021) research "When 'AI for Good' discusses AI technologies and incorporating them into humanitarian settings aiming to tackle the challenges this sector is facing. The study focuses on chatbots as a tool to improve communication and accountability with affected communities. Chatbots are increasingly utilized in humanitarian and developed by both humanitarian agencies and private companies, like X2AI, as part of initiative such as "Artificial Intelligence for good" ("AI for Good" or "AI4SG"). The study conducted by Madianou (2021) discloses that several AI tools including satellite imagery, data visualizations, chatbots and biometrics, are being used in humanitarian scenarios. The research also raises concerns about data privacy and the spread of misinformation that could negatively impact refugees and other vulnerable groups. Also, the



study identifies the impact of chatbots on inequalities and colonial legacies by highlighting power dynamics over ethical concerns. The same paper criticizes the dehumanized interactions in humanitarian contexts induced by the reduction of participation and feedback through chatbots, which imposes disconnection amid affected populations and aid communities. Research indicates that all forms of AI, regardless of their purpose, can potentially be harmful, stressing the need to reassess the essential role of AI in the humanitarian environment.

Having observed the power of AI effects in social work, the next section will provide an overview of the strategic utilization of AI applications and machine learning to enhance humanitarian action on a broad scale within specialized organizational contexts, using the example of the International Committee of the Red Cross (ICRC).

### 2.3. Strategic AI Use by Organizations (e.g., ICRC)

The ICRC, like different organizations in various fields and locations is facing the challenges in its operations posed by artificial intelligence (AI) and machine learning (International Review of the Red Cross, 2020). AI represents computer systems usage in order to perform activities linked to intelligence such, as thinking, planning, reasoning or acquiring knowledge, and machine learning systems that can learn from data and execute actions without precise instructions.

In this paper we will highlight the ways explored by ICRC (International Review of the Red Cross, 2020) on how AI and machine learning can be applied in humanitarian activities. Here are some applications:

1. **Environment Scanning and Data Analysis:** ICRC has created dashboards that using AI to monitor and analyze public data sources in specific operational contexts to assess humanitarian needs such as food, water, shelter, and healthcare.
2. **Humanitarian Services Enhancement:** Utilizing AI and machine learning for specific tasks like improving identification of facial recognition for locating missing persons or natural language processing for name matching. The development of these technologies can provide aid to the ICRC in supporting its Central Tracing Agency in reuniting family members separated due to conflict.
3. **Satellite Imagery Analysis:** Likewise, the ICRC is investigating the application of AI and machine learning techniques in image analysis and pattern recognition for satellite-based analytics. This technology can be used to map population density and assess urban infrastructure needs as well as to enhance the documentation of compliance with humanitarian policies.
4. **Legal and Ethical Considerations:** The deployment of these technologies introduces concerns related to ethical issues concerning confidentiality of the data, rights of privacy, civil rights, and liability. These technologies must be implemented based on “do no harm” principle and must respect privacy rights, particularly concerning data protection.
5. **Guidance and Standards Development:** The article asserts that ICRC will guarantee that the fundamental principles and values of independent, neutral and impartial actions are incorporated into the development and utilization of AI and machine learning technologies.

Considering the fact that AI is being used to enhance humanitarian actions, it's essential to understand how these innovative technologies are seen from the user's perspective. The Technology Acceptance Model (TAM) provides a scheme that allows us to explore the influence on system's acceptance, as well as to assess the effectiveness of these applications. Its use in earlier studies will be explored in the forthcoming section.

### 3. TECHNOLOGY ACCEPTANCE MODEL (TAM)

The technology acceptance model (TAM), introduced by Davis et al. in 1989, in conjunction with the theory of acceptance and use of technology (UTAUT), which was developed by Venkatesh et al. (2003), has been broadly employed as a framework for examining users' adoption of chatbots. Originating from the theory of reasoned action (TRA), the TAM focuses on the determinants of behaviors that are deemed "intended." Its primary objective is to clarify and predict users' acceptance of information systems, as stated by Davis et al. (1989). In their study it was revealed that individuals' actions are influenced by their intention to utilize information systems, which is influenced by their attitude towards the behavior as two key beliefs: perceived usefulness and perceived ease of use. A revised edition of the TAM integrates perceived enjoyment as a factor (Van der Heijden, 2004), with perceived usefulness being seen as a motivational factor.

In their article about research in chatbot trust, Subburaj & Mehrolia (2023) assert that many scholars have emphasize the importance of practicality and user friendliness when it comes to embracing these applications. Further, they explain those concepts by quoting different authors and stating that perceived ease portrays how easily users can use the product, while perceived usefulness represents users understanding of how usage of specific techniques can enhance job performance. The level of perceived ease of use is linked with increased trust. Due to that, Subburaj and Mehrolia (2023) indicate that the enjoyment construct has become equally

crucial as usability and perceived ease and plays an essential role in adopting information technology-related products and services. Moreover, they state in their study that information quality, service quality and interface design contribute positively to building trust in chatbots. Information quality is assessed by looking at how timely accurate, understandable, interesting, reliable, and trustworthy the information is. They attach no less importance to the design interface. The design of the interface refers to the flow organized on the website and how easy it is to navigate. Additionally, a key factor in building trust with chatbots is providing assurance. Apart from factors like beliefs, contextual relevance and familiarity, ensuring a structure could be an important predictor of how reliable users perceive a website vendor to be. Trust plays a role in how users view things. Similarly having availability can increase chatbots' social presence making them more accessible and visible to users which can enhance trust. As Venkatesh and Davis (2000) concluded - the TAM suggests that users' trust in technology is influenced by their perceptions of its usefulness and ease of use.

In the direction of TAM adoption in a humanitarian environment, the same questionnaire proposed by Davis (1989) can be valuable in the humanitarian framework for evaluating the adoption and effectiveness of digital tools such as chatbots. TAM framework can offer a structured way to analyze and understand the factors affecting the acceptance of chatbots and other AI-driven tools in humanitarian organizations.

Recognizing the importance of technology acceptance factors is crucial in a context where technology is used to improve efficiency and responsiveness in crisis. During the process of the implementation of AI, organizations are faced with challenges such as data protection and misinformation. The next section will address these particular barriers.

### **3.1. Challenges to Digital Transformation for Non-Profits**

While AI provides opportunities for increased efficiency and service delivery, it also presents significant risks regarding data protection and the spread of misinformation. O'Grady et al. (2019) in their study pointed out that a few factors inhibit NPO implementation on the digital transformation agenda: short-term and restrictive funding models, public perception – low trust, expectations to see donations spent at the front-line, NPO management – cautious incrementalism rather than transformation. The study indicates that most of the funds are provided through annual government grants and the NPOs are contractually obliged to utilize them solely for social purposes or service delivery. Additionally, the public demands higher transparency from charities, impelling them to distribute the proportion of donated funds on service delivery reducing administrative costs, including technology-related expenses. Given the combined pressure of budget constraints and low public trust, there is an amplified potential risk of reputational damage, which leads to a cautious and risk-averse approach towards strategic technology investment.

One of the examples cited in the study by the aforementioned Subburaj and Mehrolia (2023) is that circumstances unfamiliar to users might introduce risks that could impact their confidence.

The existence of perceived risks can negatively impact the trust people have in chatbots. Concerns related to privacy and security also play a role in affecting trust in chatbots along with issues related to technology. Researchers point out that despite the potential benefits chatbots can offer, users' concerns about data security and privacy can undermine trust. In terms of technology-related concerns many researchers have described the fear of technology as either anxiety or computer related anxiety associating it with the nature of the technology being adopted. Additionally, researchers imply that the Technology Acceptance Model (TAM) suggests that trust in technology is dependent on how users perceive its usefulness and ease of use. These studies have shown that trust plays a significant role for users resulting in increased intentions to act and impacting customer satisfaction regarding factors, like ease of use and usefulness.

## **4. CONCLUSION**

This paper explores the use of artificial intelligence solutions, such as chatbots, and their potential to improve operations by emphasizing the importance of user perception and ease of use when adopting technologies. These findings confirm that the implementation of innovative strategies in humanitarian services is not without challenges and the study highlights those challenges in implementing strategies in services including issues related to data protection, misinformation, and ethics that require strict governance. Humanitarian organizations can use AI techniques to provide services and run their operations effectively, yet they need to invest in training and establish governance structures to ensure successful implementation and address ethical concerns.

Based on prior studies and key elements for organizations, this paper suggests using TAM along with other models like UTAUT to effectively analyze factors for addressing future challenges. The TAM provides a framework for understanding how different factors impact the acceptance and effectiveness of AI technologies, but the integration of TAM with other methodologies can provide different aspects and a more comprehensive understanding and analysis of the research.

## 4.1. Limitations and Future Research

A significant limitation is the reliance on data from existing literature, which may not fully capture the evolving field of AI in humanitarian work. Focusing on AI applications such as chatbots may not cover all aspects of AI capabilities and their potential impacts.

For future research, it is recommended to conduct empirical studies to explore the long-term effects and sustainability of AI implementations in diverse humanitarian contexts. Furthermore, further investigation into implications and developing frameworks to guide AI use are also deemed essential. In addition to that, it's crucial to keep track of how AI tools are being used in humanitarian settings by analyzing survey data and feedback gathered from users. This is key to guaranteeing that they are integrated into projects in a way that's both effective and ethical. By tackling these obstacles and constraints upcoming studies can improve the implementation of AI technologies to better meet the needs of vulnerable populations worldwide.

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# BRAND PERSONALITY OF AN EDUCATIONAL INSTITUTION

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**Abstract:** *The brand personality, as a part of the branding domain, draws its foundation from two sciences: marketing and psychology. The basic premise of the field is that a brand, as a marketing construct, is perceived as a person by adding human characteristics to an abstract form such as brand and exploring consumers' perception of the brand if it was a person. For the purpose of the paper, concept of brand personality was observed and analyzed on the example of high-education institution. The study aims to determine the state of brand personality perception of a higher education institution by exploring the example of the Faculty of Organizational Sciences. Field research among the student population of the Faculty of Organizational Sciences in Belgrade was conducted for the study. Research participants were asked to imagine the Faculty abstractly as a human being and attribute personality characteristics to it. Based on the collected data, several conclusions were reached. Most of the students involved in the research perceive the Faculty of Organizational Sciences as a male person 24 years old. As the most impressive brand personality trait, respondents highlighted that the Faculty of Organizational Sciences is perceived as a resourceful, modern, and ambitious person. If the Faculty of Organizational Sciences was perceived as a person, respondents further highlighted that it would hold a managerial position in a corporation, be full of ideas, and meet innovations. The research results also indicated that the dominant color of the Faculty of Organizational Sciences brand would be blue.*

**Keywords:** *Brand personality, Higher education institution, Students' perception, Faculty of Organizational Sciences*

## 1. INTRODUCTION

Nowadays, many experts in the field of branding share the view that brand personality is something that distinguishes brands from one another and is one of the main means of brand differentiation (Aaker 1997; Epley et al. 2007; Keller, 2012; Novčić Korać and Šegota, 2017). The reason lies in the fact that the consumers' perception of a certain brand is something unique to each brand, difficult to "transfer", thus something that makes a difference among brands. The pioneer in the field, Jennifer Aaker (1997) defined brand personality as "a set of human characteristics that can be associated with a brand." As Starčević (2016) pointed out, "during research and individual interviews with respondents, they have no difficulty humanizing the brand, that is, giving answers to questions like: "Imagine that the given brand is a person. What type of person could the brand be, what kind of character would it have, how much do you identify with it?" and questions similar to this". For determining brand perception, brand personification is of particular importance, because it allows respondents to describe abstract brands and express their real attitudes and opinions through their answers. By analyzing the personality traits of a brand, valuable data are obtained for creating a brand profile, which reveals the attitude users have towards the brand. Furthermore, for this paper, the concept of brand personality is observed and analyzed to determine its function for brand positioning in the future.

## 2. BACKGROUND

The concepts of brand identity, image, and personality have attracted the attention of many researchers. Herzog (1963), Aaker (1991), Ditcher (1985), and Kotler (1988) researches brand image, and what all authors have in common is that "brand image is constructed by consumers". In other words, "consumers attribute a person or characteristics to the brand based on subjective perceptions of a set of associations they have about the brand". De Chernatony (1999) and Harris and de Chernatony (2001) presented their idea that "brand identity is a harmonious combination of elements such as brand vision, brand culture, positioning, personality, relationship, and presentation". Park et al. (1986) presented the concept of brand by explaining the abstraction of the mentioned term. Gardner and Levy (1955), in their article, consider that "brands can be a personality that can be more important to the consumer than the technical characteristics of the product". Keller (1993) explained the connection of brand associations with information nodes in the memory that consumers have about the brand. Schmitt and Simonson (1997) described the advantages of companies that have an influential, recognizable, and valid brand identity. In her study, Jennifer Aaker (1997) established five basic dimensions of brand personality and 42 personality traits, defining brand personality as

"a set of human characteristics that can be associated with a brand." She established a theoretical framework of brand personality that is applicable to a wide range of products and is sufficiently generalized. In this way, the measurement scale is verified and reliable. Brand personality is describing the brand by adding human traits and specific characteristics to the brand. This primarily means adding demographic characteristics (such as gender, age, and occupation), external characteristics (such as tall, attractive, and beautiful), but also character human traits (such as calm, humorous, noble, and confident). In addition, people's preferences such as hobbies, music, occupations, or overall lifestyle, can be added to the brand.

### **3. METHODOLOGY**

For the paper, an online survey of brand personality perception of the Faculty of Organizational Sciences was conducted by using the Google Forms tool. The inspiration for creating the questionnaire used in the research was the works of the authors Aaker (1997) and Starčević (2016), who examined brand personality through their research. The research conducted in this paper heavily relies on the research conducted by Aaker (1997) related to the development of a scale for measuring brand personality. The questionnaire used in this survey consisted of nine questions that were divided into two parts. The first part of the questionnaire focused on questions that examined students' perception of the brand personality of the Faculty, in other words, questions that humanize the brand. The aforementioned target group of respondents was asked to attribute personal characteristics to the Faculty according to their feelings and perceptions. The respondents were tasked to first imagine the Faculty of Organizational Sciences as a person, and then to determine its gender, estimate the age of the imagined person, describe the person with character traits, state what profession it would do, what kind of music it would listen to and what its dominant color would be. In order not to deny the breadth of answers, as well as the imagination of the respondents, the questionnaire consisted of open-ended and closed-ended questions. The second part of the questionnaire referred to the demographic characteristics of the respondents. The sample for the research consisted of current and former students of the Faculty of Organizational Sciences, of all study levels and both genders, who were selected using the random sampling method.

After data collection, coding and testing of the data was conducted using SPSS software, where a statistical analysis of the collected data were performed. Answers were homogenized according to significant characteristics. The Crosstabs statistical tool was used to cross-reference the data and observe their correlation. In particular, the data were cross-referenced between the gender of the respondents on one side and the color of the Faculty, the occupation of the Faculty, and the gender of the Faculty on the other side. Additionally, the Descriptive Statistics tool was used to provide a quick overview of the basic characteristics of the data distribution and summary statistics for the variables in the dataset. Using the Chi-square test, it was examined if there are statistically significant differences in the perception of the gender and color of the Faculty of Organizational Sciences as a person among students of different genders and age groups. In other words, if the gender and age of the respondents influence their perception of the Faculty.

The research was conducted in the period from June 27th to September 3rd, 2023. In total, 100 respondents, students and non-students, filled out the survey during that period. The questionnaire was anonymous. The survey was distributed through students WhatsApp groups, which included members of all years of study.

### **4. RESULTS**

The research aims to determine internal, students' perception of the Faculty of Organizational Sciences brand personality. By applying descriptive statistics, it was determined that 82.7% of respondents were students of the Faculty of the Organizational Sciences, and 17.3% were found to be students of other faculties. For this reason, external responses from students from other faculties were excluded from further analysis.

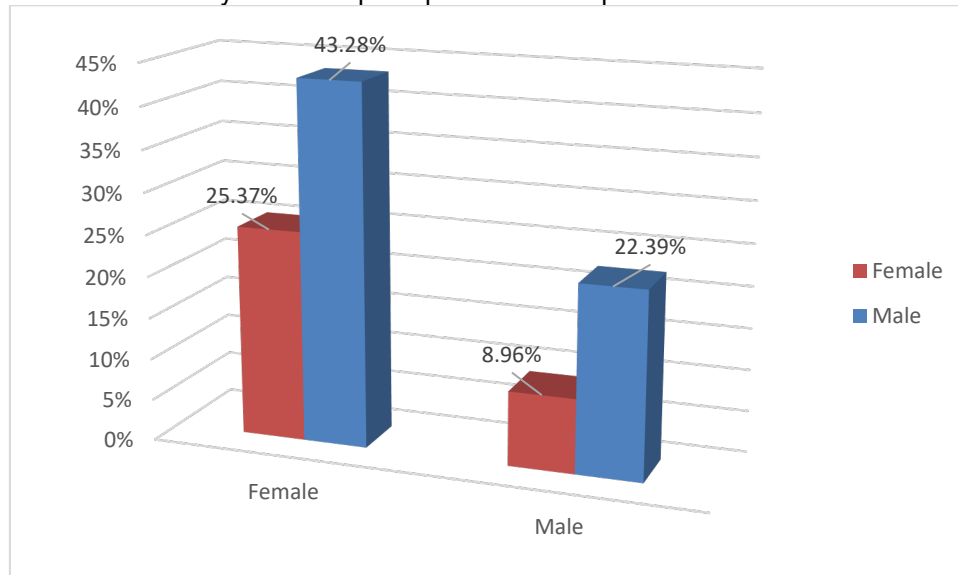
Further statistical analyses were performed exclusively on part of the sample of Faculty of Organizational Sciences respondents. The research results indicate that out of 100 collected responses, 81 were valid, and statistical analyses were conducted on this part of the sample.

The obtained findings indicated that 69.1% (56) of the respondents were female, while 30.9% (25) of the respondents were male.

The respondents were grouped into three different age categories: 19 to 24 years, 25 to 30 years, and 30+ years. The largest number of respondents who participated in the research, 89.6%, were respondents aged 19 to 24, who are current students of the Faculty. A significantly lower percentage of respondents, 10.4%, was made up of respondents aged 25 to 30, which implied master's students and former Faculty students.

#### **4.1. Brand gender**

Gaining deeper insights into brand personality perception, began with a question related to the gender of the brand "If Faculty of Organizational Sciences were a person, what gender would it be?". 65.7% of respondents pointed out that Faculty as a person would be a man, while 34.3% of respondents answered that it would be a woman. To further examine the relationship between the gender of the respondents and the perceived gender of the Faculty, in the next step of the research, the data regarding the gender of the Faculty of Organizational Sciences was cross-referenced with the gender of the respondents (see Figure 1). A significant conclusion obtained is that the female respondents perceived the Faculty as a dominantly male person. A possible reason why Faculty is characterized as a male person is that the noun "faculty" itself is male, which could unconsciously affect the perception of the respondents.



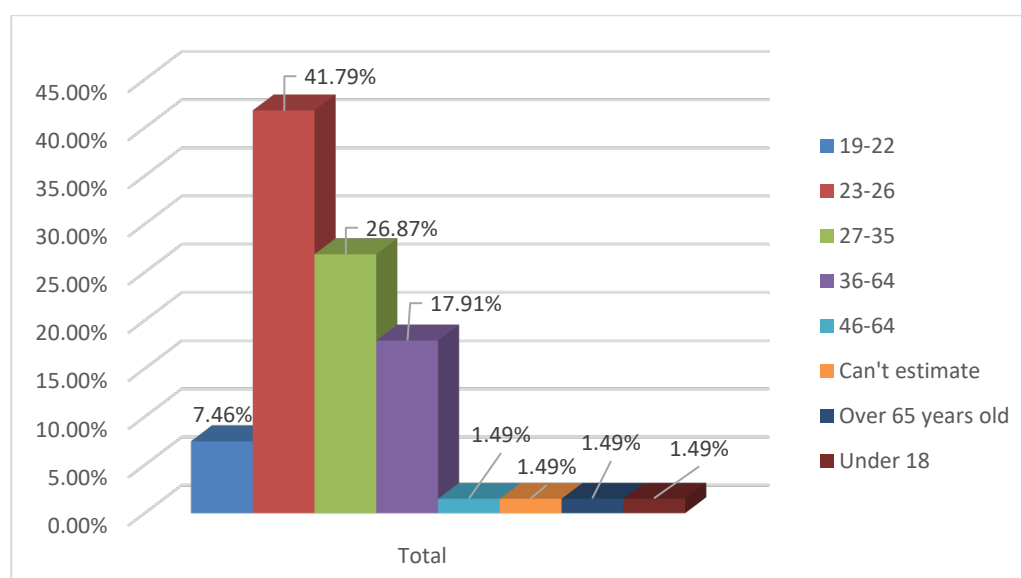
**Figure 1:** Respondents' answers regarding the gender of personalities at the Faculty of Organizational Sciences concerning respondents' gender

The p-value obtained from the Chi-square test when examining the statistical significance between the perceived gender of the Faculty and the gender of the respondents is 0.587. It can be concluded that there is no statistically significant difference in the perception of the gender of the Faculty of Organizational Sciences between male and female students. This means that the gender of the respondents does not significantly affect the perception of the Faculty's gender. This conclusion is expected, considering Figure 1, which shows that students' responses about the Faculty's gender favor the male gender.

The p-value obtained from the Chi-square test when examining the statistical significance between the perceived gender of the Faculty and the respondents' age is 1. It can be concluded that there is no statistically significant difference in the perception of the gender of the Faculty of Organizational Sciences between different age groups of students. This means that the Faculty is perceived as male regardless of the respondents' age.

## 4.2. Brand age

In the next step, the survey focused on the respondent's perception of the age of the Faculty as a human, with the question "If Faculty of Organizational Sciences were a person, how old would it be?". The obtained research results indicate that 41.8% of respondents believe that the age of the Faculty brand is between 23 and 26 years old, which means that the Faculty is seen as a young individual, who is starting his career (see Figure 2). Considering that these are the years when students on average finish university and start working, Faculty of Organizational Sciences is perceived as an independent, young individual at the beginning of professional career.



**Figure 2:** Respondents' answers regarding the age of the Faculty of Organizational Sciences

### 4.3. Brand personality characteristics

The survey continued with a question related to the brand personality characteristics: "What three key character traits describe Faculty as a person?". Based on the obtained responses, it is concluded that positive personality characteristics predominate in the general perception of the Faculty's brand personality, which is reflected in 85% of the answers. However, among 15% of the answers, negative characteristics that Faculty of Organizational Sciences is described were also identified. The three most frequent brand personality characteristics are resourceful 17.3%, modern 13.6%, and ambitious 13.6%. The total number of frequencies is 189.

According to the respondents' answers, the dominant characteristic of Faculty of Organizational Sciences as a person is resourcefulness. The Faculty of Organizational Sciences nurtures the qualities necessary for future leaders among its students, including resourcefulness. Through practical aspects of their education, students face various challenges, putting themselves in new situations. Students work on real tasks and projects, which increases their adaptability to new situations. The fact that organizational science graduates have in front of them a wide range of activities that they could engage within one corporation, shows how ready they are to face new, different experiences.

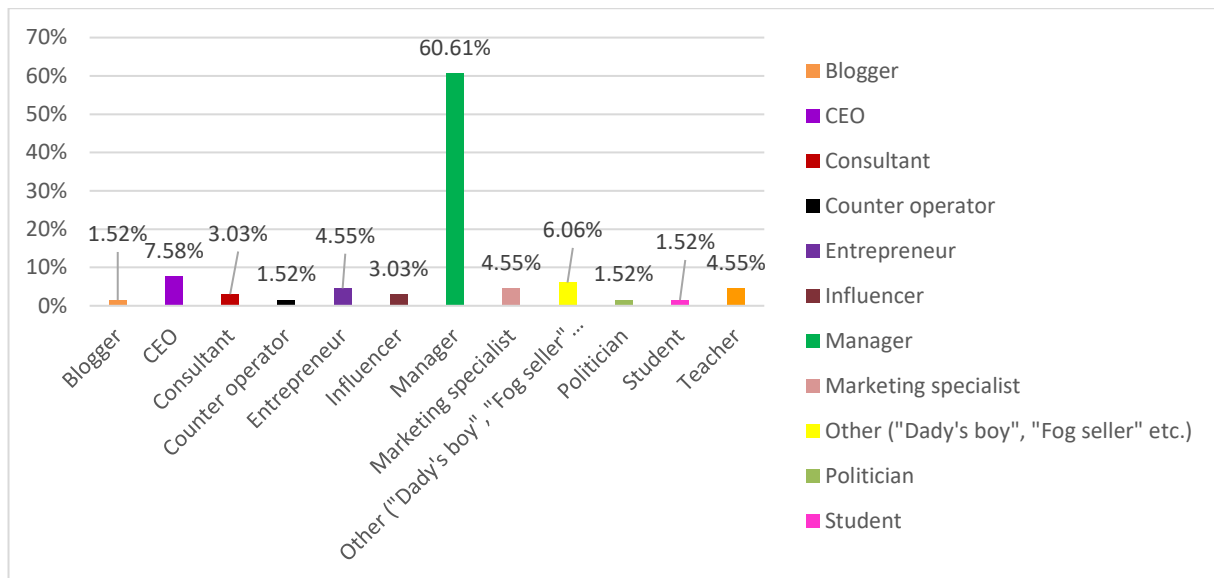
The next feature that stood out among the answers is modernity. Observing certain aspects of the Faculty, from the teaching part, through the methods and techniques used in education, to the work of laboratories, departments, and services, it can be concluded that each of them keeps pace with the times. The Faculty of Organizational Sciences is responsive to initiatives from both students and staff. Faculty expresses its modernity through constant improvements in study programs, teaching methods, and the equipment it uses. Also, Faculty encourages students to have an innovative approach to both academic and extracurricular activities.

An equally frequent personality trait is ambition. In addition to regular activities, students cultivate extracurricular activism, through involvement in student organizations, supported by the Faculty. The Faculty of Organizational Sciences is at the top of the University of Belgrade in terms of the number of student organizations. And lastly, students at the Faculty of Organizational Sciences have ambitious professors who serve as good examples and role models for setting higher goals.

### 4.4. Brand profession

In the next step of the research, the students answered the question "If the Faculty of Organizational Sciences were a person, what profession would it be?" were analyzed. 60.6% of respondents pointed out that Faculty of Organizational Sciences as a person would be the professional manager (see Figure 3).





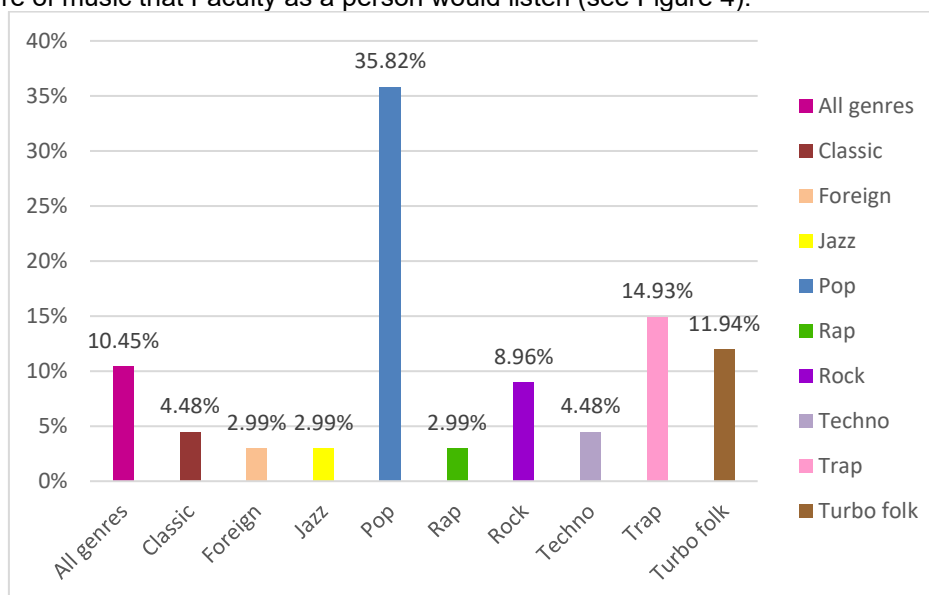
**Figure 3:** Respondents' answers regarding the profession of Faculty

An answer gained regarding the profession of the Faculty as a person is expected since Faculty of Organizational Sciences is an institution that educates dominantly young managers. At the Faculty students are taught to develop long and short-term strategies, goals, and plans for the company. Also, students are taught to establish the organizational structure, determine the roles and responsibilities of employees, and motivate, guide, and support the teams they lead. They communicate both with superiors and subordinates, control the progress of achieving goals, and solve business problems. All these activities are studied through the curriculum and program at Faculty of Organizational Sciences.

The next step in the survey was to examine whether there is a correlation between the respondents' answers to the question about the profession of the Faculty and respondent's gender. It is noticeable that female respondents were more creative in giving answers, resulting in 12 variations of answers, while the number of male respondents was twice as small. It is also noted that female respondents perceived Faculty through inappropriate professions such as "daddy's boy", "fog seller" and similar, which were classified in the "Other" category, while answers of this type didn't appear among male respondents.

#### 4.5. Brand music

In the next step of brand personality perception research, the answers about the music genre that Faculty as a person would listen were analyzed. Gathered results covered various genres, including pop, rock, trap, jazz, classical, techno, folk music, and others. The biggest percentage of respondents, 35.8%, believe that pop is the genre of music that Faculty as a person would listen (see Figure 4).

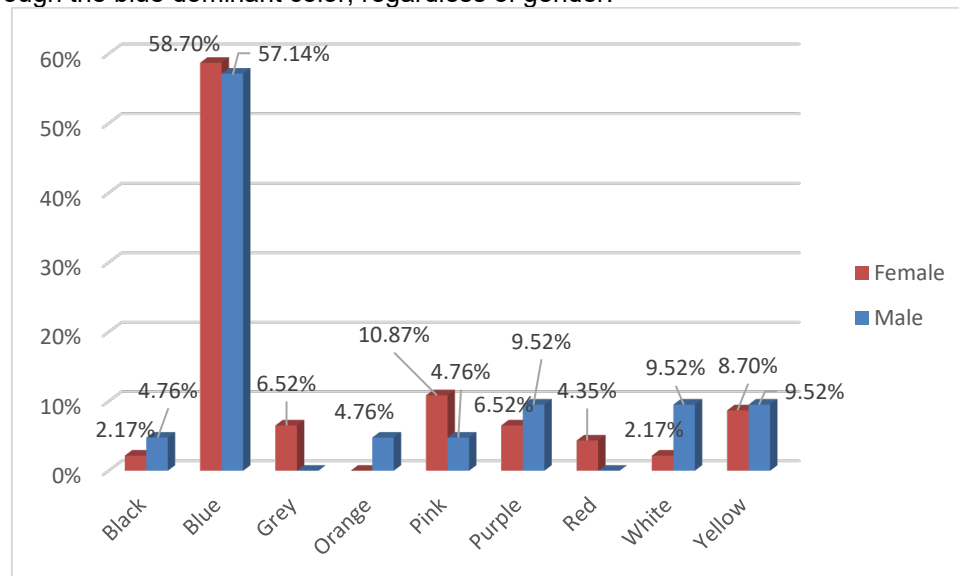


**Figure 4:** Respondents' answers regarding the genre of music that Faculty listens to

#### 4.6. Dominant brand color

In the research, the perception of the dominant color of the Faculty of Organizational Sciences as a brand was examined through the question "If Faculty were a person, what would be its dominant color?". According to the opinion of 58.2% of respondents blue is recognized as the dominant color of the Faculty of Organizational Sciences.

Since blue is the primary color of the corporate branding of the Faculty, it is understandable why respondents chose it as the dominant color. On the other hand, in the positive version of the FON logo, two out of three letters are written in blue, while the letter "O", which has the central place in the corporate logo, contains blue, but also other colors recognized by the respondents – pink (8.96%), purple (7.46%) and yellow (7.46%). To further examine the relationship between the gender of the respondents and the perceived color of the Faculty, the data on the gender of the respondents were cross-referenced with the data on the perceived color (see Figure 5). By cross-analyzing the mentioned data, it is concluded that Faculty is perceived through the blue dominant color, regardless of gender.



**Figure 5:** Respondents' answers regarding the color of Faculty concerning respondents' gender

After conducting the Chi-square test to examine the statistical significance between the perceived color of the Faculty of Organizational Sciences and the gender of the respondents, the p-value is 0.482. As the Chi-square test showed a value greater than 0.05, it was concluded that there is no statistically significant difference in the perception of the Faculty's color regarding the gender of the respondents. In other words, the gender of the respondents does not significantly influence the perception of the Faculty's color. This statistically based conclusion can be observed in Figure 5. It can be noticed that the highest number of responses, both from male and female respondents, was for the blue color.

The Chi-square test showed a p-value of 0.521, which means that there is no statistically significant difference in the perception of the color of the Faculty of Organizational Sciences between age groups of students. In other words, the age of the respondents does not significantly influence the perception of the color of the Faculty.

#### 5. CONCLUSION

Brand personality is a very popular and studied topic in the field of marketing today. According to Aaker (1997), "the process itself is challenging because one should try to base the entire brand image on its personality". Applying the results of brand personality research has many advantages, and the term "brand as a person" is gaining more and more importance considering the favorable marketing results based on building relationships between brands and consumers. People responsible for managing brands have long desired to "animate" and "humanize" their brands. The findings obtained through this research indicate that the respondents, primarily female students of the Faculty of Organizational Sciences, age between 19 and 24, described the brand personality of the Faculty as follows: "The Faculty of Organizational Sciences is perceived as a male person around 24 years old. He is very resourceful, modern, and ambitious. He currently holds a managerial position in a corporation. He is full of ideas and embraces innovations. He listens to pop music, and his dominant color is blue." The statistically significant findings highlighted that there are no significant differences in brand perception based on the gender and age group of the respondents.

It is important to highlight several key limitations of this research that could affect the generalization of the results. The most significant limitation of this research is the fact that only the attitudes and opinions of current students of the Faculty of Organizational Sciences were taken into account. The presented conclusions may show an incomplete image in terms of perception because it does not take into account other aspects of internal perception (perception of alumni and employees of the Faculty). Furthermore, the research does not examine external perception of students from other faculties, nor external perception of Faculty by corporations, employees in companies, and employers. Mentioned limitations could serve as a space for future improvements and research directions. The findings obtained through this research represent a valuable starting point for further exploration of brand personality perception and provide modest insight into the perception of Faculty of Organizational Sciences brand personality. However, the obtained results can be valuable in creating further research and considering potential corrective measures in practice if the established perception of the brand personality is found inadequate for the further development of the corporate brand of a higher education institution.

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# AI POWERED ADVERTISING STRATEGIES

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**Abstract:** *This paper examines the evolution of marketing strategies from traditional methods to advanced strategies powered by artificial intelligence (AI). Traditional forms of advertising, such as print media and radio, are increasingly being transformed into digital strategies that use the Internet and digital platforms. Digital marketing enables faster implementation, better measurability and greater adaptability compared to traditional methods. With the introduction of artificial intelligence, marketers can use advanced algorithms and machine learning to target audiences more precisely, personalize campaigns and optimize marketing processes. AI also enables automation of routine tasks, improved interaction with consumers and better real-time data analytics. Through a comparative analysis of traditional, digital and AI-driven advertising, their advantages, disadvantages and effects on the target market are explored. Digital marketing and AI advertising provide greater measurability, adaptability and interactivity, while traditional advertising can have a longer-lasting impact through memorable advertisements. AI also enables personalization of content, optimization of campaigns and prediction of consumer behavior, which contributes to improving marketing strategies and achieving better results. AI enables marketing teams to create advertising campaigns that are relevant and attractive to each target audience resulting in greater effectiveness of advertising campaigns. AI is a key tool in modern digital marketing and the further development of this technology will lead to even greater personalization and optimization of advertising strategies in the future.*

**Keywords:** Artificial intelligence, Advertising, Strategies, Marketing

## 1. INTRODUCTION

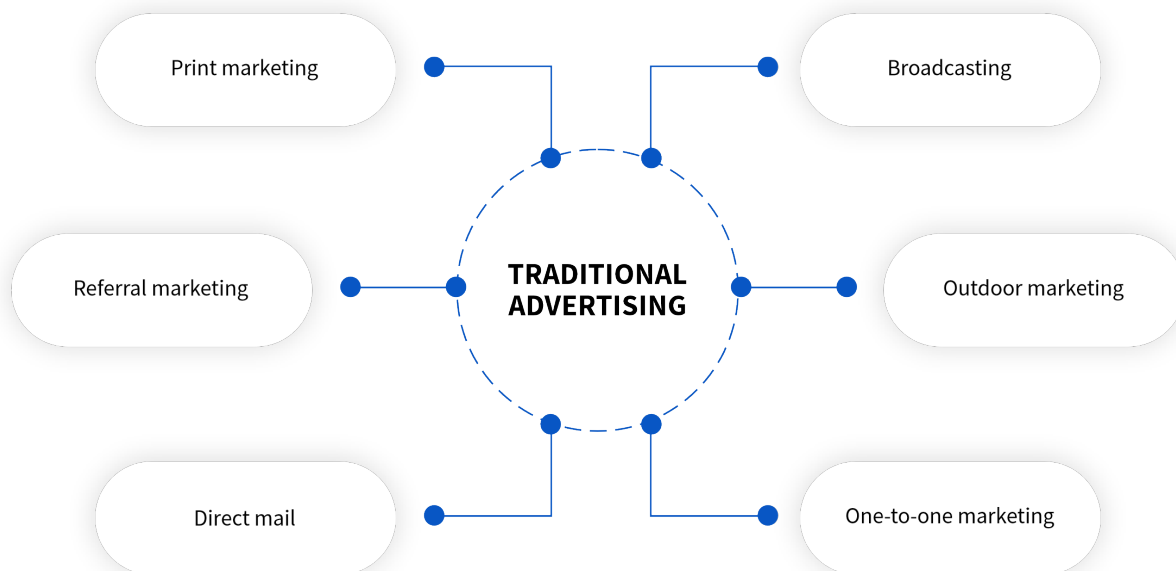
In today's digital age, the marketing landscape is constantly evolving, posing new challenges and providing endless opportunities to promote products and services. Traditional marketing methods that were once the foundation of any marketing strategy are now experiencing revolutionary changes, especially with the growing role of artificial intelligence (AI) in the marketing world. This article explores advanced marketing strategies that are powered by artificial intelligence, with a focus on advertising. The paper will examine how traditional marketing strategies have been transformed in the digital space and how AI is changing the way companies communicate with consumers and promote their products or services. AI is changing the advertising landscape through personalization, targeting, data analysis and process automation. Through comparative analysis of traditional advertising and advertising powered by artificial intelligence, investigating their advantages, disadvantages and effects on the target market we will provide deeper insight into how the marketing landscape is changing as technology advances and how marketers can adapt to stay competitive in this dynamic environment. Faced with the rapid development of technology and changes in consumer habits, marketers must be ready to adapt to new trends and take advantage of what AI can offer. Through this research, we hope to provide insight into the latest innovations in AI-powered advertising and help marketing professionals better understand how to integrate AI into their strategies and deliver successful marketing campaigns.

## 2. DEVELOPMENT OF MARKETING ADVERTISING METHODS

The evolution of advertising methods in marketing, from traditional through digital to AI, has changed the way companies communicate with consumers and promote their products or services. According to Kesić (2003), definition of advertising is: advertising represents a paid, mass communication form of specific content with the aim of informing, reminding, and encouraging potential customers to take action regarding a particular idea, product, or service. It is a paid form of promotion. When certain information and entertaining messages appear in mass media and are not paid for, it is referred to as publicity. On the other hand, advertising is a

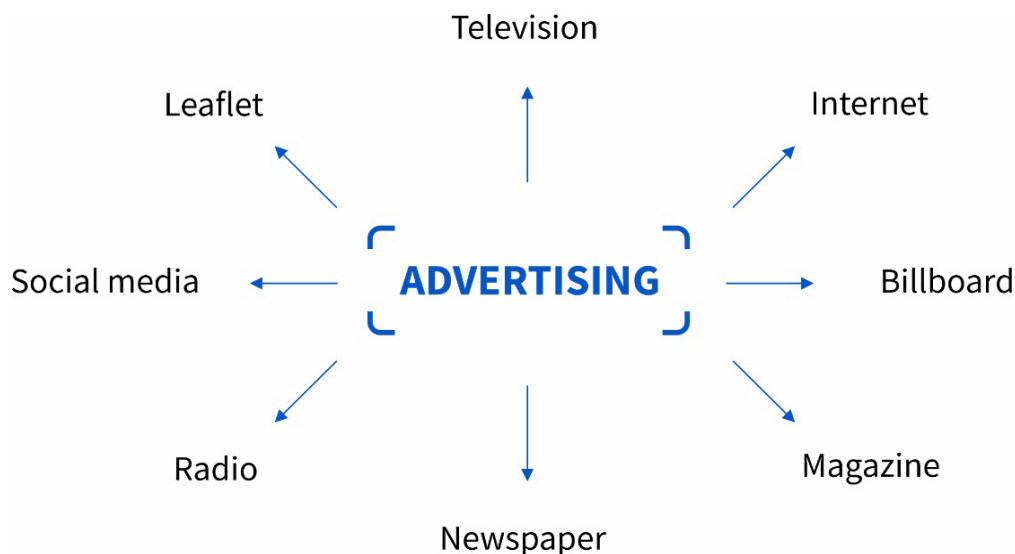
paid form of promotion, and its purpose is to present a product or service to a wider audience with the aim of achieving communication, economic, or both effects. Advertising does not involve direct communication, as is the case with personal selling, but communication occurs through mass media to a large number of unknown recipients (Kesić, 2003). According to Kotler et al. (2006), the goal of advertising is to elicit a response from the target audience. This response can manifest in the form of consumers forming certain attitudes or opinions about the product or brand, or by changing their attitudes through the advertisement (Kotler & Keller, 2006).

When it comes to traditional advertising, it's a broad category that includes various forms of marketing. It's the most recognizable form of marketing, including ads that can be seen and heard daily. Most traditional marketing strategies fall into one of the categories shown in Figure 1.



**Figure 1:** Traditional advertising

Features of traditional advertising include utilizing offline channels for product development, pricing, placement, and promotion; targeting a broader audience without specific segmentation; fostering stronger relationships through physical interaction; increasing value and customer loyalty through interaction with sales representatives; being perceived as more reliable by customers; and reaching a wider audience through various strategies, often via direct mail campaigns (Kapoor, 2022).

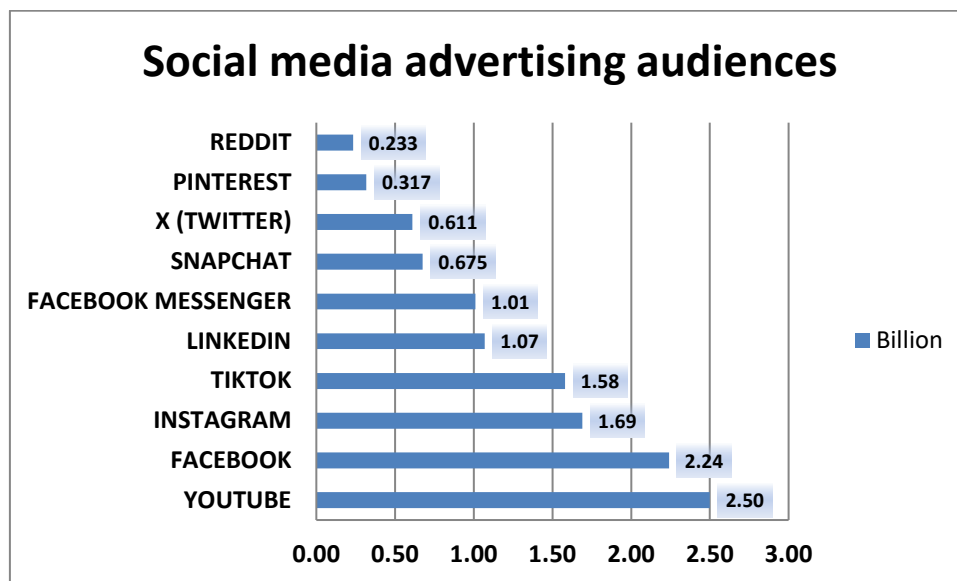


**Figure 2:** Types of advertising media

With the information explosion and the revolution produced by the evolution of information and communication technologies appeared the concept of digital marketing that synthesized all the activities developed through the information systems that use the binary or digital environment, specific to ITC application. Thus was born the digital marketing, known also as online marketing, cybermarketing, webmarketing, e-marketing, i-marketing, electronic marketing, digital marketing of marketing on the internet (Paşcalău & Urziceanu, 2020). Digital marketing has emerged as a new phenomenon that combines customization and mass distribution to achieve marketing goals, replacing conventional marketing subsets (Machado & Davim, 2016).

Integrated marketing communication tries to arrange and coordinate all marketing communication directed towards the client in order to form a whole that encourages the client to buy (Schulz, H., Kitchen, P.J., 2013). Contemporary advertising is user-centric, meaning users have more control, choice, and flexibility concerning their needs, desires, and limitations. Kotler et al. (2016) even refer to contemporary advertising as human-centric, where brands behave like people treating customers as their friends (Kotler, P. Kartajaya, H., Setiawan, I., 2016). Online marketing does not differ much from classic marketing, the ultimate goal being sales, regardless of the object of sale (products, services, information, etc.). At the same time, this type of marketing has some distinct features, the integration of the new media into the marketing mix (Paşcalău & Urziceanu, 2020).

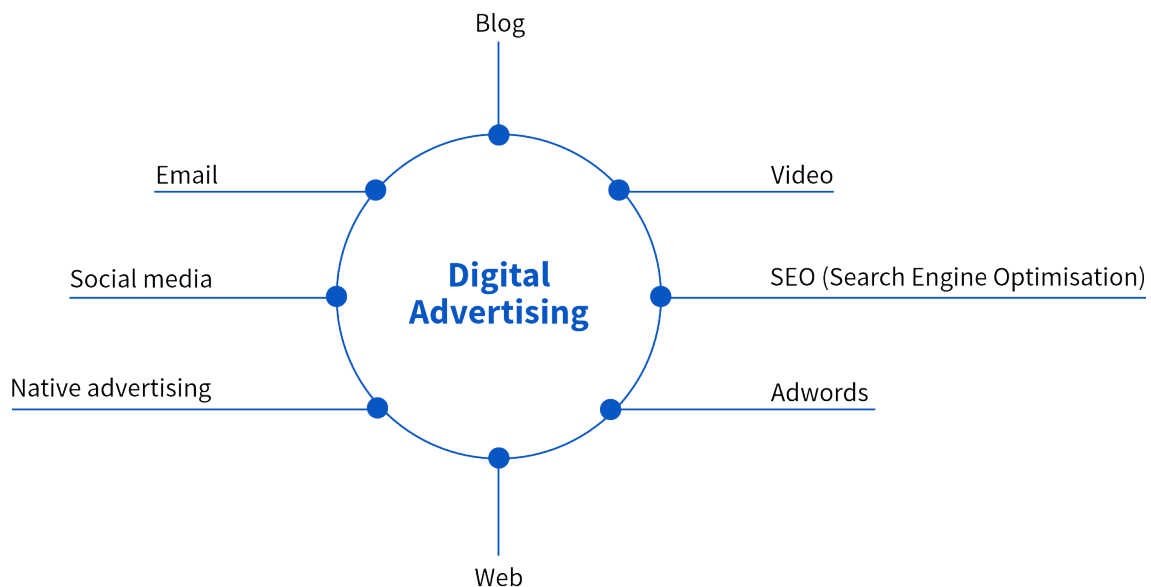
The main difference between digital and traditional marketing is the medium used to communicate the marketing message. Traditional marketing uses traditional media like magazines and newspapers, while digital marketing uses digital channels such as social media or websites. Digital marketing is a broad term describing various marketing processes using all available digital channels to promote products, services, or build a brand. Social media marketing strategy connects actions on social media with company goals such as attracting new customers, increasing sales, providing post-purchase services, and guiding sales staff (Quesenberry, K. A., 2021). Contemporary consumers are oriented towards digital media, the average consumer aged between 18 and 35 has profiles on nine social media platforms simultaneously.



**Figure 3:** Social media advertising audiences in April 2024

Source: Kepios analysis of data published in platforms advertising resources at datareportal.com

As digital platforms are increasingly incorporated into marketing plans and everyday life, and as people use digital devices instead of visiting physical shops, digital marketing campaigns are becoming more prevalent and efficient. Digital marketing allows marketers to see accurate results in real time. If an advert is put in newspaper, it is difficult to estimate how many people actually flipped to that page and paid attention to ad. There's no surefire way to know if that ad was responsible for any sales at all. Yet digital marketing would help you to know reach for your product/service, to get engaged with prospective customers, to have global reach, to promote in personalized manner (Desai, V., 2019).



**Figure 4: Digital advertising segments**  
Source: (Desai, V., 2019)

Digital marketing also offers superior interactivity and engagement. Unlike traditional marketing, where the effectiveness and reach are challenging to measure, digital marketing provides immediate feedback through user interactions such as clicks, likes, and shares. This not only allows companies to gauge the effectiveness of their campaigns but also to engage with customers directly, fostering better relationships and customer loyalty. The global reach of digital marketing is another significant advantage. A small local business can market internationally using digital platforms without the substantial investment that traditional marketing would require. Additionally, digital marketing provides detailed data analytics, enabling businesses to analyze consumer behavior, refine marketing strategies, and optimize resource allocation based on real-time data. Moreover, customer support has been transformed by digital marketing. Traditional methods often required a substantial in-person staff presence, but now companies can offer customer support through online chats and emails, providing quick and effective solutions to customer inquiries and issues (Paşcalău & Urziceanu, 2020; Coltman, T., 2007).

The personalization potential in digital marketing is a game-changer, and with the integration of AI, this aspect is poised to advance even further. AI represents a revolutionary tool that brings innovations to the marketing world by enabling a deeper understanding of consumers, personalizing campaigns, and optimizing marketing processes (Škavić, F., 2019).

### 3. AI IN MARKETING STRATEGIES

The introduction of AI in marketing has transformed how companies communicate with consumers, analyze data, and implement marketing strategies

AI has significantly transformed marketing through data-driven decision-making, enhanced customer engagement, tailored experiences, and streamlined operations (George et al., 2024). Using advanced algorithms and machine learning, marketers can analyze large datasets instantly, gaining valuable insights for informed strategic choices (Lee & Kim, 2020). This not only improves the precision of decisions but also allows for rapid adaptation to changing market conditions and consumer preferences. AI is pivotal in improving customer experiences, crucial to modern marketing tactics. It helps companies understand individual customer needs and preferences, enabling the design of personalized, smooth customer journeys (Mason & Patil, 2015). Personalization is key in marketing today. Machine learning algorithms examine past data to predict customer behavior, allowing for the creation of specific and relevant marketing messages (Brown & Jones, 2019). Whether through customized product recommendations or adaptive email marketing, AI-enabled personalization offers unique experiences to each customer. This capability to deliver personalized interactions on a large-scale boosts customer satisfaction and fosters brand loyalty (George et al., 2024).

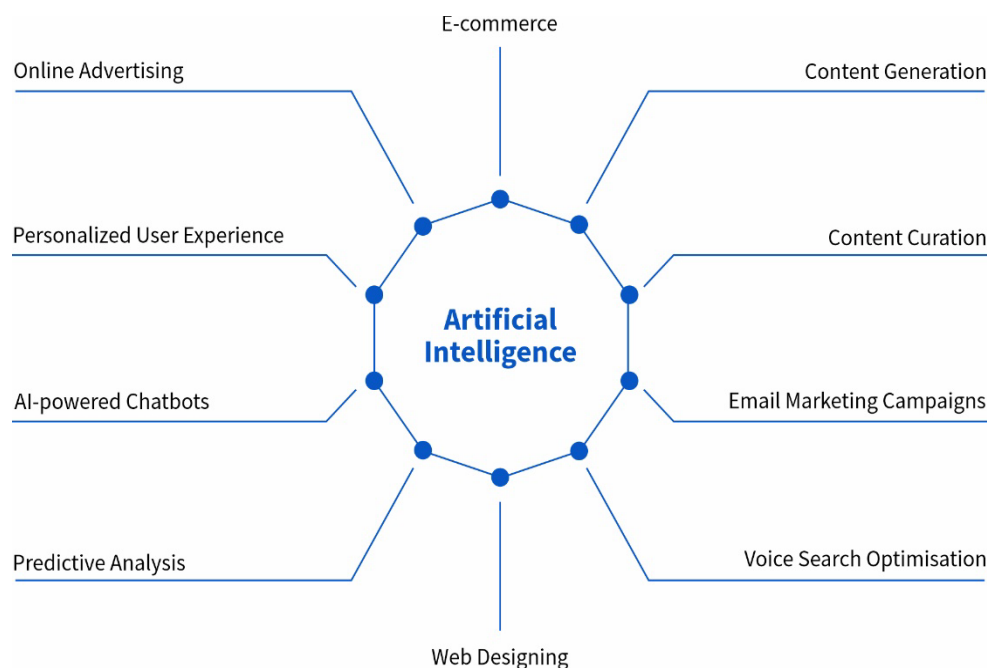
AI can further supply the processed data for strategic planning and decision-making by gathering marketing information from databases or stakeholders or forums and online techniques. AI further facilitates companies to better forecast and meet customer needs. This competitive environment allows them to maintain an edge by processing information more rapidly and launching new products and services either at a lower cost or with unique features (Weng, W., 2020).



## 4. AI POWERED ADVERTISING

With new technology and the explosion of digital media, advertising has progressed from traditional forms such as newspapers, billboards, radio, and television to various new and exciting media and platforms. Advanced advertising media use AI to increase advertisement effectiveness and optimize ad delivery (Ford et al., 2023). AI advertising strategy is a powerful tool for businesses looking to streamline their campaigns and reach their target audience with personalized and engaging experiences. AI has made advertising more competent, personalized, targeted, and intelligent by automating and facilitating vital advertising functions such as consumer insight discovery, media planning, buying, advertisement creation, and impact evaluation (Chen, Xie, Dong, & Wang, 2019; Deng, Tan, Wang, & Pan, 2019).

Advertisers have traditionally used market research, web analytics, and data mining to develop consumer profiles to be able to more effectively comprehend and define needs. However, AI now makes it possible to comprehend evolving needs and desires in the moment, as they are communicated online, and to faster develop better profiles (Ezzat, 2024). Implementing AI in different digital marketing strategies can change the way businesses interact with their customer.



**Figure 5:** Artificial Intelligence in Marketing

AI solutions can autonomously optimize advertising expenditure and targeting by analysing data and determining the best actions for performance improvement. Unlike human-powered and conventional software-based systems, AI's ability to learn and adapt without human intervention provides a significant competitive edge. Personalization is driven by predictive analytics, which can foresee customer needs and preferences before they are expressed. This allows marketers to proactively deliver highly tailored experiences (Yu, 2022).

AI tools for advertising are increasingly popular and can significantly enhance the efficiency, personalization, and impact of advertising campaigns. These tools leverage AI capabilities to deliver highly personalized messages, automate content creation, and optimize ad testing and performance.

AI-powered chatbots and virtual assistants deliver immediate and contextually appropriate interactions, giving customers a sense of promptness and attentiveness. Moreover, AI-driven personalization customizes content, suggestions, and communication channels according to individual preferences, ensuring that every customer interaction is both pertinent and enhances the overall experience. (George et al., 2024).

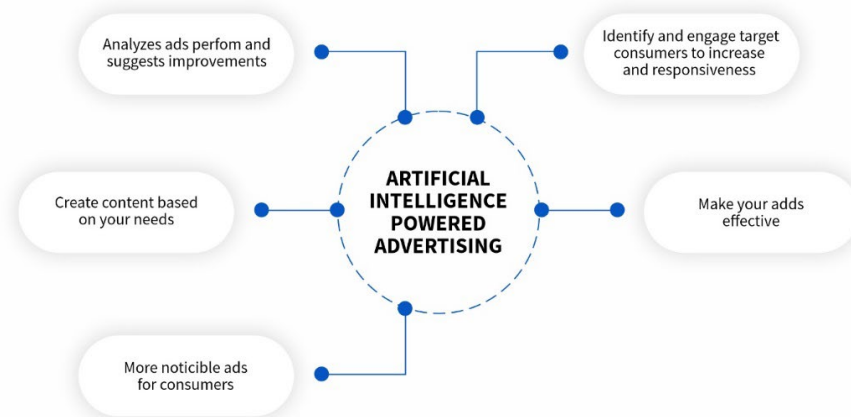
One of the most common ways marketers are using AI is for content creation including generating fresh ideas, outlining, editing, and producing written copy for social media posts, blog posts, and emails. AI tools like Chat GPT can generate content for social media posts, headings, and blog posts, saving time and resources for content marketers. AI tools like Phrasee can generate and optimize content for marketing campaigns, improving engagement and conversion rates.

AI analyzes campaign performance, adjusts strategies accordingly, and targets ads based on consumer behavior and trends. This results in improved customer engagement and retention while saving time and resources by focusing on the most successful ads. In advertising, personalization means using data or



consumer insights to make ads more relevant to their target market. Advertisers can enhance their relationships with customers, strengthen their bond with their brand, and improve the purchasing experience by using a customized AI solution like conversational marketing (Ezzat, 2024).

Segmenting, targeting, and positioning, which involves developing an understanding of customer segments and assisting marketing managers in their targeting and positioning decisions. In this process, marketers seek to group consumers according to certain criteria, enabling precise targeting of messages and the creation of brands and products that can best appeal to each segment. AI enables marketers to segment customers into more precise groups and predict their intent. Given the large heterogeneity of consumer tastes and preferences, the potential of segmentation is immense, from tailoring promotions and ads to making better product and brand recommendations (Campbell et al., 2019). AI tool like Albert AI can automate digital marketing campaigns, improving targeting and segmentation, and enhancing personalization and predictive analysis.



**Figure 6:** Ways AI improves advertising

Technologies, such as predictive analytics, have been essential in forecasting customer behaviour, allowing marketers to develop strategies that are not only responsive but also proactive (Haleem et al., 2022). AI can analyse customer data and trends to provide insights into future customer behaviour, enabling businesses to anticipate and prepare for upcoming demands with greater effectiveness. Programmatic advertising, powered by AI, has enabled marketers to navigate the fragmented digital advertising landscape, automating ad buying processes and optimizing ad placements in real time, ensuring that ads reach the right audience at the right time (Ford et al., 2023).

## 5. COMPARATIVE ANALYSIS

Traditional marketing, methods incur high costs due to materials, printing, and postage. They also tend to be slower, with a lengthy process required for design, approval, and distribution (Paşcalău & Urziceanu, 2020). In contrast, digital marketing leverages the internet and digital platforms, presenting a cost-effective, swift, and flexible alternative. Digital methods reduce the need for physical materials, drastically cutting costs and environmental impact. Changes to digital content can be made in real-time, and the content itself can be made available globally 24/7 (Jaworski & Kohli, 1993).

As technology advances, so does the way businesses interact with their customers. Therefore, AI provides the advantage to define and track a customer's journey through an advertisement which can then be used to improve future campaigns.

**Table 1.** Comparative analysis traditional, digital and AI powered advertising

Parameters	Traditional advertising	Digital advertising	AI powered advertising
Targeting	Targeting is generally broad and does not allow precise audience segmentation.	Specific targeting based on demographics, interests, behaviors.	It upgrades digital advertising using algorithms and machine learning for more precise targeting and personalization of content, and in real time.
Measurability	Difficult to measure, except through a survey or market study.	Detailed analytics and measurability	Improves analytics, enabling predictive analysis for deeper insight into user behavior.
Costs	Expensive, refers to the prices of media space and	Cheaper, possibility to control budget and costs.	Initially, it requires larger investments in technology, but it can reduce total

	production.		costs through greater efficiency and better results.
Interaction	Limited opportunities for interaction.	It increases engagement through clicks, comments and shares.	It automates and personalizes interaction and optimizes user experience based on individual preferences.
Adaptability	Limited adaptability.	It enables quick changes and real-time testing.	It provides maximum adaptability, optimizing campaigns automatically and adapting to changes in user behavior or market trends.
Impact	It can make a lasting impact through memorable advertisements.	It may have a less lasting impact due to the large amount of content that users encounter on a daily basis.	It can increase the durability of influence by personalizing and continuously optimizing that content is relevant and engaging.
Reach	It often has a very wide reach through media that reach large masses of people.	Global reach and access to a wider audience via the Internet, the possibility and targeting of specific segments.	Adjusts reach based on performance and real-time data analysis.
Message control	High control of the broadcast message because the formats are fixed and predetermined.	It provides control, but user interaction and comments can influence perception.	Algorithms can tailor messages independently, which can reduce control over content.
Safety	Safe in the context in which the advertisement appears.	It sometimes results in ads being displayed in inappropriate online environments, which can damage a brand's reputation.	Careful management is required so that automation does not lead to unwanted insertions of advertisements.
Implementation	It requires more time for production and distribution.	Fast implementation where campaigns can be launched within hours.	Quick implementation and additional optimization of the process through the adjustment of campaigns.

## 6. CONCLUSION

This paper analyzes in detail the transformation of marketing strategies in the digital age, with special emphasis on the role of AI in advertising. It is clear that AI is changing the way companies communicate with consumers, analyze data, adjust campaigns and optimize marketing processes. AI-driven advertising is increasingly present in modern marketing strategies, as it enables more precise targeting, personalized communication and more efficient resource management. AI is driving innovation in data analysis, enabling marketers to gain a deeper understanding of consumer behavior and adjust marketing campaigns in real time. However, we are also aware of the challenges arising from the use of AI in advertising, including issues of data privacy, transparency of algorithms and ethical dilemmas. The combination of the human creative mind and the power of AI can create powerful marketing campaigns that deeply engage the target market and drive business growth. Through future research, it is recommended to examine the results of different methods on different customer profiles or the results of different advertising methods in different industries in order to adapt advertising to, for example, different customer profiles and achieve the best results in different industries.

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# CHALLENGES IN DEFINING THE FRAMEWORK FOR ESG REPORTING

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**Abstract:** ESG has emerged as one of the most prominent trends impacting corporate governance, management, and investment over the last twenty years. Despite its widespread use, there remains a lack of clarity regarding its application in corporate practice and in defining the correct way companies should approach meeting the need for nonfinancial reporting on the way they conduct their business. As trillions of dollars pour into investment products labeled as ESG, and as companies and regulators engage with ESG policies, the term has taken on various interpretations, causing inconsistencies in the ways in which companies create their ESG reports.

*This article firstly aims to achieve clarity in defining the ESG reporting framework that can be universally used as a standard form of ESG reports. Secondly, it emphasizes the challenges corporate representatives have in making these reports, and the various differences in the way they are constructed. Finally, it offers a critical analysis of different ESG frameworks and gives guidelines on how ESG reporting should be conducted.*

**Keywords:** ESG reporting, framework, sustainability, challenges

## 1. INTRODUCTION

In response to the growing importance of sustainable business practices and increased investor demand for non-financial performance indicators of companies, there has been a clear need for ESG reporting and defining a framework that provides information on companies' activities related to their impact on the environment, society, and overall business management. While financial reports primarily serve as insights into the outcomes of relations between companies and their stakeholders, they can not be used for enhancing sustainable business practices (Lokuwaduge & Heenetigala, 2016). Investors, consumers, regulatory bodies, and other stakeholders increasingly demand transparency and accountability from companies in these areas, and ESG reporting precisely enables companies to convey the required information to these stakeholders to better understand and assess the risks and opportunities associated with investing or doing business with a particular company.

The integration of Environmental, Social, and Governance into one term has created a common phrase that can vary greatly depending on the context it's used for and be appealing to investors and stakeholders. While these factors contribute to corporate success, they also pose challenges, such as the difficulty of empirically demonstrating a causal connection between ESG and financial success and performance, the proliferation of ratings that may deviate from the original purposes of ESG, or facilitate "sustainability arbitrage" (Pollman, 2022). ESG stands for Environmental, Social, and Governance factors, which have become crucial elements considered in assessing investment opportunities and decision-making by investors and company management. Each of these components can be broken down and explained as follows (Mgambe et al., 2021):

- E - Environmental factors encompass all aspects related to the company's impact on the environment. Environmental responsibility centers on safeguarding the natural environment, prioritizing its well-being and sustainability. This entails efforts like biodiversity preservation, waste management, emission reduction, water conservation, and adherence to environmental laws. It involves using natural resources wisely to mitigate harm and secure their availability for

future generations. Sound environmental practices encompass setting environmental policies, investing in eco-friendly initiatives, and implementing pollution control measures.

- S - Social aspect of the ESG framework refers to the company's relationships with employees, the communities in which it operates, as well as the broader societal consequences of its activities. It emphasizes corporate social responsibility (CSR), focusing on how organizations interact with their communities and employees. This involves actions like investing in communities and creating internal policies. Social responsibility covers a broad spectrum of actions including human rights, diversity, health, education, labor practices, and customer satisfaction. It emphasizes that organizations should be accountable to all those affected by their decisions and operations, acting as responsible corporate citizens by contributing to society while also benefiting from it. This can include employment policies, human rights, supplier relations, social engagement, and other social initiatives.
- G - Governance factors relate to how the company is managed and controlled. Corporate governance involves the structure and procedures used to oversee and manage organizational activities. It acts as the driving force behind other aspects of the ESG reporting framework, aiming to build trustworthy relationships among stakeholders and the public. Governance includes tasks like setting goals, monitoring strategy execution, overseeing operations, and reporting to shareholders, as outlined by Pavlopoulos et al. (2017).

ESG, unlike other innovations in management represented by three-letter acronyms like TQM, JIT, and BSC, isn't a singular concept. It is often used more as a trendy term than a comprehensive solution to the growing demands for corporate performance information. Each of its three components — Environmental, Social, and Governance — represents distinct measurement opportunities and challenges, a complexity that ESG proponents often overlook. What ties together E, S, and G is their non-financial nature; however, building a reporting, evaluation, and investment system solely around what they're not isn't necessarily a recipe for success (*Kaplan & Ramanna, 2021*).

## 2. THE NEED FOR ESG REPORTING

An impending question that confronts us is to what extent should companies prioritize their commitment to environmental, social, and governance aspects? As articulated by Vlastelica (2016), the pursuit of business decisions solely driven by their societal benefits may prove unwarranted, potentially inflicting harm upon the company. Such short-sighted approaches could undermine operational integrity, the profitability of core business activities, as well as the livelihoods of employees within the organization, consequently impacting entire economic sectors in the long term. Conversely, a business ethos and strategy that disregards the needs of the community can yield equally adverse repercussions for all stakeholders involved. Sustainability issues have gained global significance in recent decades, and this is one reason why countries worldwide have begun taking measures to work on the Sustainable Development Goals (SDGs). This comes from both institutional and corporate efforts, which is precisely what ESG addresses, as a practice aimed at achieving sustainability within the corporate environment (*Mgambe et al., 2021*). There are numerous studies analyzing the effectiveness of using ESG frameworks in achieving business sustainability, concluding that ESG reporting is an ideal tool for achieving SDGs (*deVilliers et al., 2014*). ESG reporting provides insight into how companies manage these factors and how they impact its long-term success and sustainability. Some studies, like the Diwan et al. (2023), outline that the non-financial performances of companies seem to be a more and more important factor in the evaluation of their overall performance.

ESG factors are considered by 89% of investors when making investment decisions. Investors increasingly recognize the significant impact that ESG factors can have on a company's financial success and thus should be considered when making investment decisions. Daves et al. (2020) suggest the dissatisfaction of investors in the variety of ESG reporting disclosures, as they seem to consist of unclear and incomparable information about the non-financial corporate performances, which can not be used for investment decision making. Hence, there is a higher need for defining a framework for ESG reporting that will provide more consistent, readily accessible information that is easy to interpret and crucial for investors to evaluate the sustainable impact of their investment choices (*Bose, 2020*).

However, *Bose (2020)* points out that here lies the problem of collecting the data itself and using relevant non-financial information to generate ESG reports. In most cases, only standardized data and

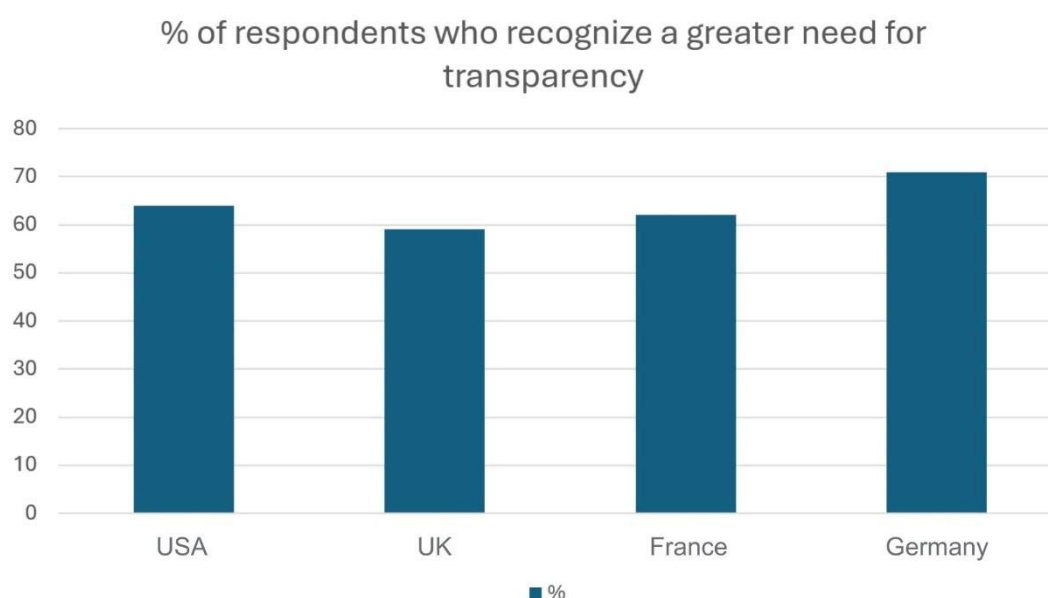
information that are readily available and often published by the companies themselves are accessible. They are simultaneously far less valuable than the key information needed to define strategies capable of providing a competitive advantage, which can only be obtained through conducting complex analyses, gaining specific insights, and collaborating with experts in certain fields. Some authors believe that a way to effectively use ESG reporting is through incorporating qualitative measures into financial reporting, leading to the development of an integrated report where all elements directly impact financial decision-making (*Mgambe et al.*, 2021).

When it comes to USA, ESG reports are being issued 90% of S&P (*Standard & Poor's*) 500 companies. In spite of that, Europe is the leader in the ESG investment market holding 83% of all ESG assets, while USA and Canada are more cautious when it comes to ESG-focused institutional investments. The proof of the positive impact of ESG performance on the market evaluation lies in results of numerous studies, such as *Mervelskemper & Streit* (2016). They noted that the sole decision of a company regarding if they will report on ESG initiatives or not affects their ESG performance valued by investors, regardless of that if the report is integrated or not. More importantly, publishing an integrated report can further enhance the market valuation of a firm's composite ESG and corporate governance performance to an economically and statistically significant extent at no additional cost.

### 3. THE EVOLUTION OF ESG REPORTING

The beginners phases of ESG reporting date back to the 1970s when companies like General Motors, Ford, and Cummins Engine began compiling reports on their activities regarding philanthropy and which include the involvement of the community (*Wilburn & Wilburn*, 2013). With the emergence of more frequent environmental disasters caused by corporate actions such as oil spills and chemical leaks, the environmental aspect became included, and business management was recognized as an integral part of ESG reporting due to its significant contribution to corporate social responsibility, not just performance (*Kocmanova et al.*, 2012).

As previously mentioned, there is an evident need for increased transparency in company operations, as well as accessible. As many as 83% of consumers believe that companies should actively promote best practices related to ESG. ESG data that investors can rely on when making investment decisions. The following graph depicts the percentage of respondents who believe that investors should increase pressure on companies to be even more transparent:



**Figure 1:** Respondents who recognize a greater need for transparency

Source: <https://www.workiva.com/resources/esg-reporting-101-what-you-need-know>

Initially, specific reporting requirements arose due to a set of troubles related to company operations, but they did not provide a comprehensive overview of business, focusing only on a random set of the ESG elements. The efforts of global institutions the United Nations Global Compact (UNGC) and the Global Reporting Initiative (GRI) have created more comprehensive sets of ESG data published by companies in recent years. Some organizations advocate for the need to make ESG reporting and its integration with financial reporting mandatory (*Mgambe et al.*, 2021).

The framework of integrated reporting represents the latest innovation in ESG development. Before integrated reports were developed, the ESG reports were published as part of financial reports on an annual level, as separate sections where organizations reported on non-financial issues. Today, the requirements for compiling these reports are becoming increasingly complex.

The introduction of the EU's CSRD - Corporate Sustainability Reporting Directive represents a notable change in the realm of ESG reporting. With the CSRD, there are 12 European Sustainability Reporting Standards (ESRSs) applicable across various industries, necessitating disclosures on a wide range of metrics and objectives. This directive impacts close to 50,000 companies, including both EU-based firms and non-EU entities with subsidiaries in the EU or listed on EU-regulated markets. Even companies with extensive prior experience in sustainability reporting may need to improve their ESG data collection, processing, and reporting mechanisms to meet CSRD standards. Many consulting firms, drawing on their expertise in sustainability reporting, have developed swift readiness assessments to evaluate companies' CSRD readiness levels, providing external assistance in data collection for reporting purposes. These assessments can identify pertinent ESG data deficiencies, benchmark CSRD readiness against industry peers, and formulate a clear strategy and actionable plan to achieve CSRD compliance (*Mgambe et al.*, 2021).

#### **4. THE CHALLENGES OF DEFINING THE FRAMEWORK FOR ESG REPORTING**

Today, one of the main challenges in compiling relevant ESG reports lies precisely in the methods of collecting and organizing the information to be included. Corporate ESG reporting frameworks provide insights into methods of clarifying the meaning of non-financial information and are used to improve the accuracy, validity, consistency, and interoperability of reports (*Bose*, 2020). The ESG reporting faces many challenges such as the high degree of diversification and conflict in various frameworks. Differences in ESG frameworks have the greatest impact on company representatives compiling reports who face the challenge of responding to multiple and diverse information requirements, rather than those who will be consumers of the information. However, there are arguments in favor of the diversity of ESG frameworks, emphasizing the importance of experimentation and the diversity of analytical approaches. Nevertheless, *Bose* (2020) concludes that the development of standards for defining ESG frameworks is an iterative process that continues to evolve, and it is still uncertain whether frameworks for generating ESG reports will develop into a global standardized form or into decentralized and flexible guidelines for their creation.

A variety of frameworks exist that categorize different aspects of sustainability. Upon reviewing the frameworks available to investors, it becomes evident that there is a strong relation between them, with minimal redundancy or inconsistency. In most cases, these frameworks can be used together. They all employ the Triple Bottom Line as a foundational conceptual framework for incorporating non-financial performance measures into corporate assessments. The Triple Bottom Line, introduced by John Elkington in 1997, is defined with the terms profit, people, and planet representing the three dimensions. In the concept of ESG, the economic, social, and environmental dimensions corresponded to profit, people, and planet, respectively, emphasizing the measurement of net performance across three dimensions. The Triple Bottom Line serves as a widely embraced foundation for the used ESG frameworks. Some of the frameworks used in ESG reporting focus on a different target audience and emphasise one aspect particularly, as *Bose* lists (2020):

- Global Reporting Initiative

The Global Reporting Initiative (GRI), founded in 1997, provides sustainability reporting standards outlined in its 4th version of reporting guidelines. These standards direct the voluntary creation of sustainability reports, typically distinct from regulatory submissions, and are broadly embraced, with 58% of sustainability reports in 2017 adhering to GRI guidelines. GRI aims to enable decisions that

promote social, environmental, and economic well-being for diverse stakeholders, reflecting its origin in United Nations discussions on sustainable development.

- International Integrated Reporting Council

The Integrated Reporting framework by the International Integrated Reporting Council (IIRC) targets the financial capital providers, and aims to improve information quality and promote accountability for various forms of capital. The IIRC framework is based on principles and requires re-evaluating the business models of organizations, emphasizing the value creation narrative through six types of capital. The IIRC has lower adoption rates compared to GRI, because while recognized for acknowledging stakeholder importance, it has gained criticism regarding its focus on financial capital and the absence of context-based considerations of sustainability.

- Sustainability Accounting Standards Board

The Sustainability Accounting Standards Board (SASB), similar to the International Integrated Reporting Council (IIRC) but unlike the Global Reporting Initiative (GRI), targets investors as its primary audience. Established by Jean Rogers under Michael Bloomberg's patronage in 2011, the SASB Foundation aims to establish disclosure standards facilitating companies' communication of decision-useful sustainability information to investors. With 77 standards issued in 2018 covering minimum sustainability reporting requirements for 11 sectors, SASB emphasizes financial materiality, tailoring standards to address sustainability issues likely to impact financial performance or condition in specific sectors.

- Impact Reporting Frameworks

While the previously mentioned frameworks primarily cater to large corporations, particularly publicly traded ones, equipped with extensive reporting infrastructure and specialized professionals. For small and medium enterprises lacking such resources, simplified frameworks offer comparable performance measures, serving as examples for easier reporting. The Impact Reporting and Investment Standards (IRIS), crafted for impact investors, emerged from a collaborative effort led by the Global Impact Investing Network (GIIN) and have garnered backing from a wide array of impact investors since their establishment in 2009. These standards provide specialized metrics tailored for small enterprises and social ventures. Likewise, the B Impact Assessment, overseen by B Lab, accredits businesses as part of a network of "B Corporations" through thorough evaluations of their impact scores. Concurrently, the Future-Fit Business Benchmark offers accessible guidelines for self-evaluation, with a focus on social and environmental objectives crucial for a sustainable future.

- The Sustainable Development Goals

The United Nations expanded social and environmental performance measures in 2015 through the release of the Sustainable Development Goals (SDGs), urging nations and private entities to create a balance between economic growth and social development and environmental sustainability. The involvement of the business sector in formulating the SDGs indicates its potential to contribute innovation, efficiency, and skills to achieving these goals, with investor-driven capital allocation playing a significant role. Initiatives like the SDG Compass provide frameworks for aligning business strategies with the SDGs, offering tools, standards, and assessment frameworks to assist companies in achieving each SDG.

## **5. THE ESG REPORTING FRAMEWORK GUIDELINES**

Each of the frameworks mentioned offers its own way of looking at how to include different ESG measures into deciding where to invest money. Investors might see all these different frameworks and measures as either problems or chances. While some complain that there aren't standard rules for these frameworks and this makes it hard to compare how well companies are doing, others think having different ways to look at things is good because investors have different goals and there isn't always enough information. Being able to change and improve these frameworks and indexes is important as we learn more about sustainability. Because investors have different reasons for investing, there's a place for simple rules and more complicated, hard-to-understand information (*Boose, 2020*).



Defining a comprehensive framework for ESG reporting is a complex task as it should provide clear guidelines and definitions to ensure consistency in reporting across different companies and industries. The framework should focus on ESG factors that are material to a company's operations, industry, and stakeholders, avoiding unnecessary data collection and reporting burdens. While allowing flexibility and customization to accommodate the diverse needs and circumstances of different companies, the framework should also strive for a certain degree of standardization to facilitate comparisons between companies and benchmarking over time. Above all, the ESG reporting framework should promote transparency by providing detailed information about the methodologies, assumptions, and data sources used in reporting. Another important element of the framework is incorporating stakeholder engagement in the form of feedback from key stakeholders, including investors, regulators, NGOs, and communities, to ensure that it addresses their information needs and concerns.

Another important question imposed in previous literature review is the data and information that can be used in ESG reports. Based on the different ESG reports encountered in corporate practise, in the next section are the guidelines and steps for providing the ESG reporting:

1. Conduct situational analysis

Conduct thorough research to comprehend existing and forthcoming regulations regarding sustainability reporting and evaluate their potential implications on the company.

2. Identify relevant ESG factors

Determine which environmental, social, and governance (ESG) factors are relevant to operations, industry, and stakeholders of a company. This may include issues such as carbon emissions, employee diversity, labor practices, community engagement, data privacy, and board diversity, among others.

3. Set ESG reporting goals

Define the objectives for ESG reporting, including the scope of reporting (e.g., global operations, specific business units), the frequency of reporting, and the intended audience (e.g., investors, customers, regulators).

4. Collect relevant data

Develop standardized processes for collecting ESG data, including identifying data sources, defining data collection methods (e.g., surveys, interviews, internal records), and assigning responsibilities for data collection within the company. In this step it is of high importance to involve relevant stakeholders to ensure that their perspectives and concerns are adequately represented. This may include employees, customers, suppliers, investors, NGOs, and local communities. Also, the data needs to be gathered from a variety of sources to ensure accuracy and reliability. This may include internal data sources (e.g., financial reports, employee records) as well as external sources (e.g., industry benchmarks, third-party databases, stakeholder feedback).

5. Design the ESG reporting setup

Define the standard architecture design of the ESG report with defined KPI's. An effective ESG report design should be tailored to the company's unique circumstances, audience expectations, and reporting requirements, while adhering to best practices in sustainability reporting.

6. Implementation

The final step refers to the implementation of the above mentioned. This requires training and support for the company employees responsible and also communicating ESG performance effectively to internal and external stakeholders through clear, transparent, and accessible reporting mechanisms, fostering trust and accountability. It is of high importance to conduct continuous improvement by setting targets, establishing benchmarks, and implementing corrective actions to address any gaps or deficiencies in ESG performance.



**Figure 2:** The framework for ESG reporting

By focusing on these aspects and following these steps, companies can establish a robust and effective ESG reporting framework that aligns with their strategic objectives, enhances their reputation, and drives long-term value creation.

## 5. CONCLUSION

In conclusion, the landscape of ESG reporting is complex and multifaceted, reflecting the diverse needs of stakeholders and the evolving nature of sustainability challenges. While ESG has become increasingly prominent in corporate governance and investment decisions, the lack of a universally accepted framework presents significant challenges for companies seeking to report their ESG performance accurately and consistently.

This research paper has highlighted the necessity of defining a comprehensive framework for ESG reporting to address these challenges. It has underscored the importance of clarity and standardization in reporting practices, while also recognizing the need for flexibility to accommodate the diverse needs and circumstances of different companies and industries. Moreover, the paper has emphasized the critical role of stakeholder engagement in shaping ESG reporting frameworks to ensure that they meet the information needs and concerns of investors, regulators, NGOs, and communities.

By examining the evolution of ESG development and reviewing major reporting frameworks, this paper has provided insights into the complexities and opportunities inherent in ESG reporting. From the Global Reporting Initiative to the Sustainability Accounting Standards Board, each framework offers its own approach to integrating ESG factors into corporate evaluations, reflecting the growing recognition of the importance of non-financial performance metrics.

Furthermore, the paper has outlined practical guidelines and steps for companies to establish robust ESG reporting frameworks, from conducting situational analysis to implementing reporting mechanisms and fostering continuous improvement. By following these guidelines, companies can enhance transparency, accountability, and long-term value creation, ultimately contributing to the achievement of sustainable development goals.

In summary, while the challenges in defining a framework for ESG reporting are significant, they also present opportunities for innovation, collaboration, and progress towards a more sustainable and responsible business environment. By working together and leveraging best practices in reporting, companies, investors, and other stakeholders can advance the adoption of ESG principles and contribute to a more prosperous and resilient future for all.

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# RESEARCH ON CORPORATE REPUTATION IN COMPANIES IN SERBIA

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**Abstract:** *Corporate reputation stands as a cornerstone among the intangible assets crucial for contemporary business, serving as a linchpin for long-term success and competitive edge. Embedded within the realm of intellectual capital, corporate reputation intertwines intricately with the overarching organizational image, an amalgamation shaped by a myriad of influences. It encompasses perceptions at the managerial, employee, product, service, and public levels. Companies employing diverse strategies to cultivate and manage corporate reputation witness augmented market appeal, heightened sales, fostering of contented and loyal customers, and optimization of financial outcomes. The aim of this paper is to examine the corporate reputation of companies in Serbia by the employees in these companies. In the research, a sample of 110 respondents who are employed in different companies in Serbia was formed. Using descriptive statistics and ANOVA test, it was determined that companies in Serbia have a positive corporate reputation. Also, it was determined that there are no differences in the corporate reputation of companies of different sizes, activities and ownership structures.*

**Keywords:** *corporate reputation, image, competitive advantage, non-tangible assets*

## 1. INTRODUCTION

In modern business environments, careful asset management and strategic decision-making are imperative for enhancing market competitiveness. However, traditional physical assets like buildings, machinery, and land no longer wield the capability to generate sustainable competitive advantage. In line with the Resource-based view of the firm, resources that are rare, inimitable, and lacking substitutes are deemed essential. Corporate reputation emerges as a valuable intangible resource meeting these criteria, thereby ensuring long-term success for companies (Pires & Trez, 2018). Indeed, corporate reputation is hailed as the paramount intellectual asset, with the potential to significantly contribute to financial prosperity (Almeida & Coelho, 2018). The challenging and gradual process of building corporate reputation renders it difficult to replicate (Vlasterlica et al, 2018). As a culmination of a company's endeavors to foster a positive perception among various stakeholders, corporate reputation is inherently multidimensional. It encompasses not only product and service quality but also encompasses employee relations, working conditions, corporate social responsibility (CSR), financial performance, innovation, and marketing efforts (Kircova & Esen, 2018; Bigus et al, 2023). Thus, corporate reputation embodies a spectrum of attributes shaped by past decisions, actions, and strategies, which collectively define a company's image in the market and among internal stakeholders. Enhancing product and service quality, fostering innovation, implementing sound human resource management practices, and delivering favorable financial outcomes are avenues through which a company can bolster its corporate reputation (Singh & Misra, 2021). Internally, corporate reputation often materializes through the employer brand, reflecting a company's endeavor to position itself as an attractive and distinctive workplace, capable of attracting and retaining top talents from the labor pool. Achieving this necessitates equitable recruitment and selection practices, ongoing training and skill development, and a mixture of tangible and intangible reward systems (Silva & Dias, 2023; Pavlović & Zdravković, 2019; Slavković et al, 2018; Pavlović, 2018). Externally, understanding the nexus between corporate reputation and CSR is pivotal. Sponsorship of events, community investment, and philanthropy demonstrate a company's commitment not only to profitability but also to societal well-being (Gomez-Trujillo et al, 2020; Park, 2019; Axjonow et al, 2018; Le, 2022; Singh & Misra, 2021). Moreover, corporate reputation encompasses factors such as customer satisfaction, business transparency, employee and managerial competence, adherence to performance measurement policies, and the perception of corporate reputation itself (Almeida & Coelho, 2018). Hence, corporate reputation transcends mere market perception of a company (Silva & Dias, 2022).

While papers on corporate reputation exist in Serbia, they predominantly focus on theoretical constructs elucidating the significance of management practices, product quality, CSR, competencies, and similar factors

(Vuković et al, 2021; Vlastelica et al, 2017; Vujović, 2014). Ognjanović (2020) explores the correlation between employer brand and corporate reputation, concluding that crafting an appealing workplace, grounded in the functional, economic, and aspirational value of the company, positively impacts corporate reputation. Given the research gap in domestic academic literature, this study aims to examine the corporate reputation of companies in Serbia by the employees in these companies companies. Accordingly, two research questions were formulated:

1. What are the key attributes characterizing the attained corporate reputation of companies in Serbia?
2. Are there observable variations in the extent of corporate reputation among companies differing in size, industry, and ownership structures?.

## 2. METHODOLOGY

To achieve the research objective and address the defined research questions, a survey was conducted to assess the corporate reputation of companies operating in Serbia. The survey took place in March 2024 and targeted respondents employed in companies, primarily within the Belgrade region. Drawing from the research conducted by Caruana & Chircop (2000), statements were formulated to guide the survey process. The questionnaire was structured into three sections. The first section aimed to gauge respondents' general perceptions of corporate reputation within their respective companies. The second section comprised statements derived from the aforementioned research, designed to delve deeper into specific dimensions of corporate reputation. Lastly, the third section sought informations about the respondents and their employing companies. A sample of 110 respondents was selected for the study, and therefore it can be said that it is an indicative research. The questionnaire was administered electronically to the participants. Subsequently, the collected data underwent analysis using the statistical software SPSS V25. Various research techniques including frequency analysis, descriptive statistics, internal consistency analysis, and the ANOVA test were employed to analyze the data and draw meaningful insights..

When it comes to the sample, 46.4% of male and 53.6% of female respondents participated in the research. In terms of companies, 26.4% are small companies (up to 50 employees), 20% are medium-sized (50-250 employees) and 53.6% are large companies (over 250 employees). A total of 19.1% of companies belong to the production sector, 10.9% to the trade sector and 70% to the service sector. Finally, 36.4% are domestic private companies, 10% are public organizations, 1.8% are non-profit organizations and 51.8% are private foreign or multinational companies.

## 3. RESULTS AND DISCUSSION

Before proceeding to a descriptive analysis of the statements used to measure corporate reputation, it is necessary to look at the answers to some of the general questions in this regard. The results of the analysis are shown in Table 1.

**Table 1:** General attitudes of employees about corporate reputation

Questions	% YES	% NO
1. Does the company I work for conduct corporate reputation research?	53,6	46,4
2. As an employee, do I have insight into the metrics for measuring the image of the company I work for?	27,3	72,7
3. Am I aware of the reputation of the company I work for?	74,5	25,5
4. Is the company I am working for a desirable place to work?	86,4	13,6
5. Does the company I work for conduct employee satisfaction surveys?	61,8	38,2

Based on the research results presented in Table 1, it can be concluded that more than half of the companies surveyed engage in research and measurement of corporate reputation. However, a significant majority of employees within these companies lack insight into the specific metrics utilized for assessing corporate reputation. Despite this, employees generally possess awareness regarding the reputation of the company they are associated with, largely based on their overall impression and market information. Remarkably, in over 86% of cases, the company is perceived as a desirable workplace, indicating a well-developed employer brand, which serves as a key indicator of corporate reputation, as noted by Ognjanović (2020). Furthermore, in nearly two-thirds of instances, companies regularly assess employee satisfaction, underscoring a concerted effort towards enhancing working conditions and bolstering the employer brand. Table 2 provides a summary

of descriptive statistics pertaining to the research findings, offering a comprehensive overview of the key metrics utilized in the study.

**Table 2:** Corporate reputation: results of descriptive statistics

Items	Mean	Standard deviation
1. The company I work for produces good products and services that meet or exceed the standards that are expected.	4,07	0,99
2. The company I work for implements innovative marketing efforts.	3,55	1,24
3. The company I work for is a sponsor of numerous events and activities.	3,21	1,49
4. The management of the company contributes with its personal reputation to the corporate reputation of the company I work for.	3,61	1,24
5. The company's management is ready to ensure a good relationship between strategic priorities and the company's business reputation.	3,74	1,17
6. The company's management collects information from subordinates in various ways and integrates the strategies of different business units, which would aim to improve the company's reputation on the market.	3,42	1,32
7. In my opinion, the employees of the company where I work are very competent for the work they do.	3,75	1,02
8. In my opinion, the company I work for offers a variety of products and services in the market.	3,63	1,29
9. According to the references, the company where I work has a very competent management.	3,60	1,22
10. The company where I work is very active in applying marketing activities according to the results of market research.	3,21	1,29
11. I think the company I work for has a very promising future.	4,08	1,05
12. The company I work for is highly profitable.	4,03	1,11

The most favorable attitudes, reflected by the highest arithmetic mean, are observed in statement 11, where employees express confidence in their company's promising future (mean score: 4.08). This optimism is underpinned by strong financial performance (mean score: 4.03) and a commitment to delivering quality products and services that surpass industry standards (mean score: 4.07). Across the five-point scale, all other statements also garner positive and favorable ratings. Hence, besides profitability and product quality, companies earn acclaim due to the competence of their employees and managers, coupled with proactive management aligning strategic priorities with the company's reputation, as highlighted by Singh & Misra (2021). Moreover, positive reputation is attributed to the diversity of the product and service offerings, innovative marketing strategies, and community engagement through event sponsorship, showcasing a commitment to socially responsible business practices rather than solely profit maximization. Notably, statements with low standard deviation exhibit the highest consensus among employees, such as statement 1, where there is unanimous agreement regarding the company's production of quality products and services meeting or exceeding expectations (standard deviation: 0.99). With an overall arithmetic mean of 3.66 across all statements, indicative of a relatively high value on the five-point scale, it can be concluded that companies in Serbia enjoy a positive corporate reputation. However, there is still space for enhancing corporate reputation, especially through strategies aimed at addressing statements with lower arithmetic means. As per the research findings, enhancing corporate reputation can be achieved through heightened innovation in marketing endeavors, increased support for extracurricular activities, and refinement of strategic priorities.

To evaluate the internal consistency of the variable utilized in the research and thereby ensure scientific objectivity, the Cronbach's alpha test was employed. It is widely acknowledged that for a variable to be reliable, the Cronbach's alpha coefficient should ideally exceed 0.7 (Nunnally, 1978). The analysis revealed a Cronbach's alpha coefficient of 0.895, significantly surpassing the recommended threshold. This indicates optimal internal consistency within the variable under examination. Consequently, it is justified to assert that the scientific results derived from the research are objective, substantiating the rationale for further analysis and interpretation. In identifying corporate reputation, it is useful to look at whether there are differences in reputation between companies of different sizes, activities and ownership. When it comes to size, in order to determine the differences in the level of reputation, the ANOVA test was applied, the results of which are shown in Table 3.

**Table 3:** Corporate reputation: differences between companies of different sizes

Items	F	Sig
1. The company I work for produces good products and services that meet or exceed the standards that are expected.	1,13	0,326
2. The company I work for implements innovative marketing efforts.	0,864	0,424
3. The company I work for is a sponsor of numerous events and activities.	1,548	0,217
4. The management of the company contributes with its personal reputation to the corporate reputation of the company I work for.	0,241	0,786
5. The company's management is ready to ensure a good relationship between strategic priorities and the company's business reputation.	0,123	0,885
6. The company's management collects information from subordinates in various ways and integrates the strategies of different business units, which would aim to improve the company's reputation on the market.	1,158	0,318
7. In my opinion, the employees of the company where I work are very competent for the work they do.	1,495	0,229
8. In my opinion, the company I work for offers a variety of products and services in the market.	2,108	0,127
9. According to the references, the company where I work has a very competent management.	0,936	0,395
10. The company where I work is very active in applying marketing activities according to the results of market research.	0,013	0,987
11. I think the company I work for has a very promising future.	0,944	0,392
12. The company I work for is highly profitable.	0,460	0,632

Since the ANOVA test results did not identify a statistically significant difference ( $p > 0.05$ ), it can be concluded that there is no statistically significant difference in corporate reputation between companies of different sizes. Consequently, it is not necessary to apply post tests. The results concerning the difference in corporate reputation depending on the activity are shown in Table 4.

**Table 4:** Corporate reputation: differences between companies of different industries

Items	F	Sig
1. The company I work for produces good products and services that meet or exceed the standards that are expected.	1,75	0,178
2. The company I work for implements innovative marketing efforts.	0,041	0,960
3. The company I work for is a sponsor of numerous events and activities.	2,69	0,072
4. The management of the company contributes with its personal reputation to the corporate reputation of the company I work for.	1,29	0,279
5. The company's management is ready to ensure a good relationship between strategic priorities and the company's business reputation.	0,854	0,429
6. The company's management collects information from subordinates in various ways and integrates the strategies of different business units, which would aim to improve the company's reputation on the market.	0,293	0,746
7. In my opinion, the employees of the company where I work are very competent for the work they do.	2,347	0,101
8. In my opinion, the company I work for offers a variety of products and services in the market.	0,817	0,445
9. According to the references, the company where I work has a very competent management.	0,812	0,447
10. The company where I work is very active in applying marketing activities according to the results of market research.	1,16	0,315
11. I think the company I work for has a very promising future.	0,751	0,474
12. The company I work for is highly profitable.	3,09	<b>0,049</b>

A statistically significant difference was found only in the case of statement 12, which refers to the company's profitability. The results of the Scheffe alpha post test show that there is a statistically significant difference between manufacturing and service companies. The average value on the side of manufacturing companies is 4.57, while that of service companies is 3.9, which indicates higher profitability of manufacturing companies in Serbia. However, the difference in only this finding and not in the others is insufficient to claim the presence

of a statistically significant or partially significant difference. The results of the ANOVA test related to the differences in the corporate reputation of companies under different ownership are shown in Table 5.

**Table 5:** Corporate reputation: differences between companies of different ownership

Items	F	Sig
1. The company I work for produces good products and services that meet or exceed the standards that are expected.	1,63	0,187
2. The company I work for implements innovative marketing efforts.	0,591	0,622
3. The company I work for is a sponsor of numerous events and activities.	0,328	0,805
4. The management of the company contributes with its personal reputation to the corporate reputation of the company I work for.	1,402	0,246
5. The company's management is ready to ensure a good relationship between strategic priorities and the company's business reputation.	1,18	0,318
6. The company's management collects information from subordinates in various ways and integrates the strategies of different business units, which would aim to improve the company's reputation on the market.	0,171	0,916
7. In my opinion, the employees of the company where I work are very competent for the work they do.	0,252	0,860
8. In my opinion, the company I work for offers a variety of products and services in the market.	1,70	0,171
9. According to the references, the company where I work has a very competent management.	1,88	0,137
10. The company where I work is very active in applying marketing activities according to the results of market research.	0,51	0,671
11. I think the company I work for has a very promising future.	1,06	0,367
12. The company I work for is highly profitable.	2,53	0,061

Regarding differences in ownership, the ANOVA test did not reveal statistically significant distinctions. Therefore, it can be inferred that there is no notable difference in corporate reputation among companies with varying forms of ownership. This finding suggests that management in companies across the Republic of Serbia faces a similar landscape in terms of reputation enhancement, irrespective of ownership structure. Building upon these findings, the improvement of strategic priorities emerges as a pivotal step in enhancing corporate reputation. It should be regarded as a paramount intellectual resource capable of furnishing a competitive advantage. Consequently, managerial and employee efforts should be channeled towards fortifying reputation. Subsequently, innovative marketing initiatives should be employed to effectively communicate corporate reputation both internally and externally. Furthermore, companies should seek additional avenues to support the external community and stakeholders, including internal stakeholders such as employees, with the aim of enhancing the overall image of the company in the market. Transparency emerges as a crucial factor in augmenting corporate reputation (Almeida & Coelho, 2018). Thus, management should inform employees about measurement metrics and factors contributing to corporate reputation. By doing so, employees gain insights that can inform their engagement efforts towards crafting a favorable corporate reputation. This not only fosters a sense of involvement but also aligns employees with the company's reputation-building endeavors.

In addition to the above results, it is useful to determine whether there are differences in the attitudes of respondents of different genders and ages. For the purposes of the first mentioned, the t test was used. As the difference in all used statements reached a value that cannot be considered statistically significant ( $p > 0.05$ ), it can be concluded that there are no statistically significant differences between male and female employees regarding the corporate reputation of the companies they work for. To compare the attitudes of respondents of different ages, the t test was also used. As in the previous case, the achieved results are at the level of  $p > 0.05$ , as a result of which it can be concluded that there are no statistically significant differences between employees of different ages in terms of the corporate reputation of the companies they work for.

#### 4. CONCLUSION

The aim of this research was to assess the corporate reputation of companies in the Republic of Serbia. The findings indicate a positive corporate reputation across the sampled companies, with no significant disparities observed based on company size, industry, or ownership structure. Consequently, management can pursue strategies to enhance corporate reputation without the necessity to tailor efforts to these contextual factors. Practically, this study offers valuable insights to management on avenues for further improving corporate



reputation. Theoretical contributions lie in advancing scientific understanding of corporate reputation, a domain relatively underexplored in domestic academic circles, thus laying groundwork for future research endeavors.

Nevertheless, this study is not without limitations, which also serve as pointers for future research. Firstly, the sample size should be expanded in subsequent studies to enhance statistical robustness. Additionally, employing representative sampling methods is imperative to ensure a balanced representation of various groups within the sample. Broadening the geographical scope beyond the Belgrade region is essential for a more comprehensive understanding of corporate reputation dynamics across Serbia. Future research could delve deeper by correlating corporate reputation with specific company performance metrics, such as financial results, employer brand perception, customer satisfaction, and more. This necessitates the adoption of more sophisticated statistical analyses like regression, factor analysis, structural equation modeling (SEM), among others, to glean nuanced insights into the interplay between corporate reputation and various performance indicators.

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# EVOLUTIONARY PATHS IN HUMAN-CENTERED DIGITAL MARKETING: INSIGHTS AND APPLICATIONS

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**Abstract:** *In the era of the fourth industrial revolution, digital marketing is pivotal for business growth, especially for large enterprises. Recognizing the significance of human factors in digital strategies, there's a growing inclination towards human-centered approaches. This trend is reflected in the development of products customized to human needs, indicative of broader innovations in the digital realm. Through hybrid-bibliographical research, this study aims to elucidate insights into human-centered digital marketing, thereby enhancing comprehension of its implications on contemporary issues and laying the groundwork for future research endeavors in the field.*

**Keywords:** *human-centered design, human-centered digital marketing, end-user preferences*

## 1. INTRODUCTION

In recent years, a discernible trend has emerged toward increased online user engagement, evident in both content dissemination and commercial transactions. This phenomenon underscores the imperative of enhancing user experience and tailoring product offerings to human preferences, as underscored in Štavljanin and Pantović (2017). The significance of end-user needs has increasingly come to the forefront in product placement strategies as well as in the reshaping of products as a form of optimization and enhancement based on user feedback (Patricio et al., 2022). A dual-flow communication approach establishes relationships between providers and end-consumers through active communication with users, thereby ensuring better positioning and sales growth (Kostić-Stanković et al., 2020).

In addition to the introduction, this paper is structured as follows. Section 2 provides a theoretical overview of the fundamental concepts of human-centered and digital marketing, as well as their convergence. This is followed by an exploration of metadata research from the Web of Science database, along with a review of implications. The paper concludes with a summary.

## 2. THEORETICAL BACKGROUND

Human-centered design is a technique that effectively communicates with end-users based on their needs and desires through empathy, thus creating a product within the user's framework (Flood et al., 2021). MacDonald et al. (2020) elaborate that practitioners of human-centered design are dedicated to the ongoing development of solution-oriented approaches. Their emphasis lies not in the perpetual advancement of products, but rather in the meticulous alignment with user needs and the resolution of human-centric issues. Although the concept of human-centered design is initially emerged within the realm of software development, it has transcended these origins to a broader spectrum of disciplines. From design initiatives addressing human needs in global health equity to the implementation of agile methodologies in software development, which notably prioritise user feedback for enhancing product value and extending to the domain of artificial intelligence (Leonardi et al., 2011; Garcia, 2015; Holeman and Kane, 2020; Flood et al., 2021; Capel and Brereton, 2023).

The benefits of digital marketing, as outlined by Damnjanovic et al. (2020), manifest in low costs and the ability to personalize advertising materials. Consequently, it is not surprising that there is a convergence of the human-centered approach with digital marketing. More to the point, human-centered digital marketing represents a strategic concept that underscores the importance of meeting user needs and enhancing user experiences within the digital landscape, as defined by Agafonova (2021). This approach involves active engagement from various stakeholders, notably placing the end-user at the forefront of the product lifecycle (Caballero et al., 2014; Hofkirchner and Kreowski, 2022). Such an approach requires a deep understanding of

potential customers, their communication dynamics and the ability to tailor the marketing mix to specific target markets (Astitiani, 2023).

### 3. RESEARCH METHODOLOGY

Considering the review papers that pertain to a comprehensive understanding of a particular research field, the authors adopted the research methodology for human-centered digital marketing. In general, a research methodology might holistically be perceived as presented in Figure 1.

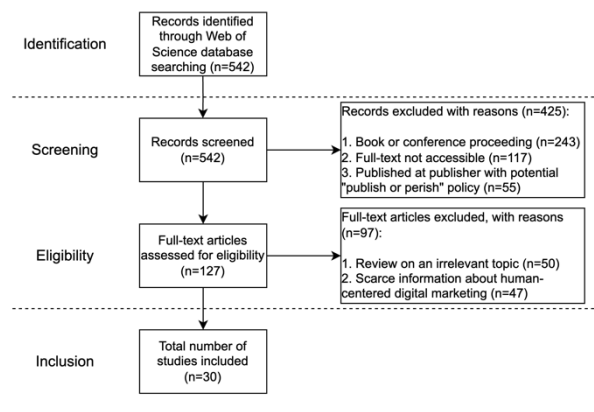


**Figure 1:** Methodological Framework (the authors’ work adapted by Machado and Martens, 2015)

To conduct a hybrid-bibliographical research, a two-step process has been devised to summarise the key insights from the existing body of knowledge in the research domain. Firstly, a bibliometric analysis of metadata sourced from a renowned database will provide a comprehensive overview of research trends and performance in the field. Subsequently, stringent criteria will be applied to refine the articles identified in the bibliometric analysis, resulting in a concise and pertinent selection suitable for detailed examination. This study endeavours to undertake bibliometric research to fill the identified gap in the literature and lay the groundwork for future exploration and deeper investigation in the field.

The proposed methodological procedure begins with the utilisation of bibliometric analysis. Initially, data acquisition is performed through the Web of Science (WoS) database, renowned for its integrity and reliability (Birkle et al., 2020). The search query, employing Boolean operator OR, focuses on human-centered digital marketing, human-oriented digital marketing, or digital marketing and human needs within article titles, abstracts, and keywords. Only articles, review articles, and proceeding papers in English from 1997 to May 6, 2024, are considered. This process yields a corpus of 542 publications, forming the basis for the subsequent bibliometric analysis. Analysis and comprehension of this dataset are facilitated by the biblioshiny package in the R language software, enabling an understanding of the bibliometric landscape of the research field (Aria and Cuccurullo, 2017).

The second phase of the hybrid-bibliometric analysis involves a qualitative approach. Initially, a set of 542 publications is subjected to rigorous criteria to facilitate a systematic literature review. The objective is to derive insightful implications for academia, practitioners, and policymakers in the realm of human-centered digital marketing. Following the guidelines outlined by Xiao and Watson (2019), the authors apply refined criteria across various categories, fields, and properties within the WoS database (Figure 2). This process results in the refinement of the publication pool to 30 articles (Appendix), ensuring a focused and thorough analysis of the literature.



**Figure 2:** Literature scrutinisation for qualitative exploration (the authors' work adapted by Xiao and Watson, 2019)

## 4. RESEARCH RESULTS AND DISCUSSION

Following the methodology that has been adopted, results and discussion of the two analyses are given in the following sub-sections. Firstly, bibliometric results are presented in both textual and graphical manner. Secondly, qualitative findings are systematised as a form of agglomeration between research findings and the implications that the authors outline. Notably, to meet the submission guidelines, only a few distinguishable findings and limitations are outlined.

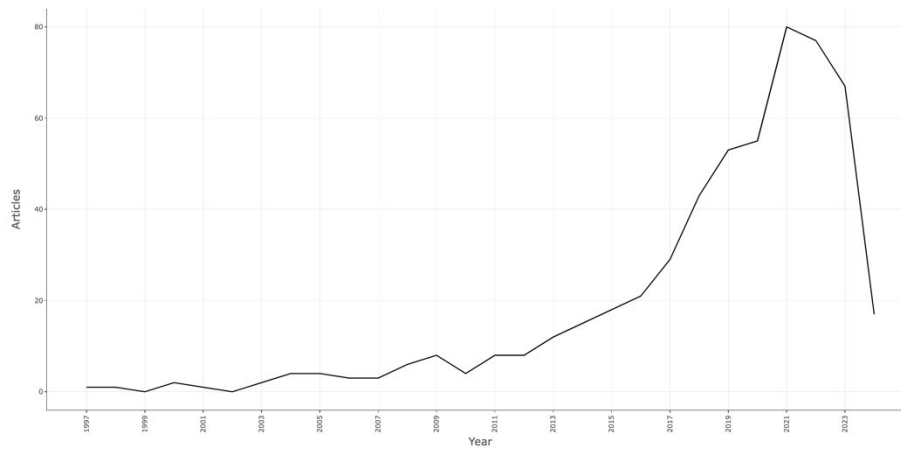
### 4.1. Bibliometric Analysis

The research covers papers from 1997 to the current year, 2024. Within this database, an annual growth rate of 11.07%. An International Co-Authorship rate is 20.66%. Other data is observable from Table 1.

**Table 1:** Main Research Database Information (the authors with the data collected from WOS and generated with bibliometrix)

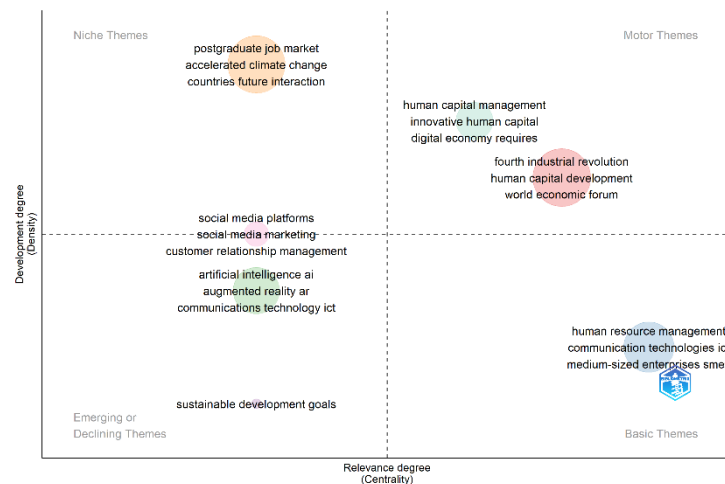
Description	Results
<b>MAIN INFORMATION ABOUT DATA</b>	
Timespan	1997:2024
Sources (Journals, Books, etc.)	457
Documents	542
Annual Growth Rate %	11,06
Document Average Age	5,38
Average citations per doc	11,16
References	23209
<b>DOCUMENT CONTENTS</b>	
Keywords Plus (ID)	811
Author's Keywords (DE)	2370
<b>AUTHORS</b>	
Authors	1723
Authors of single-authored docs	102
<b>AUTHORS COLLABORATION</b>	
Single-authored docs	103
Co-Authors per Doc	3,31
International co-authorships %	20,66

Figure 3 illustrates the development and publication of papers on the topic of human-centered digital marketing. Significant growth is noted from 2012 onwards, peaking in 2021 with 80 documents. It is noteworthy that the year 2024 is only in its fifth month, hence the number of papers is significantly lower at this point.



**Figure 3:** Annual Scientific Production (the authors with the data collected from WOS and generated with bibliometrix)

The bibliometric analysis places particular emphasis on topic-modelling techniques aimed at identifying the most conspicuous terms within the scientific literature pertaining to the research inquiry. As depicted in Figure 4, the Thematic map offers a graphical representation of the prevalent terms found in the abstracts of the scrutinized scientific papers.

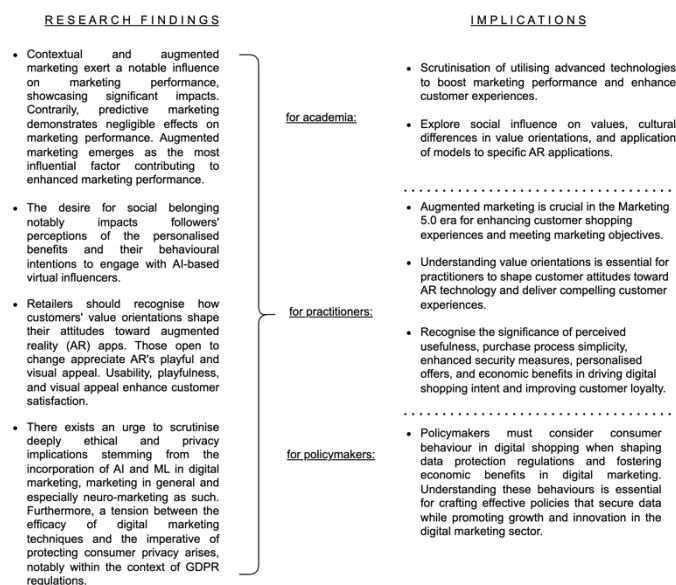


**Figure 4:** Thematic Map (the authors with the data collected from WOS and generated with bibliometrix)

The Thematic map is delineated into four quadrants: motor themes, niche themes and elementary themes, respectively, corresponding to quadrants within a two-dimensional space. These quadrants are delineated based on two key dimensions: centrality, indicating the significance of a theme in the development of the analysed research field and density, reflecting the level of development of the theme (Cobo et al., 2011). Several prerequisites precede the elaboration of the Thematic map. Trigrams are utilized for identification due to the complex nature of the research question, which involves the confluence between human-centered and digital marketing. These trigrams are tracked within the abstracts of scientific papers, leveraging the capabilities provided by the Biblioshiny application. Using the Leiden clustering technique, clusters of themes are formed based on a minimum frequency threshold of 6 within the corresponding cluster. The Thematic map reveals four distinct clusters of topics within the selected papers. The first quadrant, Motor Themes, highlights terms originating from the World Economic Forum that lay the groundwork for future development. Conversely, the third quadrant encompasses topics related to sustainable development goals and AI-based practices, indicating potential advancements driven by artificial intelligence. The second quadrant, Niche Themes, features topics with moderate occurrences but limited impact, such as climate change concerns and postgraduate job markets. Lastly, the fourth quadrant comprises Basic themes like human resource management, information communication technologies and medium-sized enterprises, which serve as foundational aspects within the field. In essence, the Thematic map underscores the association of human-centered digital marketing with various marketing-oriented terms, advocating for a multidisciplinary approach in utilising digital marketing tools to understand modern customer needs and value frameworks better.

## 4.2. Qualitative Analysis

As outlined in the methodological section, the qualitative analysis was utilised to identify credible examples from literature related to the research topic. The richness, complexity and underexplored features of the latter might be presented in one of the 30 identified publications after a rigorous sequence of selection constraints. More to the point, Jin and Viswanathan (2024) underscore the significance of adopting a human-centered approach within AI-driven digital marketing, advocating for AI systems that offer sustained emotional and functional support to users. It examines the emotional component of AI interactions through the lens of users' need to belong, highlighting the importance of fostering inclusivity and fairness in AI design. Moreover, the study suggests that AI-based virtual influencers should cultivate welcoming and inclusive personas to foster user engagement, emphasising the role of consumer identification with both the brand and its AI endorsers. Ultimately, while the paper does not explicitly employ terms such as "human-centered digital marketing" (HCDM), the concept discussed aligns closely with the principles of HCDM, emphasising the importance of human-centricity in shaping digital marketing strategies. The research findings and proposed implications for future research agenda are summarised in Figure 5.



**Figure 5:** Research Findings and Implications (the authors' work)

## 5. CONCLUSION

The research motivation for exploring crisp trends in digital marketing is mainly concerned with AI-based technology and practical implementations. As a possible remedy to the lack of innovative approaches to broaden the horizon of digital marketing, this research aims to grasp the essential role of human-centered digital marketing. In the modern digital landscape, human-centered digital marketing stands out as a strategic approach that prioritises human elements, encompassing consumer perception, social responsibility, and user experience. This paradigm involves leveraging human-centered design principles to recalibrate digital strategies, cultivate empathy among stakeholders, and co-create innovative digital solutions. Furthermore, the results presented in the study go hand in hand with the latter. As it was discussed, there are various distinctive relations between this confluence of topics with plenty of other modern issues such as sustainability, human resources management, digital positioning strategies, accelerated climate change and others. However, detailed overview of carefully chosen publications showed that it is a complex task to identify how human-centered digital marketing manifests in different occasions and situations. Therefore, the authors amplify that future ameliorations of the study might consider utilising a more robust systematic literature review technique, which could foster scientific capabilities for setting up a foundation of the research field at stake. In today's fourth industrial revolution, digital marketing is crucial for business development, especially for large companies. As contemporary business models deal with the challenges of digital marketing, they are realising the necessity of considering human factors. This awareness has led to more companies creating products with people in mind. It shows a bigger trend of focusing on what people need in digital strategies and product development.

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## APPENDIX

**Table 2:** Total number of studies included (the authors with the data collected from WOS)

Authors	Publication Year	DOI
Qian, JW; Lin, PMC; Law, R; Li, X	2022	<a href="http://dx.doi.org/10.1016/j.heliyon.2022.e12002">http://dx.doi.org/10.1016/j.heliyon.2022.e12002</a>
Jin, SV; Viswanathan, V	2024	<a href="http://dx.doi.org/10.1007/s00146-023-01832-9">http://dx.doi.org/10.1007/s00146-023-01832-9</a>
Segal, NL	2018	<a href="http://dx.doi.org/10.1017/thq.2018.38">http://dx.doi.org/10.1017/thq.2018.38</a>
Silva, SC; Feitosa, W; Duarte, P; Vasconcelos, M	2020	<a href="http://dx.doi.org/10.1108/REG-02-2019-0030">http://dx.doi.org/10.1108/REG-02-2019-0030</a>
Petit, O; Velasco, C; Spence, C	2019	<a href="http://dx.doi.org/10.1016/j.intmar.2018.07.004">http://dx.doi.org/10.1016/j.intmar.2018.07.004</a>
Gesualdo, F; Bucci, LM; Rizzo, C; Tozzi, AE	2022	<a href="http://dx.doi.org/10.1080/21645515.2020.1865048">http://dx.doi.org/10.1080/21645515.2020.1865048</a>
Schilling, J; Klein, D; Bartholmae, MM; Shokouhi, S; Toepp, AJ; Roess, AA; Sill, JM; Karpov, MV; Maney, K; Brown, KP; Levy, BL; Renshaw, K; Dodani, S; Jain, P	2023	<a href="http://dx.doi.org/10.2196/37550">http://dx.doi.org/10.2196/37550</a>
Kinal, J	2022	<a href="http://dx.doi.org/10.9770/jesi.2022.9.3(3)">http://dx.doi.org/10.9770/jesi.2022.9.3(3)</a>
Menon, S; Bhatt, S; Sharma, S	2021	<a href="http://dx.doi.org/10.1080/23311886.2021.1903149">http://dx.doi.org/10.1080/23311886.2021.1903149</a>
Thomas, T	2020	<a href="http://dx.doi.org/10.21272/mmi.2020.2-12">http://dx.doi.org/10.21272/mmi.2020.2-12</a>
Mahdizadeh, MS; Bahrak, B	2020	<a href="http://dx.doi.org/10.1016/j.comnet.2020.107618">http://dx.doi.org/10.1016/j.comnet.2020.107618</a>
Wang, WS; Cao, DM; Ameen, N	2023	<a href="http://dx.doi.org/10.1108/ITP-04-2021-0293">http://dx.doi.org/10.1108/ITP-04-2021-0293</a>
Alanazi, TM	2022	<a href="http://dx.doi.org/10.21272/mmi.2022.4-06">http://dx.doi.org/10.21272/mmi.2022.4-06</a>
Roy, S; Sural, S; Chhaya, N; Natarajan, A; Ganguly, N	2021	<a href="http://dx.doi.org/10.1145/3450445">http://dx.doi.org/10.1145/3450445</a>
Wei, HH; Zhang, FZ; Yuan, NJ; Cao, C; Fu, H; Xie, X; Rui, Y; Ma, WY	2017	<a href="http://dx.doi.org/10.1145/3018661.3018717">http://dx.doi.org/10.1145/3018661.3018717</a>
Sharma, N; Kumar, A	2023	<a href="http://dx.doi.org/10.1002/cb.2128">http://dx.doi.org/10.1002/cb.2128</a>
Tahlil, KM; Obiezu-Umeh, C; Gbajabiamila, T; Nwaozuru, U; Oladele, D; Musa, AZ; Idigbe, I; Okwuzu, J; David, AN; Bamidele, TA; Airhihenbuwa, CO; Rosenberg, NE; Tang, WM; Ong, JJ; Conserve, DF; Iwelunmor, J; Ezechi, O; Tucker, JD	2021	<a href="http://dx.doi.org/10.1186/s12879-021-06212-6">http://dx.doi.org/10.1186/s12879-021-06212-6</a>
Perdices, D; Ramos, J; García-Dorado, JL; González, I; de Vergara, JEL	2021	<a href="http://dx.doi.org/10.1016/j.comnet.2021.108357">http://dx.doi.org/10.1016/j.comnet.2021.108357</a>
Goncalves, M; Hu, YW; Aliagas, I; Cerdá, LM	2024	<a href="http://dx.doi.org/10.1080/23311975.2024.2333063">http://dx.doi.org/10.1080/23311975.2024.2333063</a>
Stefko, R; Gavurova, B; Olearova, M; Bacik, R; Nebesky, L	2023	<a href="http://dx.doi.org/10.15240/tul/001/2023-5-002">http://dx.doi.org/10.15240/tul/001/2023-5-002</a>
Franco, P; Canniford, R; Phipps, M	2022	<a href="https://doi.org/10.1177/14705931221079407">https://doi.org/10.1177/14705931221079407</a>
Rundle-Thiele, S; Pang, B; Knox, K; David, P; Parkinson, J; Hussenoeder, F	2019	<a href="https://doi.org/10.1080/14486563.2019.1599740">https://doi.org/10.1080/14486563.2019.1599740</a>
Renz, A; Vladova, G	2021	<a href="http://doi.org/10.22215/timreview/1438">http://doi.org/10.22215/timreview/1438</a>
Stitzlein, C; Baldock, JA; Roxburgh, SH; Mooij, M; Smith, D; Fitch, P	2023	<a href="https://doi.org/10.1080/17583004.2023.2265156">https://doi.org/10.1080/17583004.2023.2265156</a>
Alkire, L; Russell-Bennett, R; Previte, J; Fisk, RP	2023	<a href="https://doi.org/10.1108/JOSM-02-2022-0070">https://doi.org/10.1108/JOSM-02-2022-0070</a>
Cooke, FL; Dickmann, M; Parry, E	2022	<a href="https://doi.org/10.1080/09585192.2021.2021732">https://doi.org/10.1080/09585192.2021.2021732</a>
Magistretti, S; Allo, L; Verganti, R; Dell'Era, C; Reutter, F	2021	<a href="http://dx.doi.org/10.1108/JKM-09-2020-0687">http://dx.doi.org/10.1108/JKM-09-2020-0687</a>
Salmon, M; Salmon, C; Bissinger, A; Muller, MM; Gebreyesus, A; Geremew, H; Wendell, S; Azaza, A; Salumu, M; Benfield, N	2015	<a href="https://doi.org/10.1371/journal.pone.0134332">https://doi.org/10.1371/journal.pone.0134332</a>
Kisaalita, WS; Katimbo, A; Sempira, EJ; Mugisa, DJ	2016	<a href="https://doi.org/10.1177/0018720815623146">https://doi.org/10.1177/0018720815623146</a>
Patrício, L; Sangiorgi, D; Mahr, D; Caic, M; Kalantari, S; Sundar, S	2020	<a href="http://dx.doi.org/10.1108/JOSM-11-2019-0332">http://dx.doi.org/10.1108/JOSM-11-2019-0332</a>

# THE CHALLENGES AND OPPORTUNITIES OF APPLYING NEUROSCIENCE METHODS IN MARKETING RESEARCH

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**Abstract:** *Neuromarketing is a subfield of consumer neuroscience that studies how consumers respond to advertising stimuli using various brain imaging and biometric methods. A closer look at the available literature points towards a promising, multidisciplinary field that aims to marry marketing with neuroscience but a field that is at the same time fraught with pitfalls, both practical and theoretical, such as the lack of suitable theoretical work, the large datasets and complicated treatment, and the high costs of the studies. The paper deployed a narrative literature review methodology and aims to shed light on some of those promises and pitfalls.*

**Keywords:** *Consumer Neuroscience, Neuromarketing, Consumer Behavior, Marketing Research*

## 1. INTRODUCTION

The potential of neuroscience to help study consumer behavior was recognized even as far back as 1979 (Kroeber-Riel, 1979). It was the advances in noninvasive neuroimaging techniques, such as EEG and fMRI, that allowed the two fields to merge. In parallel, but at a much slower pace, the theoretical work on how brain activity correlates with behavior has also evolved to provide the theoretical linchpin between theory and practice of consumer behavior and marketing with empirical evidence yielded by brain imaging techniques.

The earliest use of the term in academic papers dates back to 2007 (Lee, Broderick, and Chamberlain 2007, Fugate 2007), but the first use of neuroscience in marketing is attributed to Gerald Zaltman (2003), Professor Emeritus at Harvard Business School who was the first to use fMRI to correlate brain activity to marketing stimuli. As brain imaging and biometric methods and tools become cheaper and more accurate, and computation capacities sufficient to process the rims of data yield by such methods, the field has morphed into a "cottage industry" in academia and the business world.

In this paper, we outline the complexities, pitfalls, and concerns surrounding the use of neuromarketing methods and tools from practical and theoretical perspectives. We start by briefly outlining the methods and their main characteristics. Then, we will address the theoretical and methodological constraints before going over the operational complexities. The paper ends by pointing out scenarios in which neuroimaging and biometric techniques are appropriate and desirable. The omission of ethical issues concerns is not on any other grounds, but the allowed length of the paper as those are essential and, as such, deserve every attention.

## 2. METHODS AND THEIR MAIN CHARACTERISTICS

Ever since the Roman physician Galen pointed out that the seat of behavior is the brain, there's been a desire to peek inside of it. However, it was only after Hans Berger, in 1924, managed to register the electrical activity of a living brain that it was allowed to do so without harming the subject (Panteliadis, 2021). Since then, the methods of studying the brain in action have proliferated, both direct and indirect. For this paper, we will stick to the two all-inclusive categories as presented by Cerf (2017): a) the brain imaging tools that record brain activity and the biometrics and b) other recordings that pick up secondary, indirect cues such as eye movements or perspiration.

Unlike the complete list presented by Cerf (2017) we removed several techniques from our list (Table 1) for reasons such as invasiveness, as in the case of Positron Emission Topography (PET) or Electrophysiology, or because the method is a variation of already existing methods, such as in the case of Solid State Topography (SST), or due to a lack of commercial availability as in Magnetoencephalography (MEG), and

finally as in the case of Transcranial Magnetic Stimulation (TMS), because it is used to induce activity in the brain as opposed to reading it. The remaining tools are functional magnetic resonance imaging (fMRI), Electroencephalography (EEG) as far as brain imaging tools go, Galvanic skin response GSR, Eye Tracking (ET), Facial Action Coding System (FACS), and Implicit Association Test (IAT) as far as biometric tools go. All are actively used in the field of neuromarketing.

**Table 1:** Overview of the neuroscience methods

Methods	Description	Costs of a study	Complexity	Spatial and temporal resolution	Applications
Functional Magnetic Resonance Imaging (fMRI)	Detects changes in blood flow and oxygenation levels in specific areas of the brain	High	High	High/Low	Brain function during various cognitive tasks and behaviors
Electroencephalography (EEG)	Measures electrical activity in the brain using electrodes placed on the scalp	Medium	Medium	Low/High	Brain function and activity patterns
Eye Tracking (ET)	Measures and analyzes the movement and focus of a person's gaze	Medium	Medium	Low/High	Visual attention, cognitive processes, and decision-making
Galvanic Skin Response GSR	Measures changes in the skin's electrical conductance in response to emotional arousal or psychological stress	Low	Medium	Low/Low	Emotional arousal or psychological stress
Facial Action Coding System (FACS)	Analyzes facial expressions based on the movement of individual facial muscles	Low	Medium	Low/Low	Emotional states and nonverbal communication
Implicit Association Test (IAT)	Assesses the strength of associations between concepts	Low	Low	n/a	Implicit biases or attitudes

In addition to the basic descriptions and application, we score each tool according to the following four dimensions: costs, complexity, and spatial and temporal resolution. For “costs,” low, medium, and high values correspond to values ranging from below \$1k for “low” to above \$100k for “high.” In the case of complexity, the three values denote no need for programming or neuroscientific training to some or a lot of need for both.

### 3. CHALLENGES WITH NEUROSCIENCE METHODS

There are three main challenges that research faces when doping neuromarketing research: the need for more theoretical work (Voytek, 2022), the large datasets requiring complicated treatment (Cerf, 2017), and the high costs of the studies (Cardoso, 2022).

Neuroscience is often considered “data-rich and theory-poor” (Favela, 2021). The “theory poor” side of neuroscience should not come as a surprise, considering that the brain is often called the most complex object in the known universe (Ackerman, 1992; Stevens, 1991). Several neuroscientific theories have been put forward over time, including unifying theories such as the Bayesian brain theory, coordination dynamics theory, free-energy principle, network theory, and neural reuse theory, to name a few (Favela, 2021). It is not the lack of actual theories in number that earned neuroscience the nickname, but the lack of any sense of convergence on which of these theories comes even close to explaining how the brain works. It poses a problem for researchers, especially those not trained as neuroscientists, as many scholars of neuromarketing are. Lee (2018) and collaborators have surveyed the literature and noted a lack of

methodological primers, reliance on reverse inference (Poldrack, 2006; Plassmann et al., 2012), and belief that complex behaviors must be functionally localized, for which we lack evidence (Friston, 2000).

The “data-rich” part presents researchers with yet another set of challenges. In a typical fMRI study with only 20 participants, an experiment can yield several gigabytes of time-series data (Cerf, 2017), and that is after data was cleaned from noise, normalized to account for different head sizes, and with signals not relevant to the study filtered out. Such datasets require treatment that is often unavailable to typical marketing scholars. Here, it is prudent to bring up the replication crisis - the inability of the researcher to replicate empirical results of often highly cited and influential papers. Since the early 2000s, researchers have started raising alarms that, for many published, peer-reviewed research, that is not the case (Ioannidis, 2005). From psychology to genetics, scientists of all creeds have tried and often failed to replicate highly cited papers published in prestigious journals (Baker, 2016; Moonesinghe, 2007; Open Science Collaboration, 2015; Altmejd, 2019). The crisis is not confined to neuroscience in general or neuromarketing in particular, but it should give researchers a pause, especially those in academia.

Finally, there are costs associated with deploying neuromarketing techniques. In the US, a typical fMRI study can cost about \$100K, a good part of which is attributed to renting the machine and hiring a technical staff. EEG experiments cost significantly less but could still go as high as \$20K. The costs of executing such studies differ per country, which could be why most neuromarketing papers are published in Europe and China (Cardoso, 2022). The advancements in technology, both in terms of hardware and software, are helping. Apple Vision Pro, a consumer-facing VR/AR device from Apple, uses eye-tracking (ET) technology to navigate the UI and is already getting traction in medical research (Zang, 2023; Masalkhi, 2023). It is only a matter of time before such a device, combined with various biometric sensors embedded in Apple Watch, for example, is turned into a powerful neuromarketing tool with off-the-shelf data analysis software. Experiments using biometric tools are cheaper but cannot compare to surveys, a tried and true marketing method. High costs of deploying neuroimaging and biometric methods can also be responsible for low sample sizes, often below 20 subjects (Khushaba et al., 2013; Telpaz et al., 2015). A low sample size lowers the statistical power of the experiment and, in turn, “undermines the purpose of the scientific research” of “detecting a true effect” (Button, 2013, pp.365).

#### **4. OPPORTUNITIES FOR NEUROMARKETING**

None of the challenges described above is a verdict against neuromarketing. It is a word of caution as more and more such research is undertaken in academic and commercial settings (Plassmann et al., 2015; Robaina-Calderín, 2021). In the rest of the paper, we propose contexts in which neuromarketing methodologies are desirable and even necessary, such as when studying the subject’s responses to stimuli in real-time, the subject’s reactions at the subconscious level, and using neuromarketing techniques to validate the results generated by classic research methods.

Most marketing research methods - whether quantitative, such as surveys, or qualitative, such as interviews - depend on subjects remembering and reporting what they remember after the fact, which is considered a fundamental flaw (Macdonald, 2012). The gap between what subjects think and feel at the moment of exposure to the stimuli versus the ex-post report is especially important in studying advertising effectiveness (Ohme et al. 2010; Stipp & Woodard 2011). Neuromarketing methods can help avoid such a flaw.

Traditional marketing research also relies heavily on the subjects self-reporting their thoughts and feelings about a stimulus, whether through interviews, focus groups, or surveys (Shukla, 2008; Fugate, 2007). This is not surprising given that the dominant view of a man is that of a rational agent embodied in the concept of the “homo economicus” (Singer, 2013). But as the work done by behavioral economists such as Daniel Kahneman clearly shows (Kahneman & Tversky, 1982; Kahneman, 2011), people are a lot less rational and a lot more biased, emphasizing the importance of the implicit attitudes and subconscious processes (Plassman, 2015). Neuroimaging and biometrics are precisely such techniques that can illuminate those processes. Consider the role of emotions in decision making (Damasio, 1996), the importance of cognitive dissonance in the formation of beliefs (Harmon-Jones, 2019) or the ability to articulate our own emotions (Russell, 2009; Barrett, 2017), to name a few. Understanding such processes is crucial in marketing, yet it is nearly impossible to do so via self-reporting methods. These are also phenomena with a large body of theoretical and empirical knowledge, allowing for a more straightforward mapping of behaviors to brain regions or biometric signals.

Finally, neuromarketing methods can validate the results generated by the classical quantitative and qualitative approaches, serving as quality control. Plassman (2015, pp.12) and his team of collaborators put it this way: “In summary, researchers in marketing should see consumer neuroscience not as an approach

that could replace traditional measurements of behavior, but as a complement that could improve the process of obtaining and interpreting behavioral measures.” In a comprehensive study, Venkatraman et al. (2015) tested six methods used to measure advertising effectiveness - traditional self-reports, implicit bias, eye tracking, biometrics, EEG, and fMRI - and demonstrated the “relative contribution of these measures in predicting advertising elasticities using independent and objective measures of real-world advertising success” (pp. 32). In addition to validating traditional methods, the use of neuromarketing techniques can help improve theory-building efforts, too (Alvino, 2019).

## 5. CONCLUSION

This paper outlines three key challenges encountered in neuromarketing research: the necessity for further theoretical development, the complexities of handling large datasets, and the significant costs of conducting studies. Neuroscience is often criticized for a lack of convergence towards a coherent theory of how the brain works. This is especially challenging for neuromarketing research as it often requires theories about consumer behavior and how it arises from brain activity to work in tandem. Add the unavoidably large data sets and high costs of studies, and neuromarketing research would benefit from focusing on cases where neuromarketing methods are necessary, as in the need for real-time feedback, probing subconscious thoughts and implicit attitudes or as a way of validating already established consumer behavior theories. There are reasons to be hopeful. Neuroscience is progressing, and as the cost of neuromarketing hardware and software decreases, more researchers worldwide can apply such methods. Despite the challenges, we are at the very beginning of the era of neuromarketing.

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# BRANDING IN CREATIVE INDUSTRIES: CHALLENGES THROUGH MERGING HUMANS AND DIGITALS

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**Abstract:** In the fierce struggle for competitive advantage in the global market, the brand becomes the main tool of marketing specialists, consumers are willing to pay a higher price for a product of a certain brand, believing that it provides them with the value that competing products do not able to deliver. In the first part of the paper, an overview of the concept of brand and branding will be given, and then an analysis of the specificity of the branding procedure in creative industries will be presented - through a case study of the gaming industry. Special attention will be devoted to the branding strategy of creative cities, as central points of creative industries and the creative class. Throughout the paper, based on the literature review, the importance of connecting people and digital channels will be highlighted, all in the context of emphasizing the challenges faced by branding in creative industries. Also, on the basis of the previous assessment, it will be possible to anticipate future activities in these industries.

**Keywords:** *creative industry, gaming industry, communication, digital marketing*

## 1. INTRODUCTION

The importance of this paper will be reflected in collecting theoretical review in branding in creative industries basis for understanding the creative industry, gaming industry specifically, and its challenges through merging humans and digitals. Taking into account the multiple importance of creative industries in economic and social development at the local, national, and regional level, any research that provides new and more complete knowledge is important. This especially applies to developing countries, where creative economies can be an important driver of development (Ulldemolins, 2014). After highlighting the importance of branding, the author pays special attention to the challenges in branding today. Moreover, the author will approach the importance of branding in creative industries, especially highlighting the premiere of branding in the Apple company. After highlighting the importance of this example, special attention will be paid to the challenges that the gaming industry faces. Analyzing the existing literature, the importance of branding in the gaming industry will be highlighted. Then the paper continues on the more ubiquitous topic of the creation of creative classes and the importance of the existence of creative cities. This is particularly interesting, taking into account the fact that in recent times it is considered that there are also informal creative cities, based on the development of the gaming industry above all (for example: Los Angeles, London, Tokyo).

## 2. OVERVIEW OF THE BRANDING CONCEPT

Keller by brand means a name, term, sign, symbol or shape, or a combination thereof, which aim to identify the products or services of a certain seller and to differentiate them from the competition (Keller, 2003 ). Vranešević (2007) understands the brand as a name, sign and other elements and activities that manufacturers assign to a product, service or idea in order to inform the market about their uniqueness. According to Schuilling and Moss (2004), a brand is a product name that creates a series of tangible (rational) and intangible (irrational) values in the consumer's mind. It is clear that the product itself brings certain tangible benefits to the consumer (fulfillment of a specific consumer need), while the brand provides the consumer with added value, which combines tangible and intangible benefits from the product. "Mercedes" is registered in the minds of consumers as a brand that offers a number of tangible benefits, such as German quality, reliability, safety, while intangible benefits refer to the status, prestige and success symbolized by this brand. Therefore, it can be concluded that the basic function of a brand is to create an image of a certain product in the mind of the consumer, by which it should differ from competing products. A brand can appear in different forms. Thus, one can talk about a product brand (trademark), a service brand, and a corporate brand or company brand. In recent years, the so-called brand has appeared. private, i.e. trademarks, and products and services available

on the Internet, personalities, places and organizations, sports, arts and entertainment, countries and various geographical locations, information and even ideas and actions are branded (Keller et. al, 2009).

The first definition of the term creative industries appeared in the British Creative Industries Mapping Document in 1998 (DCMS, 1998). According to this definition, creative industries are based on activities that have their origin in individual creativity, skills and talents, and which have the potential to create wealth and new jobs through the generation and exploitation of intellectual property (Flew, 2012). This document also showed which industries can be called creative, namely: architecture, advertising, art and antiques market, computer and video games, crafts and design, fashion design, film and music, performing arts, television, radio, publishing and software companies. The multinational company Apple is one of the most successful and the most popular software company, also already wellknown from music and film production to design and architecture. Also, it is more than important to highlight the fact that **Apple products have long been associated with creativity**. In fact, many authors think that Apple is the most creative tech company in the world. Moreover, Apple presents an example of branding in creative industries, because this company is it is a creative company that emphasizes the importance of branding and applies the approach of integrated brand identity (united different brand elements). Campbell and Keller (Campbell, Keller, 2003) indicate that this company started building its brand by choosing the name Apple, a well-known word that has a positive association with fruit among consumers. Steve Jobs, founder of Apple, he considered the apple to be the perfect fruit and therefore chose its name for the perfect personal computer. No less creative is the solution found for the company's logo in the form of an apple with a bite, which has the connotation of a garden of paradise and insinuates an unforgettable experience and an irresistible offer. The company's logo is cheerful, easily recognizable and striking to such an extent that the company does not even have to use the name when advertising. Effectiveness is also integrated into Apple's slogan "Think Different". The campaign launched by the company as part of the promotion of its slogan, associated with visual associations with the greats of "different thinking" - Mahatma Gandhi, Muhammad Ali, Jackie Robinson and others, made the slogan attractive, symbolic, easy to remember and communicative (Campbell, Keller, 2003).

## **2. BRANDING CHALLENGES IN CREATIVE INDUSTRIES**

According to the analyzed example of the successful Apple company brand, it can be concluded that branding in creative industries is not significantly different from branding in traditional industries. However, considering that a large number of creative industries sell intangible products, which consumers are not able to sense before buying, branding as a cycle that builds on the marketing mix, has a special importance, because a well-known brand provides consumers with a guarantee of quality. In the following part of the paper, the branding process in the gaming industry will be analyzed, and then the branding of cities - as a strategy in the promotion and development of creative industries, with which they are specifically distinguished.

### **2.1. Branding in the gaming industry: merging humans and digitals**

Gaming industry has become one of key-players within creative industries. Moreover, in the last 30 years, the gaming industry has positioned itself as an important participant in the global scene of the entertainment industry. When the game Call of Duty: Modern Warfare 3 appeared in 2011, in just 24 hours it earned over 400 million dollars in the USA and Great Britain, and after two weeks the sales of this game brought in an income of about one billion US dollars (Waugh, 2011). Similar success to the gaming industry has brought a whole series of other games, which has manifested the enormous growth that this industry has experienced over the past few decades.

Estimates of the annual growth of the gaming industry range between 9% and 15%, which has caused the economic value of games to grow rapidly from an industry that filled a niche in the market to a creative industry with unimaginable commercial success. In 2009, the gaming industry generated revenues of 13 billion dollars, and in 2012, as much as 67 billion dollars, to reach revenues of 99.6 billion dollars in 2016 (Newzoo, 2016). In addition to rapid growth, the gaming industry is characterized by a high degree of innovation and dynamism. When it comes to the products of the gaming industry, there is a growing demand for different pieces of hardware, special gaming consoles, and platforms for online games, as well as games on mobile devices (smartphones and tablets), are also developing. Online platforms have brought a number of opportunities for additional earnings, because players can buy virtual products and the necessary performances to play and move to higher levels. There was also the integration of the entertainment industry through the creation of hybrid products, so, for example, the game Lord of the Rings was produced, which accompanies the movie and the book. It is very important to look back at what forms the basis of marketing and branding in the gaming industry. Just as in the music industry it is popular bands and singers, in the film industry it is famous directors



and actors, in the gaming industry it is video and computer game designers. However, the specificity of the gaming industry compared to other creative industries is reflected in the fact that it is not necessary for a well-known designer to create a game in order for it to sell well. Although most of the best-selling games of the past decades have been created by some of the best game designers, it's actually the gaming companies that gain fans, or rather consumers. Fans of video games are well aware of companies like Atari, Sierra, Activision, Namco, Ubisoft, and when buying their products there is little reason to doubt, considering that these companies are established as well-known brands in the gaming industry market. The reason for this should be found in the fact that a certain game is associated with the company that placed it on the market, and the name of the designer is rarely highlighted. This puts the company's brand in the foreground, as one of the key elements of marketing in the gaming industry. Russell (Russell, 1998) suggests several techniques that allow gaming industry companies to develop brand awareness among consumers. First of all, it is necessary that the display of the game on the monitor contains the visible name of the company/brand; also, the audio content accompanying the game must mention the brand name, and third - the brand name must be placed everywhere along with the game name. These techniques are similar to those used in the film industry. However, due to the nature of games, companies in the gaming industry use another technique, which is to enable interaction between consumers and the company itself, which increases their brand awareness. Most brands organize their own or participate in the most important gaming tournaments, events and conventions, which allows the connection between the player and the brand. A good example of branding in the gaming industry is provided by companies that produce games with a sports theme, as one of the key ways to promote the brand, which enables the strengthening of brand awareness and brand image. In addition, in the process of branding in the gaming industry, the engagement of well-known players for promotional campaigns, such as Søren Berg (Søren Bjerg - Bjergsen), one of the most famous players of the online game League of Legends, is becoming more and more current. Søren has over 300,000 followers on Facebook, over 600,000 on Twitter (Mecglobal, 2016). This data shows that the gaming industry uses the same techniques of brand building and strengthening as traditional industries, relying on celebrities, social networks and other digital media, but also to traditional media and communication channels. However, given that the target segment of consumers (over 60% of consumers in the gaming industry are those under the age of 34) (Musterd, Kovacz, 2013), the most suitable channel of communication is digital media, led by social networks. Brands have well-designed, interactive websites where they offer consumers detailed information about their products, as well as announcements of new games. Likewise, they have their own profiles on social networks, and the technique of paid ads on the websites of other companies is widely used. A particularly important technique refers to the already mentioned announcement of new games, which have yet to be placed on the market. This is a technique similar to that used in the film industry. Trailers of novelties are usually posted on the company's website, but also on social networks, for example on the YouTube channel. Of the traditional media, magazines dealing with video and PC games, such as GamePlay or PCPlay, are more prevalent.

#### **4. BRANDING CITIES: CITIES OF CREATIVE CLASS AND CREATIVE INDUSTRIES**

One of the prerequisites for the development and expansion of creative industries are the places where they develop. Creative industries are typically concentrated in a specific area, because, as Turok states, creative industries require specific knowledge and skills of human capital that is grouped and developed in certain locations, which can meet the needs of the so-called creative class (it consists of scientists, engineers, artists, musicians, designers and all educated professionals) (Turok, 2003). Clearly, without a creative class (class of creative workers) there is no creative industry. In this sense, cities are generally seen as the optimal place for the development of creative industries, because they represent technological hubs and a source of creative human resources, i.e. basic prerequisites for the development of creative industries. However, the question is often raised whether every city can be a place where creative industries will concentrate and develop. The answer is negative.

In order to brand a city as a creative city, it is necessary to create the necessary infrastructure and develop creative industries, in order to attract the creative class. In this sense, it is necessary to pay particular attention to the provision of quality and affordable housing, rich content and services in the city, good transport infrastructure, cultural potential, as well as the quality of the city's public spaces, attractive architecture. In this sense, the strategy of creative cities as a branding strategy focuses on the economic development of the city, attracting investors, as well as creative workforce, improving the well-being of citizens and the competitiveness of the city. Mishra et. al (2016) defines creative cities as those where positive changes in social and economic processes are visible, places that exude authenticity, that are open to new ideas, where cultural life is rich and where there is a large concentration of creative creators.

It is believed that preferences in certain creative industries, of a certain locality, can be the basis for the branding of the city. Recently, we often see opinions that employees and those who have an affinity for the gaming industry develop their circles more easily, which then grow into the creative class and actively participate in the branding of

cities. For example, Brighton has been praised as a "creative hub of awesome" as the city thrives as the "perfect fit" for the gaming industry ([www.bbc.com](http://www.bbc.com)).

Therefore, in order to attract the creative class, as one of the prerequisites for the development of creative industries, the spatial elements and infrastructure required by this class are necessary. However, these are not the only prerequisites that creative industries require from cities that aspire to become their centers. Namely, it is necessary to have indispensable resources and knowledge, as well as an adequate policy related to the business of creative industries. Therefore, cities throughout developed countries establish special local/municipal services that are responsible for encouraging the development of the local creative economy, establishing and facilitating cooperation between the public and private sectors, as well as civil society, and those cities that are at the forefront of this go so far as to develop creativity indices according to the 3T model - Technology, Talent, Tolerance (Pratt, 2008). The strategy of creative cities is based on the concept of creative industries, which realizes the connection between creativity, culture, economy and technology, expressed as the possibility of creating and spreading intellectual capital, with the potential to generate income, new jobs and earnings from exports, while promoting social inclusion, cultural diversity and human progress (UNCTAD, UNDP, 2008). It can be seen that the link between the strategies of branding cities as creative and the development of creative industries is twofold. On the one hand, creative industries cannot develop in cities that do not have adequate infrastructure, resources and other prerequisites, such as policies, regulations and systemic support for creative industries. On the other hand, cities have recognized in creative industries their ability to generate economic growth and contribute to economic and economic development. Joint branding (of cities and creative industries developed in the city) enables mutual goals to be achieved. As an example, we can take Barcelona, which is branded as a creative city, which enables the intensive development of certain branches of creative industries. Despite the fact that Barcelona is not the capital of Spain, it is one of the most famous cities in the world and one of the cities with the best image. According to the well-known European city brand barometer study (Hildreth, 2008), Barcelona is one of the European cities with the best reputation and image at the global level, and the third ranked city in Europe, just behind London and Paris, and ahead of numerous well-known cities such as are Rome, Madrid, Athens. In this study, Barcelona is associated with associations such as creativity, innovation, culture, quality of life, which form the basis of its image. The branding strategy of this city was called "Barcelona model", and soon it grew into a brand that connected certain creative sectors with the image that the city wanted to sell: Barcelona - city of knowledge, city of design, city of culture, city of architecture (Balibrea, 2004). The goals of branding Barcelona were: international positioning of the city and its promotion as a place that welcomes business in defined economic sectors (higher education, logistics, information and communication technologies, culture) (Musterd, Kovács, 2013). Barcelona's image and brand have achieved remarkable international success, and the Spanish city is recognized as a high-tech city, an attractive location for conferences, a city of arts, festivals and fairs (Majoer, 2011). In this way, Barcelona managed to attract the creative class from the sectors of art, information and communication technologies, gaming industry, design and architecture, and encourage the expansion of these creative industries. On the other hand, Barcelona attracted a huge number of international tourists, investors and other stakeholders (from 2.4 million visitors in 1993, the number of visitors to the city increased to 7.13 million in 2011) (Ulldemolins, 2014), which business of creative industries in this city experienced prosperity.

## 5. CONCLUSION

Through a review of the literature it was shown that for the gaming industry one of the most important channels of communication are social networks and the company's website. Moreover, the branding strategy must be adapted to the marketing model of a given creative industry, its specifics (product, promotion, price and distribution channels), so it follows that there are differences between branding, as for example in the gaming industry and some other industries. The research also analyzed the role of creative cities as centers of creative industries, which indicated the key importance of the branding strategy of creative cities for the development and expansion of creative industries, especially in gaming industry. The fact is that the theoretical overview and previous research indicate that there is no one universal marketing model that can be applied to all creative industries, however there is an obvious need for merging humans and digitals. It is concluded that in the development of marketing models and marketing and branding strategies, a methodological approach to the management of marketing activities in creative industries can be developed. The possibility of creating a reference framework for concretizing influential marketing activities and the appropriate combination and synergy of marketing mix elements, in creative industries, leaves room for more successful management of marketing activities within these industries. Therefore, there is justification for future research that would ensure the development of a methodological framework for managing marketing activities, and the goal would be to increase sales.

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# SHAPING MILITARY HEIS' PROMOTIONAL STRATEGIES FOR GEN Z'S MEDIA LANDSCAPE

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**Abstract:** *The purpose of this paper is taking into consideration the possibility of adapting the promotional strategies of military higher education institutions in the Republic of Serbia to current trends in higher education marketing and the preferences of Generation Z. In order to collect data, a review of recent literature and a simple cross-sectional survey of the presence and activities of HEIs in Serbia on social networks have been carried out. The conclusions drawn by applying dual-perspective SWOT analysis indicate that MHEIs have a lot of room for improvement of their presence on social networks and achieving a stronger promotional effect in an environment insufficiently used by the competition.*

**Keywords:** *Generation Z, Military Higher Education Institutions, Social Networks, Digital Media, Promotional Strategies, SWOT Analysis*

## 1. INTRODUCTION: MILITARY AND CIVILIAN HEIS – DIFFERENT MISSION, SAME CHALLENGES

The mission of military higher education institutions (MHEIs) is rather specific since their focus is the preparation of students (cadets) for the future military career. MHEIs, therefore, are distinguished by a unique combination of educational rigor, military discipline and commitment to the military service (Morin & Chanut, 2018; Waitzkin et al., 2018). One of the main differences between civilian higher education institutions and the military ones is that MHEIs often prioritize the development of military culture, values and leadership capacities. Their curricula integrate physical training, discipline, and military ethics in ways that civilian institutions typically do not (Morin & Chanut, 2018; Waitzkin et al., 2018). The career development of people who graduate from military schools is usually predictable and structured, following a clear, progressive framework. This particular career path is often more determined by the nature of the military institution itself than by the nature and abilities of the individual, which contrasts with the greater individualization of career paths in civilian organizations (Morin & Chanut, 2018). The military education is a kind of service activity to the superior system for which it trains personnel - the Ministry of Defense (MoD) and/or the Armed Forces of a specific country. This is why HEIs strive to prepare their students or cadets, first of all, for specific roles in the military which differ from the broader educational focus of civilian HEIs that educate students for various careers in the public and private sectors (Waitzkin et al., 2018). For this reason, the management of MHEIs may face the problem of the so-called "double agency" because, on the one hand, they are responsible to their cadets (clients), and on the other hand, to the state institution that is the "contractor" (Waitzkin et al., 2018). Unlike private and most state universities in the Republic of Serbia, which had greater freedom to adapt to the higher education market, military higher education institutions (MHEI) – namely University of Defence, remained closely tied to the requirements of the MoD and SAF, for which it educates officer staff. This is supported by the statement of Marček and Jeremic (2009) that during the then reform of higher military education in Serbia, the key determinants were: normative and doctrinal assumptions, educational determinants (primarily the Bologna Declaration), defining the profile of the officer cadre and the previous results of research into the military schooling system. Military HEIs, however, are not isolated from other civilian HEIs and are subject to the same economic, cultural, technological and demographic influences. Morin and Chanut (2018) suggest that the changes seen in civilian HEIs could also occur within the framework of higher military education, but within the unique context of military culture and its structures. Therefore, although the institutional development of military education in Serbia is not and cannot be marketing-oriented it is important that military higher education institutions develop effective promotional strategies for competing on the "market" of future students. Hence, in this paper we will deal with the characteristics of the digital environment in which Generation Z lives and communicates, consider the

<sup>1</sup> The views, results and evaluations presented in this paper do not reflect the official position of the Ministry of Defense of the Republic of Serbia or the University of Defense.

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main trends in the field of HEIs marketing, and then perform an analysis of the presence and activities on social networks of HEIs in Serbia and finally perform a dual-perspective SWOT analysis of the adaptation of promotional strategies of MHEIs. In the paper, we will answer a research question - Can military higher education institutions in Serbia, in accordance with their specific role, endorse promotion on social networks as a part of their comprehensive promotional strategy?

## 2. GEN Z'S MEDIA LANDSCAPE - A „DIGITAL BATTLEFIELD“

Although there are numerous differences between military and civilian higher education institutions, they are united by one, probably the most important, common feature - they share the same "hunting ground". In this specific case, both groups are targeting Generation Z, which, depending on the author dealing with the topic, was born between the mid-nineties of the 20th century and the end of the first decade of the 21st century (Fedorov et al 2021). For the members of the Gen Z a world without the internet is unfamiliar. This exposure to Internet technologies fundamentally shaped their interaction with the outside world, marking them as the first true digital generation (Turner, 2015; Perić, Mamula Nikolić and Delić, 2020). Their consumption habits, information and entertainment seeking are characterized by a significant reliance on digital platforms, with a strong preference for consuming content via mobile and app-based platforms (Persada et al., 2019; Chang & Chang, 2023; Laor & Galily, 2022). They frequently consume video-on-demand services and platforms like YouTube, which is indicative of their preference for video content and the ability to watch what they want, when they want (Westcott et al., 2023). For the members of Generation Z, social media are more than a communication platform. They serve them as an essential tool for self-expression and identity formation. This generation shows a strong preference for visual and short-form content, favoring platforms such as Instagram, Snapchat, and TikTok (Turner, 2015). The Global Web Index 2020 report highlights that Generation Z singles out "chatting" or instant messaging as well as watching video clips as their main activities on social networks. It is also notable that there is a growing privacy concern among Gen Z, with a significant number expressing apprehension about how companies use their personal data, highlighting the trend towards privacy awareness and ad blocking (GWI, 2020). Generation Z's engagement and interaction with and in the media are multifaceted and encompass a wide range of activities from social networking to content creation. Their digital literacy allows them to use different platforms for different purposes with ease, including education, entertainment, and social interaction (Turner, 2015). Integrating technology into their daily lives allows them to fully synchronize their online and offline experiences. The Generation Z from the region of Balkans yet shows certain regional variations in the tendency to use certain platforms like Snapchat and TikTok less than their European peers as well as to consume TV content more than them (Perić, Mamula Nikolić and Delić, 2020). Among the population between 16 and 28 years old in Serbia, Instagram is by far the most popular social network, which is used by 59% of them, followed by Tik Tok with 21.33%, You Tube with 17.33%, Facebook 1.33% and Snapchat 1% (Savic et al. 2024).

## 3. EMERGING TRENDS IN HIGHER EDUCATION MARKETING

The marketization of HEIs increases the influence of marketing, transforming them from educational entities to market responsive service providers focusing on impact and enhanced return on capital (Gibbs, 2020). On the other hand, the process raises concerns about the erosion of the quality of education as institutions prioritize revenue generation and competition over academic standards (Altbach et al., 2010). There is also a debate about whether students should be viewed as customers, which could alter the fundamental educational mission of universities and potentially compromise the students' experience and learning outcome (Maringe & Gibbs, 2009). The *Bologna process reform*, which was implemented in Serbian educational system more than a decade and a half ago, significantly contributed to its marketization. Anatolović and Sandžakov (2022) point out a number of critically oriented studies by Serbian and regional authors regarding the effects of the reform of higher education in the country. As one of the indicators they cite the trend of marketization which put the faculties in the position of "providers of educational services" and students in the position of "clients", which led to the decline in the quality of education (Anatolović and Sandžakov, 2022). Recent studies have highlighted several emerging trends in higher education marketing, reflecting the sector's response to a dynamic global environment and changing demographics. The common ground for that entire trend is their digital nature. Generally speaking, digital transformation defines how HEIs are adapting their management patterns, culture, and technological approaches to meet the demands of a digital era (Gkrimpizi et al., 2024; Zulfikar et al., 2018). A shift towards more customer-centric approaches has also been noted as a trend. The institutions are focusing on understanding students' needs and designing the customer journey from a prospect to an enrolled student (Camilleri, 2020). The expansion of promotional activities on social media is one of the most significant phenomena in the marketing of higher education institutions in recent years. According to research conducted by Šola and Zia (2021), most students rely heavily on social media platforms to gather information about educational institutions. Alfonzo (2023) emphasizes the importance of using social media in the marketing of higher education institutions, and especially in their branding. In the context of the use of social media in the marketing of higher

education, researchers point to the importance of engaging content as a way for better storytelling and the overall effect of promotion towards future students (Peruta & Shields, 2018; Taecharunroj, 2017).

### 3. SERBIAN HEIS ON SOCIAL NETWORKS – BASIC ANALYSIS

In April 2024 the author visited 98 websites of HEIs founded by the Republic of Serbia (Public HEIs) and 58 websites of HEIs not founded by the Republic of Serbia (Private HEIs) that have accredited study programs of academic studies by the National Entity for Accreditation and Quality Assurance in Higher Education (NAT, 2024). On the above-mentioned official websites, a cross sectional survey was conducted for the existence of links to official accounts on social networks and their functionality was verified. The author accessed each of the existing accounts on the social networks Facebook, Instagram, Tik Tok, You Tube, LinkedIn and X (Twitter) for proof of the latest activity (posts). As a criterion for an account on a certain social network to be considered as active, the author took the activity (post) in the period of the last month. An overview of the analysis results is given in Table 1.

**Table 1: The presence of HEIs in the Republic of Serbia on social networks**

	Facebook	Instagram	TikTok	YouTube	LinkedIn	X (twitter)
<b>Public HEI</b>						
Active account	66%	54%	2%	19%	13%	3%
Idle account	8%	8%	2%	40%	9%	18%
No account	26%	38%	96%	41%	78%	79%
<b>Private HEI</b>						
Active account	34%	34%	5%	9%	14%	5%
Idle account	14%	9%	2%	26%	5%	12%
No account	52%	57%	93%	66%	81%	83%

Two criteria were set when selecting of HEIs. The first criterion was that they had active accounts on social networks and the second that they had at least two actively maintained accounts. It was determined that 20.4% of state HEIs corresponded to the criteria, while among private HEIs there are 12.1% that corresponded to those criteria. It was also established that not a single state university (out of 98 checked) had up-to-date accounts on the four most popular social networks. Two private higher education institutions - Singidunum and Metropolitan universities had active and up-to-date accounts on the most popular social networks Facebook, Instagram, Tik Tok and You Tube (Savic et al., 2024), but this was not the case with the accounts of their faculties. In order to understand the context and the moment in which this analysis was carried out, we will note that according to the rulebook on the calendar of educational work of secondary schools for the 2023/2024 school year in the Republic of Serbia, the ending of the school year for the final year students is planned for May 24th, 2024 (Sluzbeni glasnik, 2023).

From the given results, we can conclude that, contrary to expectations, state HEIs in the Republic of Serbia are more present and active on social networks than private HEIs. Regarding professional engagement in social networks management both groups of HEIs are failing as evidenced by the large percentage of idle accounts. The preferences of the target group - Generation Z are also neglected, since the largest number of the most active accounts of HEIs are on Facebook, which is one of the least favorite social networks among young people (Savic et al., 2024). We also point out the fact that it was established that the University of Defense, the Military Academy and the Military Medical Academy do not have their own accounts on social networks, but there are social media buttons on their websites that lead to the official accounts of the Ministry of Defense which are up to date.

### 4. INTEGRATING DUAL-PERSPECTIVE SWOT ANALYSIS

The components of SWOT analysis are traditionally viewed through the lens of the organization's internal strengths and weaknesses, in relation to external opportunities and threats. This tool is widely used for strategic planning, and it has also found its application in marketing (Benzaghta et al., 2021). The "dual perspective" presented by Novicevic (2004) suggests that the synthesis of SWOT components can be done by considering two different mental models: evaluative balance and descriptive overlap. The evaluative balance approach reconciles the inconsistencies in the SWOT components at the level of the overall objective evaluation. This approach focuses on the vision of the future from the perspective of managers and classifies factors as desirable or undesirable based on their impact on the competitive position of the organization. This approach is guided by taking into account information about customers and competitors. The descriptive overlay approach reconciles inconsistencies in SWOT components based on their descriptive characteristics and groups factors based on similar characteristics, for example whether they are internal or external in nature to the organization. This approach categorizes factors as either controllable or

uncontrollable. While descriptive/objective dimensions drive the categorization of SWOT components, evaluative/subjective dimensions drive their interpretation (Novičević et al., 2004). Dual-perspective SWOT integrates the planning view (background perspective) and the so-called "intelligence view" (front-end perspective) and suggests the need for logical coherence of SWOT components which is tested by horizontal, vertical and diagonal crossing.

## 5. DUAL PERSPECTIVE SWOT Analysis

According to the findings from the literature core components of the SWOT analysis would be:

**Strengths:** A structured military education system prepares future officers for the specific challenges of the future military profession and offers clear career prospects that match the specific career aspirations of Generation Z (Morin & Chanut, 2018; Vaitzkin et al., 2018). MHEI also develop the abilities of the future graduates by preparing them for unpredictable situations (Sookermani, 2017) and emphasize the development of physical abilities and a specific moral code of future military professionals (Morin & Chanut, 2018). Military HEIs' emphasis on developing leadership skills, physical abilities and discipline can be marketed as a key factor in attracting students who seek stability and desire a predictable career. The Ministry of Defense, through which channels the promotion of military higher education institutions is carried out, has the professionals in the field of social media, the resources for quality communication planning and the production of quality multimedia content. Military HEIs have the exclusive access to the resources of the MoD and SAF in terms of producing attractive content that encourages engagement and interaction.

**Weaknesses:** Military HEIs cannot have a private marketing orientation and cannot adapt to the demands and needs of students, but primarily focus on the demands and needs of the Ministry of Defense and the Serbian Army for officers (Marček & Jeremić, 2009). There are potential mismatches between the career aspirations and values of Generation Z and the rules and constraints of the military system (see Egerova et al. 2021). Military HEIs do not have their own accounts on social networks. The rigid traditional communication methods of MHEIs may not resonate with Generation Z, who prefer dynamic and interactive content (Savic et al., 2024). Lack of flexibility when designing the curriculum can deter future students interested in innovative educational experiences (Anatolović and Sandžakov, 2022).

**Opportunities:** Thanks to the preferences of Generation Z in terms of digital communication, military HEIs have the opportunity to use the potential of promotion through social networks with more quality and comprehensiveness as a part of their recruitment strategies (Turner, 2015; Savic et al., 2024). Competing private and public HEIs use the potential of social networks in their promotion to an insufficient extent and with insufficient quality, which opens up space for military HEIs to stand out in the offer of higher education in the Republic of Serbia. Engaging nature of digital platforms can be seen as an opportunity to engage the target public and improve the reputation of military HEIs on social networks (Chang & Chang, 2023, Alfonzo, 2023).

**Threats:** Civil HEIs are largely able to respond to the demands of the higher education market and to adapt to the demands and needs of future students. The rapid evolution of digital media and the increase in the agility of the marketing promotion of civilian HEIs represent a threat to the efficiency and effectiveness of the promotion of military HEIs (Sookermany, 2017). The nature of digital platforms also could be considered as a threat for reputation of MHEIs (Chang & Chang, 2023).

### 5.1. Evaluative Balance

This approach reconciles inconsistencies by focusing on overall evaluation, categorizing SWOT components as either desirable or undesirable (Novicevic et al., 2004).

**Strengths (Desirable Internal):** MHEIs have a structured military education system and exclusive resources which prepare students for future military professions and develop leadership skills, highly desirable for Generation Z who seek stable careers (Morin & Chanut, 2018; Vaitzkin et al., 2018).

**Opportunities (Desirable External):** There's a significant opportunity to use social networks for promotion, an area where competitors are underperforming, which could enhance MHEIs' appeal to Generation Z (Turner, 2015; Savic et al., 2024).

**Weaknesses (Undesirable Internal):** The lack of a private marketing orientation and the absence of social media accounts might not meet the digital communication preferences of Generation Z, potentially limiting engagement (Marček & Jeremić, 2009; Savic et al., 2024).

**Threats (Undesirable External):** Civil HEIs' ability to adapt quickly to market demands and digital trends could outpace MHEIs, posing a threat to their attractiveness to potential students (Sookermany, 2017).



## 5.2. Descriptive Overlap

This model groups SWOT components based on their descriptive traits-whether they are controllable/internal or uncontrollable/external.

**Strengths (Controllable Internal):** MHEIs' structured military education and development programs, along with their unique access to MoD and SAF resources, provide a strong internal capability to produce engaging content (Morin & Chanut, 2018).

**Weaknesses (Controllable Internal):** Inflexibility in marketing orientation and curriculum design are significant internal weaknesses that MHEIs can potentially control and improve to better meet the needs of Generation Z (Marček & Jeremić, 2009; Anatolović and Sandžakov, 2022).

**Opportunities (Uncontrollable External):** The evolving preferences of Generation Z towards digital communication represent an external opportunity for MHEIs to capitalize on, especially given the underutilization of these platforms by competitors (Turner, 2015; Savic et al., 2024).

**Threats (Uncontrollable External):** The agility of civilian HEIs in adopting digital media strategies poses an uncontrollable external threat, challenging MHEIs to adapt quickly or risk losing prospective students to more agile competitors (Sookermany, 2017).

## 6. CONCLUSION

The findings of a simple cross sectional survey of the presence and activities of Serbian HEIs on social networks indicate that the marketing approach in the context of the use of digital platforms for promotion has not taken root. The dual SWOT analysis conducted in this study elucidates the key role that digital media plays in shaping MHEI's promotional strategies targeting Generation Z. The strengths of MHEIs, such as structured military education and clear career options, are significant, but underutilized in the context of modern digital platforms (Morin & Chanut, 2018; Vaitzkin et al., 2018). However, institutional weaknesses, including a lack of independent social media presence and inflexibility in marketing orientation, critically hinder their ability to attract the digitally savvy Generation Z (Marček and Jeremic, 2009; Egerova et al., 2021). The opportunities for MHEIs to improve their engagement with potential students through social networks are enormous, especially since competing institutions have yet to fully exploit these platforms (Turner, 2015; Savić et al., 2024). Thus, we answered the basic research question in this paper. Conversely, the rapid adaptation of civilian HEIs to digital trends poses a significant threat with the potential to overtake MHEIs, unless they succeed in innovating their approach to recruiting and engaging students on social networks (Sookermani, 2017; Chang, 2023). In order for both MHEIs and civilian HEIs in Serbia, to be competitive and attractive to Generation Z, they should adopt dynamic and interactive promotional strategies in accordance with the preferences of this generational cohort. This means not only establishing and increasing the presence on social networks, but also looking for ways to make the content that is marketed interactive, engaging and reflecting the values and targeting the group it is intended for. Future strategies of HEIs and HEIs should focus on the integration of digital tools for marketing purposes in order to achieve a more attractive and relevant image (Chang, 2023; Alfonzo, 2023).

The main constraints of this research are that the quality, the scope and the engagement of the content that HEIs and MHEIs place through their own social media accounts in the context of their overall marketing strategies have not been analyzed in depth. Longitudinal research aimed at examining the impact of communication of HEIs and MHEIs through digital communication channels, primarily social networks, on the number of applied candidates for their study programs would be a valuable step forward in expanding scientific and practical knowledge in this area.

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# INTERDEPENDENCE OF PUBLIC DIPLOMACY AND NATION BRANDING: A LITERATURE REVIEW

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**Abstract:** *Public diplomacy and nation branding are two related concepts that share certain theoretical foundations and whose activities are intertwined in practice. The relationship and interdependence of public diplomacy and nation branding is widely recognized in the literature. However, authors have somewhat different perspectives on this issue. Taking this into consideration, the objective of this paper is to make a systematization of the literature, based on different authors' views on the relation between concepts of nation branding and public diplomacy. The findings of the literature review indicate that there are three different groups of opinion. The first group of authors considers nation branding to be one dimension of public diplomacy. On the other hand, some authors believe that public diplomacy is a subset of nation branding. Finally, the third group of authors observe these two concepts to be two equally important areas, which must be applied in an integrated manner.*

**Keywords:** *public diplomacy, nation branding, theoretical view, relationship, interdependence*

## 1. INTRODUCTION

Global competition between countries for skilled labor, foreign investment and companies, income from tourism and opportunities to influence international public encourage countries to promote their unique characteristics that make up the nation's brand. Public diplomacy and nation branding are two related concepts that share certain theoretical foundations and whose activities are intertwined in practice. In fact, public diplomacy is the area that reflects the way states and governments present themselves in the international environment, and which has a significant sphere of overlapping with the building of the state's reputation (Anholt, 2010). Public diplomacy implies the interaction and integration of instruments and means of communication used by diplomatic missions, state institutions, international organizations and associations, and even individuals, in the realization of various forms of international cooperation, public relations and branding of the nation (Iosifidis & Wheeler, 2016). Public diplomats are tasked with communicating with the publics of foreign nations. Their responsibilities include advocating views and policies, sharing cultural perspectives, increasing mutual understanding, persuading foreign audiences, and influencing the decisions of foreign governments, leaders and elites (Pike & Kinsey, 2024).

There are different perspectives in looking at public diplomacy, from those that limit it exclusively to activities carried out by the state and diplomatic missions, to those that fully include non-governmental actors in the framework of public diplomacy (Ayhan, 2018). In accordance with that, scholars discussing the new public diplomacy highlight several distinctions from the traditional approach: emphasis on two-way engagement, which involves dialogue, partnerships, listening, and collaboration; the involvement of more non-governmental actors; the use of social media; and a stronger connection between domestic and international spheres (Mark, 2022). For nations that possess a negative reputation in the international environment, strategically designed programs of public diplomacy communication must be implemented to achieve proper public influence in the context of the neutralization of sources of negative public perception (Yousaf et al., 2021), which represents the basis for further efforts towards building the desired nation brand.

Nation branding is also perceived as a way to strengthen the soft power of the state, and to some extent it is considered a geopolitical and economic method to improve the attractiveness of the state, its reputation and competitiveness. Cultivating and managing a favorable international reputation is undoubtedly in the interest

of states because national reputation is undoubtedly an instrument of power (Wang, 2006). Soft power, as the ability of states to get what they want through the appeal of culture, political ideals, and not through coercion (Nye, 2004) is a concept closely related to public diplomacy. In this sense, both building a favorable reputation of the national brand and public diplomacy are placed in the context of improving the state's soft power and the state's capacity to build relations with the international public. On the other hand, Durrani (2023) conceptualized a concept of Negative Watch as a joint theory of both public diplomacy and place branding, exploring how a consistent set of unfavourable media narratives, presented by countries, could erode a target country's political legitimacy, credibility, and soft power. As a way to combat negative representational effects in public, the authentic identity of the nation should be promoted, which will become recognizable in the public, based on the cultural, social, economic and geographical characteristics that are specific to that nation. This distinctive and positively associated national identity arises a result of communication activities in branding, which belong to the domain of public diplomacy (Piscitelli, 2021).

There is an increasing volume of literature on both nation branding and public diplomacy, and these two concepts are often considered to be closely related. Taking this into consideration, the objective of this paper is to make a systematization of the literature, based on different authors' views on the relation between concepts of nation branding and public diplomacy.

## **2. THE RELATIONSHIP BETWEEN CONCEPTS IN LITERATURE**

A successful outcome of nation branding is improved country competitiveness in various spheres, including tourism, foreign direct investment, international trade, higher education, and skilled labor. In addition, a positively perceived nation brand enables greater legitimacy and authority of the state, its leaders and institutions in diplomatic frameworks, ensuring participation in multilateral decisions and membership in international institutions and organizations. Therefore, branding can serve two purposes. It can be applied for reactive purposes if the purpose is to repair the reputation damaged by various historical, political and economic events. On the other hand, it can also be implemented for proactive purposes, as a method of managing the image and reputation of the state in the context of preventing the consequences that may arise due to future crisis situations. In this sense, nation branding, in terms of international relations, as well as public diplomacy, are both defined as an effective form of "soft" power, which is molded into the diplomatic and foreign policy interests of nations and states (Aronczyk, 2013). Although both public diplomacy and nation branding focus on managing a country's image, originally they stem from different disciplinary backgrounds. Public diplomacy has its roots in international relations and communications, specifically international public relations. In contrast, nation branding originates from marketing and involves promoting and developing a country's image through marketing activities (Lee, 2023). The relationship and interdependence of public diplomacy and nation branding, as theoretical and practical concepts, is recognized in the literature. However, authors have somewhat different perspectives on this issue, which makes three different groups of opinion.

The first group of authors considers nation branding as a dimension of public diplomacy. According to the Integrated Model of Public Diplomacy defined by Golan (2013), nation branding and state reputation building represent one dimension of the model, which includes medium- and long-term activities. The other two dimensions are mediated diplomacy (communication through various media) and relational public diplomacy (programs for developing relations with the international public). According to this author, nation branding is only one element in a broader perspective called integrated public diplomacy. While each component of integrated public diplomacy varies in its objectives and engagement with stakeholders, it's only through the integration of all three elements that three elements will there be a greater chance for nations to achieve positive long-term results. In this sense, the author concluded that nations should emphasize the common basic values of their national identity when they communicate with the foreign public and in the messages they send through the channels of the mediated approach of public diplomacy. In this sense, campaigns for nation branding and building the reputation of the state can achieve benefits from the incorporation of core values as basis of various programs of mediated and relational public diplomacy (Golan, 2013). Cull (2019) also views nation branding as one element of the concept of public diplomacy, alongside international listening, advocacy, cultural diplomacy, international exchange, international broadcasting and partnerships. As stated by Kerr and Wiseman (2018), nation branding represents a form of public diplomacy which is based on using the significant conceptual content of marketing science in the function of branding nations, with the aim of improving national reputation in international relations. Xuereb (2017) investigated the potential success of nation branding as a tool for achieving public diplomacy objectives, exemplified by Malta as a case study in cultural diplomacy sphere. The results of this author's analysis indicated that engagement with the context of nation branding represents a possible path to the development of effective public diplomacy, which is especially the case when it is combined with heritage, tradition and diverse forms of cultural expression of national identity in

communication. Ginesta & de San Eugenio (2021) pointed out to a theoretical evolution of place branding, which is, due to links with political power and order, being observed as a central spot in public diplomacy programs.

On the other hand, some authors believe that public diplomacy is, actually, a subset of nation branding. Fan (2010) included the following research areas which represent the segment of the nation branding field: branding of the export; destination/place branding; public diplomacy/political branding, and branding of national identity and culture. In this sense, the author believes that nation branding is an effort taken by state and non-state actors to obtain a better national image, and public diplomacy is one of the fields of study in that context. Moilanen and Rainisto (2009) presented public diplomacy as one of the effects of nation brand, in addition to other effects such as: improving the interests of export industries, companies and investors, positioning the country as a tourist destination and increasing the satisfaction of the population. These authors, therefore, believe that a recognizable nation brand is the basis for implementing effective communication programs in the field of public diplomacy. Within the Integrated Nation Branding Model defined by Rojas-Méndez and Khoshnevis (2023), public diplomacy is one of the components of nation branding. The authors identified six primary factors that influence nation branding: business and marketing, political dynamics, societal and cultural aspects, economic and labour conditions, international factors, and environmental considerations. A well-built nation brand results in numerous social, economic, political, financial and international consequences.

The third group of authors observes public diplomacy and nation branding as two equally important areas, which enable achieving the desired effects by their integrated action. A well-known author in this field, Anholt, first considered public diplomacy to be a subset of competitive identity, which includes everything that the nation as a whole represents. According to this author's theory of competitive identity, the public policy of a government is simply one point of a "hexagon" of national reputation, a perception of nations in the international public, either accidentally or intentionally. From this perspective, public diplomacy is evidently a facet of competitive identity as it focuses on showcasing a particular facet of national activity. However, competitive identity seeks to synchronize politics, societal values, sports and cultural achievements, products, tourism, trade and investment initiatives, and talent acquisition. Subsequently, the author's stance on this matter evolved as they came to realize that their initial perception of public diplomacy as a subset of competitive identity stemmed from a rather conventional understanding of public diplomacy as a tool for representing national interests through communication policies of diplomatic entities. Consequently, the author now equates the importance of public diplomacy and the country's reputation. The identity of the nation, as well as the way the public perceives it, are issues that are inextricably connected, which is why the state cannot achieve its goals in the modern world without a synergy of public diplomacy and competitive identity (Anholt, 2010). As stated by Anholt (2007), the nation's brand and its reputation wield considerable influence over the perceptions and behaviors of both domestic and international audiences. They shape how individuals within and outside the country perceive it, how they interact with it, and their responses to its foreign policy and global engagements. In this regard, the nation's brand and reputation exert a direct and tangible impact on virtually every facet of its interactions with other nations, playing a pivotal role in its economic, social, political, and cultural advancement. Public diplomacy is the area that has the most in common with nation branding and represents one of different manners in which nations and national governments present themselves at the global level. This author pointed out that public diplomacy, combined with brand management, supports the idea of a competitive state identity. Contemporary public diplomacy implies more cooperation and integration of activities between diplomatic missions, cultural institutions and trade and tourism offices, so diplomatic representatives perceive the promotion of trade, tourism, investments and culture as a significant segment of their engagement. But states achieve the greatest improvement in their international reputation when all major sectors are aligned with a common strategy of building a competitive identity. In cases where the state's reputation is good, the purpose of public diplomacy will be merely to promote government policy, and, unless the policy is clearly wrong, it would probably be received well by the public. Anholt (2007) furthermore explains that, in case when the country has a negative or weak reputation, then communication programs will not be enough to ensure that a certain policy is accepted with enthusiasm, and it will either be ignored or taken as additional evidence for the negative perceptions in the public. True influence over its image and reputation, transforming them into competitive advantages rather than obstacles, is attainable for a nation only when public diplomacy is conducted in concert with other national stakeholders, and all are united through efficient brand management under a cohesive, long-term national strategy. In this sense, this author points out that the combination of brand management, public diplomacy and other national promotion forms represents a powerful tool for gaining competitive advantage in the international environment.

A prominent author in the area of nation branding, Dinnie (2008), pointed out that perceptions of an image of certain nation may not always correspond to reality, and may be the result of outdated views and entrenched stereotypes. In the event that the nation's image is poor, a conscious communication strategy should be implemented to ensure that a negative or outdated perception does not damage the value of the national brand. In this context, the communication activities of various subjects (state and non-state) have a key role,

which essentially represents the basis of public diplomacy. On the other hand, if the negative image is a realistic reflection of existing problems such as high levels of crime, corruption and the like, in that case, it is necessary to take corrective measures to solve the real problems before undertaking any activities on the nation branding.

At the basis of modern public diplomacy and nation branding is the building of relations with the target public. Emphasis is placed not only on representing the national identity and building the desired image of the country, but also on building and maintaining strong and long-lasting relationships with target audiences, and this is exactly what should be emphasized in any nation branding campaign (Wu, 2017). While nation branding is a process carried out by the government or other national body, the image and reputation of the nation is determined by the target public, which in the case of nation branding is the international public and foreign governments (Fan, 2010). As the foreign public is the primary target group of public diplomacy, it is clear that the goals and activities of these two areas overlap to a significant extent and that there must be synergy between the various branding programs and public diplomacy. Therefore, different entities such as governments, companies and people must channel their actions in a common direction that is positive and productive for the reputation of the nation brand. Papadopoulos et al. (2016) emphasize the equal importance of nation branding and public diplomacy in building an international recognition of the country in specific industry. In such cases, in order to achieve improved international competitiveness among investors, the communication in branding campaigns, as well as public diplomacy programs, must present positive actions of the government intended to improve market conditions (e.g. improved infrastructure, different incentives). In addition to the "hard" factors like a country's tax policies or political stability, the literature underscores the significance of "soft" perception factors such as nation branding, country reputation building, and public diplomacy in shaping investment decisions (Papadopoulos et al., 2016).

#### 4. CONCLUSION

Nation branding and public diplomacy are interconnected concepts that play pivotal roles in shaping a country's image and reputation at the global level. Nation branding involves the deliberate and strategic efforts by a nation to cultivate a positive perception of itself among international audiences. This can encompass various aspects including culture, tourism, economy, and governance. Through nation branding, countries aim to differentiate themselves, highlight their unique strengths, and project a cohesive and appealing identity to the world. Public diplomacy, on the other hand, focuses on the communication and engagement strategies employed by governments to foster understanding, goodwill, and influence in foreign countries. It involves building relationships with various stakeholders, including foreign governments, media outlets, and the general public, through activities such as cultural exchanges, educational programs, and diplomatic outreach. Public diplomacy often serves as a means to reinforce and amplify the messages conveyed through nation branding efforts, leveraging soft power to enhance a country's reputation and influence abroad. Together, nation branding and public diplomacy form integral components of a country's strategic approach to international relations, shaping perceptions and fostering constructive dialogue on the global stage.

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# UNRAVELING HOSPITALITY: EXPLORING HUMAN, DIGITAL, AND EXTERNAL FORCES IN MARKETING COMMUNICATIONS

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**Abstract:** *This research aims to explore the impact of human resources, digital technologies, and external influences on modern hotel marketing communications. By exploring the interactions between these factors, the research seeks to enhance understanding of the complex dynamics shaping marketing strategies in the hospitality industry and provide insights to help hotels optimize their communication efforts for improved guest engagement, satisfaction, and loyalty. 545 tourists who visited Belgrade hotels in December 2023 and January 2024 were interviewed online for the empirical research. They have assessed the claims on human resource practices, digital technologies, and environmental initiatives as factors affecting the marketing communications of the hotel. For the materials of the study, statistical methods and the Likert scale were used. There are all three groups of factors having a strong combined multifaceted influence on marketing communication, where each of them has a moderate impact; digitals are found by customer assessment with the highest level of influence; and human resources has a second level of impact. Research results can yield several theoretical contributions: framework development, boundary-spanning theory, cultural and contextual considerations, a better understanding of the integration of multiple factors, more effective marketing strategies, customer engagement enhancement, and sustainable competitive advantage for hotels in the dynamic and competitive hospitality industry.*

**Keywords:** *human resources, digital technologies, marketing communication, hospitality, Serbia.*

## 1. INTRODUCTION

The modern hospitality industry is influenced by a multitude of factors, like industry trends, technological advancements, and a paradigm shift towards digitalization, driven by emerging trends such as contactless service, virtual experiences, and immersive technologies. Hotels that embrace digital innovation are better positioned to capitalize on these trends and stay ahead of the curve. Also changes in customer preferences are huge, because the industry has to improve operational efficiency, resource allocation, and readiness for adaptability and agility to change. Economic conditions, including inflation and exchange rates, can influence consumer spending patterns and travel behavior. Hotels must be

prepared to adapt their pricing strategies, marketing efforts, and operational practices in response to changing economic conditions. In today's competitive hospitality industry, hotels are constantly vying for guests' attention and loyalty. The rise of sharing economy platforms like Airbnb and HomeAway has disrupted the traditional hotel sector by offering alternative accommodation options to travelers. This trend has forced hotels to innovate and differentiate themselves to remain competitive in an increasingly crowded marketplace. The globalization of travel has opened up new opportunities for the hospitality industry, but it has also introduced challenges such as increased competition and cultural diversity. Hotels must cater to the needs of international travelers while also respecting local customs and regulations. Because of the industry trends and challenges the tourism and travel industry is facing, the authors selected digital marketing and its communication functions as a field to be researched on the impact factors, aiming to better understand their correlations and opportunities for the growth of the hospitality industry (Radović et al., 2017; Srebro et al., 2011). Digital marketing is the function that offers hotels a competitive advantage by providing cost-effective and measurable strategies to differentiate themselves, enhance their brand visibility, and attract potential guests (Srebro et al., 2023). In that context, marketing communication for a modern hotel as a hospitality organization from the consumer perspective focuses on creating meaningful connections, providing valuable information, and delivering exceptional experiences to guests.

Concerning the state of play of the hospitality industry, it is evident (UNWTO, 2024) that there were 1286 million international tourists in 2023 around the world. As for the case for the empirical research provision, it has chosen Serbia and its capital, Belgrade, as a tourist destination. According to SOS, 2024, tourist arrivals in Serbia averaged 97274.18 from 2009 until 2023, reaching an all-time high of 252728.00 in August 2023 and a record low of 1052.00 in April 2020 (SOS, 2024). Belgrade witnessed a remarkable influx of tourists in 2023, with the Serbian capital hosting 1.38 million visitors, marking a 17% increase from the previous year (with 3, 5 million. visitors). (The surge in tourism was predominantly driven by international visitors, who accounted for nearly 1.19 million of the total tourist count, registering a significant 21% jump from 2022).

Concerning the above industry trends and challenges for the hospital industry: changing consumer behavior, enhanced experience, competitive advantage, adaptation to technological trends, environmental responsibility, and meeting regulatory requirements, the authors have chosen three groups of factors that could impact the marketing communications of the hotel to be researched: human resources, digital, and external influences. This context of influences on marketing communications was the field of interest for the authors to further research, so try to cover a range of impacts related to human resources, digital, and external influences on the marketing communication of the hospitality industry, intending to also get empirical attitudes from 545 customers on the level of these influences.

The structure of the paper follows the further tasks of the study: Introduction, Literature Review, Conceptual framework development that integrates human resources, digital technologies, and environmental influences within the context of hotel marketing communications, establishing theoretical linkages between humans, digital and environmental influences, and marketing communications outcomes, and defining four hypotheses. Research design methodology and data collection techniques for the study, definition of the target population, sampling strategy, development of online survey instruments, and collection of data through a survey of 545 customers who have visited Belgrade hotels in the period of December 2023 and January 2024, by gathering customers' attitudes on the 24 claims within 3 factors of impact on the marketing communication of these hotels, are given in the methodology part. Findings of the data analysis are discussed within the discussion of the findings in that part of the paper, and the conclusion and the literature used in the paper are given at the end.



## 2. THEORETICAL FRAMEWORK

Here are the factors and hypotheses of the research definition presented through a literature overview.

**Human resources.** Human impacts on marketing communication could be understood through the ways individuals perceive, engage with, and respond to marketing messages. Overall, human impacts on marketing communication highlight the importance of understanding and empathizing with consumers' needs, preferences, and behaviors to create meaningful and impactful marketing experiences (Dessler, 2019; Armstrong, 2019), including: Psychological Factors, Cultural Differences, Cognitive Processes, Social Influence, Ethical Considerations, Technological Adoption, and Consumer Decision-Making. The more direct impact of humans on the marketing communication of the hotel can be seen in talent acquisition (Moy, 2006) and training programs, which may cover areas such as digital marketing techniques, social media management, content creation, and data analytics (Cascio, 2018). Human resources foster a collaborative work environment where marketing teams can collaborate with other departments, such as IT, sales, and guest services, to integrate communication tools seamlessly across the hotel's operations. Leadership and strategic planning (Wright & McMahan, 1992). Employee engagement, where Humans foster a positive work culture where marketing professionals feel motivated and empowered to contribute their ideas and creativity to: communication initiatives (Hoque, 2013), diversity and inclusion, ethical standards and compliance, change management, and employee wellbeing. On a theoretical basis, first, the hypothesis can be defined: **H1: HR enhances employee satisfaction and productivity in marketing communications roles.**

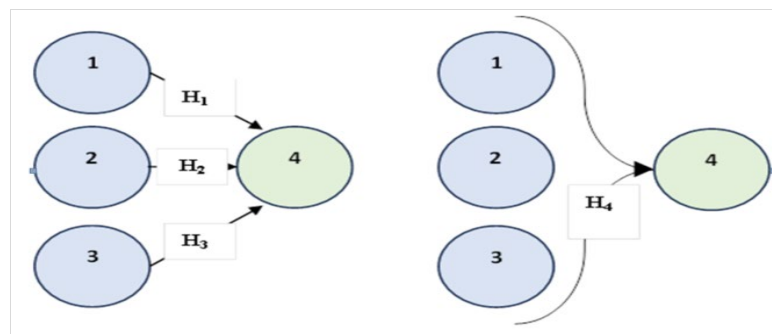
**Digitals.** Digital technologies streamline the operations of a hotel (O'Connor & Frew, 2008; Fesenmaier & Xiang, 2017; Gretzel et al., 2006; Ayeh & Law, 2013; Gretzel and Yoo, 2008; Huang & Sarathy, 2016). Digitals impact modern hotel marketing communications through personalization, efficiency, targeting, predictive analytics that forecast consumer behavior and trends, customer experience enhancement, content optimization, real-time insights, multichannel integration, data security and privacy, and digital systems that continuously learn and evolve. Based on new data and feedback, marketers can adapt strategies in response to changing markets and enable tailored communication and messaging catering to individual preferences and behaviors. For implementing modern hotel marketing communication with customers, which encompasses the use of a range of innovative tools and platforms designed to enhance engagement, personalization, and efficiency in the guest experience, hotels use AI tools. These technologies utilize AI algorithms and data analytics to analyze customer preferences, aiming to improve guest satisfaction, loyalty, and overall business performance (Buhalis & Licata, 2022). Face recognition technology, occupancy-based sensors, cloud hotel property management systems (PMS), and mobile hotel PMS integrated technology solutions. Some of the hotel digital technologies that foster hotel marketing and communication are: booking on mobile devices; text-message marketing; voice search; 360-degree videos; and chatbots (Xiang & Gretzel, 2010; Sigala et al., 2020). The literature and studies provide insights into the use of digital technologies in modern hotel marketing communication with customers, including the role of social media, online travel reviews, destination marketing, personalization of services, and the impact on consumer behavior and destination image, supporting the definition of the second hypothesis: **H2: The adoption and effective utilization of digital technologies enhance the effectiveness of marketing communication efforts.**

**External influences.** Some aspects of government impact can include problem-solving, user-centered, friendly design, collaboration and partnerships, data-driven decision-making, experimentation and risk-taking, technology and digital transformation, policy innovation, leadership and culture change, open government, and transparency. External contexts and their influence on marketing communication were a matter of interest for many authors to research. Meyer et al. (1992), and Tung (1979) explored organizational environment issues in their studies; Huber & Daft (1987) researched the information environment of organizations. External environmental factors can be more clearly presented as: Local cultural influences, which significantly influence guests' preferences and expectations regarding hotel amenities and services (McCammon, 1971); Economic conditions (Bieger & Laesser, 2017; Ouchi, 1980;

White et al., 2003; Stone & Tudor, 2005); Seasonal fluctuations in tourism demand; Technological (Sigala, 2018; Gibbs, 1994); Environmental sustainability (Lindell & Brandt, 2000; Achrol & Stern, 1988; Lindsay & Rue, 1980); Political stability in destination regions (Kelman, 1987); Competitor actions and market dynamics; Regulatory requirements and standards (Suchman, 1995; Xin & Pearce, 1996); Demographic shifts and preferences (Zucker, 1977; Stinchcombe, 1965; Milliken, 1990), and Social media influence and online reviews (Xiang et al., 2016). On this theoretical basis, the third hypothesis of the research is defined as follows: **H3: External contextual factors significantly impact the effectiveness of marketing communication strategies and outcomes.**

**Digital marketing communications.** Many authors and studies provide insights into various aspects of marketing communication within the modern hotel and hospitality industry, including strategic management, technology adoption, market segmentation, crisis management, branding, and the role of intermediaries. Kotler et al. (2014) on the marketing for hospitality and tourism; Sigala (2018) on the application of social media in hospitality and tourism management; Prideaux & Kim (2002); Neuhofer et al. (2015) on the technology as a catalyst of change in the tourist experience; Scott et al. (2011); Morrison et al. (1996), on the future of tourism intermediaries. Some key components of digital marketing in the context of modern hotel communications include: Website optimization, SEM, and social media. Hotels utilize email campaigns to communicate with past, current, and potential guests, sending out newsletters, promotional offers, event invitations, and personalized recommendations to drive bookings and repeat visits; content marketing; online reputation management; and feedback on platforms like TripAdvisor, Yelp, and Google My Business. Positive reviews and ratings can significantly impact a hotel's reputation and booking conversion rates. Influencer marketing: Hotels collaborate with influencers and travel bloggers to showcase their property, amenities, and experiences to a wider audience. Influencer partnerships can help hotels reach new demographics and generate buzz around their brand. Mobile marketing: With the increasing use of smartphones, hotels optimize their digital marketing efforts for mobile devices, ensuring that their website is mobile-friendly and leveraging mobile advertising, apps, and messaging platforms to reach travelers on the go; Data analytics and personalization Emerging technologies include virtual reality (VR/AR), chatbots, and voice search to enhance the guest experience, provide interactive content, and streamline customer interactions.

Based on a literature review, a theoretical model for the research is defined as follows (Figure 1):



**Figure 1: Theoretical model (Source: Author's)**

Also, the fourth hypothesis is defined: **H4: The combined influence of human resources, digital technologies, and external context factors synergistically enhances the effectiveness of marketing communication strategies and outcomes.**

### 3. METHODOLOGY

For research in 2024, an empirical survey was conducted on the territory of Serbia using an electronic questionnaire on a sample of 545 respondents who visited Belgrade in Serbia between December 2023

and January 2024. Their attitudes were collected, utilizing a five-point Likert scale on four domains delineated by the author's expertise: human resources (as explanatory variable 1), digitals (as explanatory variable 2), and external influences (as explanatory variable 3) on the marketing communication of hotels (as explanatory variable 4). Participants assessed 24 statements (six statements across each of the four research domains) in the e-questionnaire. Considering a sample size of 545 respondents and a significance threshold of 0.30 for factor loadings with a sample size exceeding 350, it can be deduced that the factor loadings are statistically significant. This conclusion is supported by the calculated Cronbach's coefficient for all research statements, which stands at  $\alpha=0.9224$  (exceeding the recommended threshold ( $\alpha < 0.9$ ), demonstrating excellent consistency).

### 3.1 Results and Discussion

According to the analysis of the standard error of the mean, variance, skewness, and kurtosis data, independent variable 3 has the highest mean value, which are 4.510 with a standard deviation of 0.277. The second independent variable has a mean value of 4.970, and StdDev 0.419, and the third independent variable has a mean value of 4.520, and StdDev 0.277. The dependent variable 4 has the lowest mean value, which are 4.287 with a standard deviation of 0.473. The Pearson's correlation values for all variables within the theoretical model set show that all connections between variables are positively oriented, signifying a positive correlation. The highest correlation coefficient observed between the independent variables 1 and 2 is 0.9229, indicating a strong positive correlation. Furthermore, the coefficient of determination, standing at 0.8436, elucidates that 84.36% of the variance in variable 2 can be explained by its association with variable 1, showcasing a robust positive relationship between these independent variables. Variables 2 and 3 have the lowest correlation, 0.6159, with a moderately strong influence. The coefficient of determination, standing at 0.3793, or 37.93% of variable 3, can be explained by its association with variable 2.

Drawing from the theoretical model illustrated in Figure 1, there were analyzed individual linear dependencies, were evaluated the influence of each independent variable (1, 2, and 3) on the dependent variable 4, utilizing ANOVA tests, interpretations for standard beta and BSquare in percentage terms, correlations between variables, confirmation of hypotheses, and regression equations. Independent variable 2, digitals, has the highest single impact of 0.407 on the dependent variable 4, marketing communications of the hotel. Independent variable 1, humans, has the next strongest impact on dependent variable 4, 0.280. The lowest impact is on dependent variable 4, the marketing communication of the hotel, independent variable 3, and external contexts, with a coefficient of 0.253.

The following findings emerge: As variable 1 (humans) increases, the significance of variable 4 (the marketing communication of the hotel) also increases. That variable 1 has a positive effect on variable 4 and supports the acceptance of the hypothesis H1. Similarly, as variable 2 (digitals) increases, the importance of variable 4 also increases. This leads to the acceptance of hypothesis H2, suggesting that variable 2 positively influences variable 4. Additionally, as variable 3 increases, the significance of variable 4 also increases. This supports the acceptance of hypothesis H3, indicating that variable 3 has a positive impact on variable 4. Furthermore, when variables 1, 2, and 4 simultaneously increase, the importance of variable 4 also increases. This supports the acceptance of hypothesis H4, suggesting that the combination of variables 1, 2, and 3 collectively influences variable 4 positive. A possible explanation for the highest impact of digital factors among other analyzed can be found in the part of the research sample characteristics: Concerning the age of customers, there were more than 50% of tourists up to 45 years old in the sample who can belong to new generations—digital natives—and the impact of their native characteristics, knowledge, skills, and needs is visible in the result, they emphasized digital factors as having the strongest influence on hotel marketing communications. Highlights of some characteristics and needs of Generation Z, Generation X, and Millennials as hotel guests can support these results (Jevtić, 2024): Generation Z (born roughly between 1997 and 2012): tech-savvy and digitally native, preferring seamless and intuitive digital experiences in hotel bookings and check-ins, seeking authentic and personalized experiences, valuing unique amenities, and local cultural immersion. Desire fast and reliable Wi-Fi access throughout the hotel premises for seamless connectivity, and value transparency and authenticity in hotel branding and marketing efforts, preferring genuine and honest communication. Generation X (born roughly between 1965 and 1980) values comfort and convenience,

seeking hotels that offer high-quality amenities and services to enhance their stay experience, appreciate loyalty programs and rewards, often choosing hotels affiliated with familiar brands or chains; and Value convenience and accessibility. Millennials (born roughly between 1981 and 1996), seek unique and Instagram-worthy experiences, preferring boutique hotels and unconventional accommodations that offer memorable moments, value technology integration and innovation, expecting seamless mobile check-in/out, smart room features, and digital concierge services, seek wellness-focused amenities and services, including fitness centers, yoga studios, and healthy dining options, and expect personalized and tailored experiences, with hotels leveraging guest data to provide customized recommendations and offerings.

#### 4. CONCLUSION

The findings of the research on the factors impacting the marketing communications of modern hotels improved understanding of the role of human resources, digital technologies, and environmental contexts in digital marketing. The research objectives realized through theoretical considerations and empirical investigation of the attitudes of the hotel customers can contribute to the literature and practices on the: Hotel brand image enhancement, Positive guest experiences, customer-centric culture fostering, Operational efficiency improvement, Sustainable hospitality practices, Competitive advantage of a hotel, Innovation canalization, Adaptability and resilience, Digital integration, Human resources practices enhancement, Environmental context leverage. Although the impact of external context is moderate compared to digital and human resources, hotels should still consider environmental factors in their marketing communications. This may involve highlighting sustainable practices, eco-friendly initiatives, and community engagement efforts to appeal to environmentally conscious travelers.

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# THE IMPACT OF CONSUMER ENVIRONMENTAL AWARENESS ON CREDIBILITY, RECEPTIVITY, AND SKEPTICISM TOWARDS GREEN COMMUNICATION

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**Abstract:** *The effectiveness of green communications depends on multiple factors, among which are consumers' environmental-related knowledge, attitudes and behaviour. The objective of the research was to investigate whether consumers' environmental awareness, consisting of variables Environmental values and beliefs, Perceived consumer effectiveness, Perception of personal gain, Conscious consumption and Disposing of waste, positively influence the effectiveness of green communication, which includes variables Receptivity to green communication, Skepticism and Eco-label credibility. The research was conducted on a sample of 270 Serbian consumers by the online survey. The study findings contribute to the growing body of knowledge in this field, and provide a valuable foundation for the development of effective communication strategies in marketing practice.*

**Keywords:** *environmental awareness, green communication, green messages, effectiveness*

## 1. INTRODUCTION

Environmental problems have reached large proportions and have been constantly increasing, thus representing one of the most important contemporary topics. The consequences of man's negative impact on the environment are increasingly visible in the domain of air, water and soil pollution, which furthermore cause great social and economic consequences. In order to prevent further negative changes in the environment, it is essential for consumers to find more sustainable ways of satisfying human needs. To mitigate the environmental impact of overconsumption, it is necessary to encourage a development of consumers' environmental awareness and acceptance of green attitudes, which further lead to the adoption of green consumer behaviour (Martinez et al., 2020). Therefore, the effort to encourage consumers to behave in accordance with environmentally sustainable practices is one of the biggest challenges in today's business practice. Green behaviour is largely determined by the level of environmental awareness of an individual, which can be greatly developed by informing consumers about reasonable options and consequences of their actions on the environment (Usrey et al., 2020). Environmentally focused communication, which includes green marketing, green advertising and eco labelling, has a significant influence with this regard, by enabling consumers to be more informed when making purchasing decisions (Shen et al., 2020).

One area which is of particular importance when it comes to green communication is the investigation of consumer responses to environmentally oriented messages and various types of green appeals. Numerous researchers in this domain have concentrated on analysing the effectiveness of green advertising, intending to furnish empirical evidence and offer actionable suggestions to advertisers on effectively communicating green messages and enhancing the perception of their company or product's environmental acceptability (Krstić et al., 2021). In accordance with that, the objective of this paper is to investigate whether there is a relationship between consumers' environmental awareness (consisting of variables Environmental values and beliefs, Perceived consumer effectiveness, Perception of personal gain, Conscious consumption and Disposing of waste) and the effectiveness of green communication (which includes variables Receptivity to green communication, Skepticism and Eco-label credibility).

## 2. LITERATURE REVIEW

Numerous studies point to the increase of consumers' environmental awareness in the process of making purchasing decisions, product consumption and disposal (Krstić et al., 2021). Environmental awareness represents consumers' knowledge that their consumption directly affects the environment and the lives of future generations (Kostadinova, 2016). Greater consciousness with this regard refers to the reduction of consumption of conventional products and giving priority to environmentally friendly products (Suki, 2013). Current research findings indicate that consumers' green awareness represents one of the major determinants of their intentions to purchase ecologically friendly products (Chang et al., 2015). Therefore, environmentally conscious consumers tend to satisfy their needs with products that are not or at least less harmful to the environment (Sama, 2020). Through green marketing and advertising strategies, an organization can influence the improvement of environmental awareness among consumers. Therefore, consumers' environmental awareness can be created or improved as the result of the marketing efforts invested by the organization. Based on the results of previous research, it was concluded that different forms of green communication have positive influence on consumers, however, the effectiveness might depend on the level of their environmental consciousness (Bailey et al., 2018).

Green communications can be focused on the relationship between products and the environment, on the promotion of environmentally responsible lifestyles, and on the building and maintaining of environmentally responsible corporate or brand image (Chang et al., 2015). Therefore, in order to position the brand in the market as environmentally responsible, it is necessary to use green communications to convey messages emphasizing the brand's green attributes (Wu et al., 2018). Green communication varies from simple claims about the environmental acceptability of products, through corporate images and public events that highlight and promote responsible behaviour towards the environment (Hartmann & Apaolaza-Ibáñez, 2009). Green communication includes green advertising, eco-labelling and other forms of conveying environmentally friendly messages. The aim of green advertising is to provide the necessary information to consumers about the ecological attributes of the products and services offered by the company (Fernandez et al., 2020) and to create the image of a "green" brand, and influence the formation of a positive attitudes towards such brands (D'souza & Taghian, 2005). It is used to promote environmentally responsible approach in all production phases, from product design, production and distribution, as well as to promote responsible consumption and disposal, in order to minimize harmful consequences for the environment (Green & Pelozo, 2014). Eco-labels, as a form of green communications, serve as certification marks or seals of approval, indicating the environmental attributes of a product or service, while simultaneously assuring consumers of the accuracy of these claims (Athinson & Rosental, 2009). Research has shown that there is a greater possibility that positive reactions to environmentally focused communications will be demonstrated by those consumers who show positive attitudes towards the preservation of the environment (Suki, 2013). However, not all green communications are necessarily effective, if they don't seem to be authentic, truthful and well argued, they can evoke consumers' confusion and skepticism towards environmental messages (Matthes & Wonneberger, 2014). Consumer reactions to environmentally friendly products stem from the individual characteristics of consumers (Tucker et al., 2012); therefore, it is reasonable to assume that consumers who possess environmental values and beliefs, understand the role of individuals in preservation of the environment, and tend to use and dispose of products in a conscious manner, will be more likely to positively react to green communication and be less skeptical regarding green messages and eco-label credibility.

### 3. METHODOLOGY

The research was conducted on a convenient sample of 270 Serbian consumers in the period from November 2022 to February 2023. An online survey was used for data collecting. The questionnaire consisted of several segments. The first segment referred to demographic characteristics of the respondents. The second segment related to consumers' environmental awareness and consisted of five variables (Table 1). The first variable in this group, entitled Environmental values and beliefs, included three items borrowed from Haws et al.'s (2014) GREEN scale, indicating individual consumption values and purchase behavior and two items related to environmental beliefs from Dunlap et al.'s (2000) NEP scale. Perceived consumer effectiveness was the next variable in this group, and it included three items borrowed from Roberts (1996). Perceived consumer effectiveness can be explained as consumers' perception of how much their consumption choices and behavior can impact the market and contribute to solving environmental issues (Higuera-Castillo et al., 2019). The Perception of personal gain was the third variable in this group, which contained two items borrowed from Palacios-González and Chamorro-Mera (2020), who explained this concept as "the individual's subjective assessment of the advantages and disadvantages of socially responsible behavior". Three items related to the concept of Conscious consumption, which describes the extent to which individual's consumption is aligned with real needs and waste reduction, were adopted from Gupta and Agrawal (2018). The last variable, Disposing of waste, which included five items, was adopted from the same source.



**Table 1:** Variables and items related to consumer environmental awareness (CEA)

Label	Environmental values and believes	Authors
EVB 1	It is important to me that the products I use do not harm the environment.	Haws et al. (2014) Dunlap et al. (2000)
EVB 2	My purchase habits are affected by my concern for our environment.	
EVB 3	I would describe myself as environmentally responsible.	
EVB 4	If things continue on their present course, we will soon experience a major ecological catastrophe.	
EVB 5	The earth has plenty of natural resources if we just learn how to develop them	
Perceived consumer effectiveness		
PCE 1	Consumer as an individual cannot do anything about pollution	Roberts (1996)
PCE 2	Since one person cannot have any effect upon pollution and natural resource problems, it doesn't make any difference what an individual does.	
PCE 3	Each consumer's behavior can have a positive effect on society by purchasing products sold by socially responsible companies	
Perception of personal gain		
PPG 1	Behaving in a socially responsible manner means paying higher prices.	Palacios-González & Chamorro-Mera (2020)
PPG 2	Behaving in a socially responsible manner means giving up certain comforts.	
Conscious consumption		
CC 1	I turn/switch things off when not in use.	Gupta & Agrawal (2018)
CC 2	I take only as much as I can consume, to avoid wastage.	
CC 3	I avoid using things in a wasteful manner.	
Disposing of waste		
DW 1	I segregate my household waste before disposing it.	Gupta & Agrawal (2018)
DW 2	I take due care to throw garbage in the assigned bins only.	
DW 3	I dispose of all hazardous waste in the manner prescribed.	
DW 4	I take due care when disposing of chemical, medical, and other harmful waste	
DW 5	I put all recyclable waste in recycle bins or sell it to the scrap dealer.	

In addition to the variables belonging to the group of consumer environmental awareness, the questionnaire included three variables in the group of green communication effectiveness (Table 2). The first variable, entitled Receptivity to green communication, consisted of four items from REGRAD scale (Bailey et al., 2016). This concept refers to consumers' level of attention and positive receptiveness towards advertisements that include environmentally friendly messages, whether aimed at promoting products or the company as a whole. The variable Skepticism consisted of three items adopted from Do Paço and Reis (2012). These items expressed the reactions that consumers might have in relation to perceived exaggerations, misleading/confusing information and perceived truthfulness of environmental claims (Mohr et al., 1998). Finally, the variable Ecolabel credibility, adopted from Taufique et al. (2019), was included in this questionnaire segment. Respondents rated the extent to which they agree with the items related to all variables on a scale from 1 to 4, where 1 meant "I do not agree at all" and 4 "I completely agree". The collected data were processed by applying descriptive statistics, correlation and regression analysis in the statistical software SPSS 25.

**Table 2:** Variables and items related to the green communication effectiveness (GCE)

Table 2. Variables and items related to the green communication effectiveness (GCE)		Authors
Receptivity to green communication		
REG 1	I tend to pay attention to advertising messages that talk about the environment.	Bailey at al. (2016)
REG 2	I am the kind of consumer who responds favorably when brands use green messages in their ads.	
REG 3	I think that green advertising is valuable.	
REG 4	I am the kind of consumer who is willing to purchase products marketed as being green.	
Skepticism		
SCE 1	Because environmental claims are exaggerated, consumers would be better off if such claims on package labels or in advertising were eliminated.	Do Paço & Reis (2012)
SCE 2	Most environmental claims on package labels or in advertising are intended to mislead rather than inform consumers.	
SCE 3	I do not believe most environmental claims on package labels or presented in advertising	
Eco-label credibility		

ELC 1	The eco-labels displayed in the product are a good way of informing consumers about environmental safety.	Taufique et al. (2019)
ELC 2	The presence of certified eco-labels increases the credibility of a product.	
ELC 3	An eco-label is a reliable source of information about the environmental quality and performance of the product.	
ELC 4	I pay full attention to the message I read on the label.	

#### 4. RESULTS

As the first step of the analysis, the descriptive statistical analysis of respondents' demographics and all variables belonging to CEA and GCE was conducted. Out of the total sample of 270 respondents, 57% were female respondents and 43% male respondents. The largest percentage of respondents was under 30 years old (49.6%), slightly less of them between 30 and 50 years old (45.2%), while the smallest number of respondents were over 50 (5.2%). When it comes to the level of education of the respondents, the largest number had university education (80.7%), while there was an equal number of those with secondary and postgraduate education (9.6% each). The largest number of respondents (87.4%) were employed, whereas the number of unemployed respondents was significantly lower (12.6%).

By looking at the mean values of the analyzed variables (Table 3), it can be concluded that the variables were, in general, favorably assessed by the respondents, given that all values exceeded the value 2. When it comes to five variables belonging to the group CEA, CC was the best rated variable, with a score of 3.17, while PCE was the lowest rated variable, with mean value 2.26. This indicated that consumers were aware of the adequate use of products in order to preserve the environment, but still considered that their roles as individuals in environmental protection were not of great importance. By evaluating the three variables related to the GCE, the respondents indicated the great importance of Eco-label credibility, which was rated the best (3.08), whereas SCE was the lowest rated variable. With this, the respondents indicated that they indeed believed in the ecological claims of brands they trust. In order to analyze the reliability of the analyzed variables a Cronbach's Alpha coefficient was determined for each variable separately. Since the values of this coefficient ranged from 0.510 to 0.871, it can be indicated that the survey instrument demonstrated satisfactory measurement characteristics.

**Table 3:** Descriptive statistics of variables

	Variable	Mean	St.dev.	Cronbach's alpha
<b>Consumer environmental awareness (CEA)</b>	EVB	2.83	0.582	0.648
	PCE	2.26	0.649	0.785
	PPG	2.36	0.822	0.510
	CC	3.17	0.754	0.709
	DW	2.36	0.762	0.763
<b>Green communication effectiveness (GCE)</b>	REG	2.87	0.807	0.863
	SCE	2.35	0.809	0.783
	ELC	3.08	0.668	0.871

In the next step, a correlation analysis was applied in order to determine the mutual relations between the variables from the group CEA and GCE. The correlation analysis results revealed a positive and statistically significant correlation between the variables from both the CEA and GCE groups (Table 4).

**Table 4:** Correlation between the variables belonging to Consumer environmental awareness (CEA) and Green communication effectiveness (GCE)

	EVB	PCE	PPG	CC	DW
<b>REG</b>	0.622**	0.216**	0.180**	0.463**	0.539**
<b>SCE</b>	0.328**	0.500**	0.414**	0.206**	0.400**
<b>ELC</b>	0.503**	0.287**	0.215**	0.515**	0.460**

\*\*The correlation is significant at the 0.01 level

The highest degree of correlation was shown between variables EVB and DW and variable REG. Therefore, consumers who had already developed habits towards environmental protection and were not using products that may harmfully influence the environment, appeared to be more responsive to green communication. Similarly, when they recognized the importance of proper disposing of waste, they expressed greater responsiveness to green advertising and other forms of environmental communication. In addition to the above, a significant correlation was established between the variables CC and EVB and the variable ELC. Therefore, eco-label credibility was better expressed among those consumers who demonstrated greater environmental values and beliefs, and who were more conscious with their consumption and product disposal. The lowest degree of correlation appeared between the variables PPG and PCE and variable REG. This

indicated that there was a predominant attitude among the respondents that individuals cannot have much influence on the preservation of the environment, and therefore, such consumers did not have highly positive reactions to environmental messages in communication. This statement is supported by the established low correlation between the variable PCE and the variable ELC.

Through regression analysis, which was the final step of the analysis, the influence of the independent variables belonging to CEA on the variables belonging to GCE group was determined (Table 5). The achieved  $R^2$  values showed statistical significance. It was shown that CEA variables significantly influenced REG ( $R^2=0.471$ , F change - 46.966,  $p<0.000$ ), as well as SCE ( $R^2=0.335$ , F change - 26.546,  $p<0.000$ ) and ELC ( $R^2=0.366$ , F change - 30.469,  $p<0.000$ ). The greatest impact was established in the case of REG, as can be concluded that 47.1% of REG was explained by the environmental awareness among consumers.

**Table 5:** Regression model of the influence of CEA variables on GCE variables

Dependents	Independents	$\beta$	t	Sig.	$R^2$	F	Sig.
REG	EVB	0.463	7.918	0.000	0.471	46.966	0.000
	PCE	-0.108	-1.928	0.055			
	PPG	-0.021	-0.387	0.699			
	CC	0.128	2.336	0.020			
	DW	0.279	5.044	0.000			
SCE	EVB	0.036	0.544	0.587	0.335	26.546	0.000
	PCE	0.326	5.171	0.000			
	PPG	0.177	2.952	0.003			
	CC	-0.076	-1.246	0.214			
	DW	0.257	4.139	0.000			
ELC	EVB	0.244	3.813	0.000	0.366	30.469	0.000
	PCE	0.024	0.392	0.695			
	PPG	0.007	0.124	0.902			
	CC	0.292	4.869	0.000			
	DW	0.183	3.021	0.003			

The analysis of the obtained regression results determined that the greatest statistical significance was achieved in the case of DW, where its individual influence on all analyzed variables of GCE was confirmed. The variables EVB and DW had the greatest individual impact on the variable REG. In other words, the results showed that consumers' values and beliefs and proper waste disposal had a positive and significant impact on consumers' responsiveness to green communications, as a component of GCE. Statistical significance and positive impact of PCE, PPG and DW on variable SCE was also found. Finally, significant and positive impact of EVB, CC and DW on ELC, was found, meaning that consumers' values and beliefs, habits of conscious consumption and proper waste disposal positively influence consumers' perception of eco-label credibility.

#### 4. CONCLUSION

Green communication involves distributing messages that promote awareness of environmental issues, ecological products and/or suggest certain patterns of behavior that are useful for minimizing negative impact on the environment. Green communication effectiveness has been empirically demonstrated and elucidated in the enlarging body of literature on this subject. The presented research results contribute to the existing literature with this regard. On the basis of the results of correlation and regression analysis, the existence of statistically significant relations between variables related to consumers' environmental awareness (Environmental values and beliefs, Perceived consumer effectiveness, Perception of personal gain, Conscious consumption and Disposing of waste) and variables related to the effectiveness of green communication (Receptivity to green communication, Skepticism and Eco-label credibility) was detected. Therefore, it can be concluded that the more environmentally aware the consumers are, the more likely they would positively react to green messages and they would have greater influence on them.

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# BRANDING STRATEGY IN THE SOCIAL NETWORKS ERA

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**Abstract:** *The paper explores how social networks have changed the game of branding strategies during the digital age. It explores the need for brand change in communication and engaging mode with pervasiveness brought by social media. That simply means a shift from traditional, one-way communication to even interactive and relational strategies where consumer engagement becomes the central aspect. The paper tries to see how the changes occurring are helping the brands to remain relevant and help consumers create real bonding even in a fiercely competitive digital world. The paper is also considering challenges in digital branding, which include the overload of content and how to keep the consumer trust high versus the issues of data privacy. The literature is used to note a comprehensive view on the subject matter in the last fifteen years.*

**Keywords:** *branding strategies, social media, consumer engagement, digital communication, interactive marketing*

## 1. INTRODUCTION

The condition of branding today will demonstrate how potential is revolutionized by the digital age. In fact, over the past ten years, social media applications have become more widely used and accessible, opening up a whole new realm for how consumers interact with their brands: a generation that is highly engaged and connected. In view of the benefits and challenges this changing environment offered for brands, conventional branding techniques would need to be reevaluated.

Ever since digital marketing first appeared in the internet age, brands have come to understand how crucial it is to project a professional image. This included the use of branding strategies at this time according to Kingsnorth, (2022, p. 45). As more people turn to the Internet for entertainment and information gathering, brands are compelled to modify their communication methods in an effort to reach their target market. In the meantime, Schwartz (2021, p. 112) states that social media advertising, content marketing, and search engine optimization (SEO) have become essential components of brand communication.

One of the most significant shifts in brand positioning tactics has likely been the move from one-way communication to interactive involvement. Unlike traditional media, which allows for general communication, social media platforms allow for real-time communication between the brand and its customers. This strengthens and improves the relationship between the brand and its customers according to Verhoef et al. (2010, p. 207). As involvement becomes the norm, Bijmolt et al., (2010, p. 532) say that brands approach communication in a much more humane way, forming genuine connections with customers as opposed to merely disseminating information.

Finally, user-generated content and social media influencers bring the human side into modern social media. The consumers are no longer passive receivers of content that has been produced in the name of business; instead, they become active coproducers and cosharers of the content about the brands that they choose as discussed by van Doorn et al. (2010, p. 76). Additionally, brands took advantage of the effect and influence of social media to reach new audiences with their message. According to Kim et al. (2016, p. 245) influencers collaborate with individuals who have substantial and engaged fan bases.

Nevertheless, these opportunities come with a corresponding set of challenges. In the light of opportunities and threats such a changing environment presented to brands, traditional practices of branding would be thoroughly questioned. Such examples, according to Puzakova and Aggarwal (2018, p. 213), include content overload, loss of privacy, and the forever-changing algorithms of the social media platform. As discussed by Lang and Kenny (2024, p. 56) it is only then that the brand would remain highly relevant in the market,

considering the very high speed with which technological advancement is being experienced, and the brand has to be highly adaptive and flexible to the rate at which new advancements and trends in the industry would be embraced.

This paper will focus on how branding approaches have evolved in the social network era in response to its development. This essay will take a careful look at how companies use social media to communicate and engage with their clientele, as well as what happens when fresh problems and fashions emerge. Ultimately, by being more knowledgeable about contemporary branding strategies, a firm would position itself to compete in the rapidly expanding digital space.

## **2. EVOLUTION OF BRANDING STRATEGIES**

In view of the benefits and challenges this changing environment offered for brands, conventional branding techniques would need to be reevaluated. This shifting environment provided brands both benefits and problems, thus conventional branding approaches must be reevaluated.

Branding has shifted from its conventional approaches to the dynamic strategies pushed by social networks, as this article will demonstrate. As digital marketing began, Kingsnorth (2022, p. 45) infers that it became evident that the internet's rapid expansion made it difficult for companies to get recognized. Eventually, with the growth of the internet, brands soon realized that they needed to be online. Thereafter, as said by Schwartz (2021, p. 112), digital media became a prevailing mode of communication for brands to reach out and affect their target groups.

Branding methods changed with social media. Verhoef et al. (2010, p. 207) explain that social media platforms enable dynamic interaction, changing brand-customer relationships. Companies had to switch from one-way broadcasting to interactive communication. Brand live communication conversations entered a new age with such consumer interaction.

Contemporary branding tactics emphasize commitment and building lasting relationships with consumers through several touchpoints. Social media lets brands talk to customers about community building and relationships. By emphasizing interaction, transactional communications seem to have been replaced by relationship-building beyond corporate transactions.

In the social media, the introduction of social media influencers and user-generated content marked the revolution in marketing communication. Consumers co-create, develop, and share relevant content of the brand according to van Doorn et al. (2010, p. 76). This makes UGC (user-generated content) an asset for brands as it allows them to reach more people and build a real relationship with their customers, blurring the lines between the brand and the consumer.

Through user-generated content, social media influencers have become a brand exposure force. Powerful people affect others and their followers. Company strategic partnerships use these powers to boost visibility and message credibility as presented by Kim et al. (2016, p. 245). Marketing with influencers gives companies access to targeted audiences and personal connections with customers. Branding hasn't improved completely. Content-heavy ecosystems with privacy issues and algorithmic uncertainty require companies to negotiate say Puzakova & Aggarwal (2018, p. 213).

Lang & Kenny (2024, p. 56) say that companies must adapt to technology to generate new ideas and trends that can be accepted later. Branding strategy requires flexibility, creativity, and fortitude. The fast-paced digital marketing dispensation and social media age require brands to update their communication and engagement language to keep up with consumers' fashion and technology preferences. In the digital age, brand-building requires true connections and audience demands.

## **3. LEVERAGING SOCIAL NETWORKS FOR BRAND COMMUNICATION**

Social media has transformed brand communication. More than ever, brands can connect with their audience in meaningful and dynamic ways. Brands utilize social media to develop relationships, engage people, and propagate their message.

Social media allows brands and customers to interact in real time. Interactive social networks allow brands to develop communities, launch conversations, and instantly respond to customer inquiries and comments as

shown by Verhoef et al. (2010, p. 207). Communication helps brands appear more personable and connect with their audience. This creates loyalty and trust.

Social media gives marketers many content types and plot tools to communicate clearly. According to Bijmolt et al. (2010, p. 532), marketers exploit social media's multimedia features to engage their audience. This contains stunning photographs, engrossing films, and captivating stories. Making content that people want to share helps brands reach more people across digital channels.

Along with free content, corporations utilize social media paid advertising to attract specialized audiences. Facebook, Instagram, and Twitter allow corporations to target specific groups based on their hobbies, behaviors, and demographics with strong advertising tools as stated by Kingsnorth (2022, p. 45). Targeted advertising efforts can boost brand awareness and digital traffic. This helps them achieve their goals and maximize ROI.

Brands may now use social media influencers to boost their online presence. People with many fans are influencers. Their trustworthiness and authenticity help brands convey brand messages and engage with consumers as shown by Kim et al. (2016, p. 245). Influencer relationships help brands reach niche audiences and build personal interactions with customers. This boosts brand loyalty and interest.

Social media lets brands leverage user-generated content to promote their business. According to van Doorn et al. (2010, p. 76) brand stories are enhanced with consumer content regarding their brand experiences, preferences, and connections. User-generated content helps brands reach more people, form relationships, and create a community. This blurs brand-consumer boundaries.

Brands face issues like too much content, unexpected algorithms, and shifting consumer preferences note Puzakova & Aggarwal (2018, p. 213). Social media platforms are continually changing, therefore Lang & Kenny, (2024, p. 56) say that brands must be flexible and ready to adapt to new trends and technology.

Brand promotion on social media is essential for digitally successful companies. By harnessing social media's interactive features, providing engaging content, and partnering with influencers, brands can engage with consumers and promote their message across digital channels. Brands must continue to deliver value, encourage connections, and maintain long-term relationships with their audience as they improve and develop new social media strategies.

#### **4. ENHANCING CONSUMER ENGAGEMENT**

Consumer engagement is the foundation of modern branding strategies and represents the dynamic relationship that exists between brands and their target audience. This section examines the various approaches that companies employ to enhance consumer interaction in the digital sphere, drawing on insights from scholarly research and trade journals.

Social media customer engagement represents a lot more than mere passive consuming. Essentially, this is a description of how brands have social media to be an interactive way with their audience and to achieve the market segment with intimate offers of meaningful interaction through real conversation and interactive engagement according to Calder et al. (2009, p. 325). By actively engaging with consumers in real time, businesses create a sense of belonging, trust, and loyalty; these connections become enduring and go beyond simple business transactions.

The importance of interactive content formats is that they create new ways of engaging their target audience and bring them close to experiencing their brand. To improve the customer experience and foster deeper relationships, brands use a range of content forms, such as interactive polls, immersive movies, live streaming events, and surveys explains Baer (2024, p. 87). By offering entertaining and educational content, marketers encourage audience interaction and feedback, which boosts engagement and strengthens their brand's message.

By speaking directly to human tendencies of achievement, social interaction, and competitiveness, provoking higher customer engagement. Rosário, A., & Raimundo, R. (2023, p. 16) say that digital gamified interactions bring users to the platform by setting them in challenging and rewarding competition contests, which makes the digital environment look active and fun. With gamification, the most passive consumers can be turned into active players by a process of incrementally increasing engagement. Goyal, A., & Verma, P. (2024, p. 2) in their study indicate that in the integrative setting, brand loyalty mediates the relationship between brand

engagement and OBE (overall brand equity), and OBE mediates the relationship between brand loyalty and purchase intention.

Social media influencers bring validity with a power that brings forward the best in brand communication and involvement of consumers. Brands influence whose audience is similar to theirs to provoke conversations, excite, and build genuine relationships says Shao (2023, p. 112). Relationship influence thus provides brands not only the reach to a certain set of unique audiences but also in-person interactivity that basically supercharges consumer engagement and drives brand advocacy.

What is more important to understand is that user-generated content enhances customer engagement with the power to work as a very strong stimulus. The thing is that customers are allowed to build up the brand's story according to their experience, storyline, and, more importantly, a point of view according to Gambetti et al. (2016, p. 211). Opportunity to harness user-generated content for more mileage, real connections, and a community feel. This will see the brand acknowledging and featuring the user-generated content that empowers the customers and encourages them to become brand ambassadors, thus user engagement and loyalty.

However, for all of the opportunities and provocations customer interactions bear, marketers must tread slightly more challenging landscape, speckled with a host of obstacles, including oversaturation of material, skepticism about authenticity, and even doubt with algorithms referred to Lang & Kenny (2024, p.56). Besides, with changing consumer preferences, the brand has to be flexible and changeable to an extent where it can be changeable enough to modify its game plans in consonance with the rapidly changing needs and expectations of its customer base.

Improving consumer engagement represents a fundamental strategic necessity for brands aiming to prosper in the era of digitalization. Through the utilization of interactive content formats, gamification, social media influencers, and user-generated content, organizations have the ability to cultivate significant associations, stimulate participation, and magnify their brand communication throughout digital platforms. In the ever-evolving landscape of consumer engagement, it is imperative for brands to maintain an unwavering dedication to providing value, cultivating connections, and establishing long-lasting relationships with their target demographic.

## **5. EMERGING TRENDS AND CHALLENGES**

The changing dynamics of branding strategies greatly mold the trajectory of dynamism developing in interactions between brands and consumers within the dynamic field of digital branding. Thus, in this segment, an analysis into such changing dynamics of branding strategies will be provided through reviewing emergent trends, challenges to fixing, or problems. It does that through referring to scholarly research and industry practice. These papers or books have authors who consider advancement in trends. Some of the advancement in trends, as mentioned, will be explained below.

Augmented reality (AR) and VR are moving toward revolutionizing the way they allow consumers to interact into more immersive and interactive user experiences as stated by Baer (2024, p. 87). Increasingly, brands are utilizing augmented reality (AR) and virtual reality (VR) to develop immersive experiences that surpass conventional limitations, enabling customers to engage with products and services in novel and inventive ways.

The implementation of personalization and customization has become a fundamental aspect of contemporary branding strategies, as companies endeavor to provide customized experiences that deeply connect with each customer say Lang & Kenny (2024, p. 56). Thanks to that, through the use of artificial intelligence algorithm and data-based insights, brands can customize content, recommendations, and offers to the taste and particular needs of every individual consumer.

Rosário and Raimundo (2023, p. 7) say that ephemeral content emerges as a form of communication for consumer engagement through social media. Its transient nature makes ephemeral content popular among consumers. Through social media platforms like Snapchat and Instagram Stories, brands have the ability to create ephemeral but captivating content that motivates instant consumer engagement and creates a sense of urgency.

In their marketing strategies, brands prioritize diversity and inclusivity to reflect the cultural nuances and different demographics of their target audience says Gil (2019, p. 126). Inclusive marketing practices aim at creating a sense of belongingness among all types of consumers through the embracing of diversity and the challenging of stereotypes.



To allow organizations to predict search engine behavior and analyze vast volumes of data, artificial intelligence is taken up by brands say Enge et al. (2023, p. 122). The main reason behind this is that AI technologies enable organizations to understand the nuances of digital space and allows them to increase visibility and rankings of their presence on online search engines.

Visual search is a new trend in search engine optimization as users can perform information searches through the use of images rather than text-based queries as shown by Enge et al. (2023, p. 234). This means that organizations are optimizing their digital assets like videos and images so that they become discoverable and relevant to visual search results.

Barnard (2022, p. 56) says that due to effective management of Brand SERPs (Search Engine Results Pages), companies can enhance the visibility, credibility, and trustworthiness of their brands in the minds of online users who seek relevant information. This is even though there are a lot of improvements in trends and one could think that the new trends are somehow an indomitable trend, but still, there remain lots of challenges if one takes into consideration that it is still a relatively unknown area regarding legislative, privacy, etc.

Information overload and content saturation is one of the challenges. The abundance of content available on digital platforms has resulted in content saturation, which brands are finding progressively more difficult to distinguish from in order to engage consumers suggest Puzakova & Aggarwal (2018, p. 213). Brands must develop high-authority content that cuts through the competitive clutter yet at the same time has very high relevance for the target audience.

Authenticity and trust are some of the most difficult challenges a brand can face in today's digital context, where the consumer finds himself constantly massed by sponsored content and partnerships of all kinds states Gil (2019, p. 126). Transparency, honesty, and integrity should come first among the brand's ways of communicating to the consumer in an attempt to gain and build his trust.

Increasing knowledge about privacy and data security was revealing the need to follow ethical data practices and regulatory requirements, like the General Data Protection Regulation (GDPR) as shown by Lang and Kenny (2024, p. 56). Brands have an obligation to respect consumer privacy and protect consumer data. The failure to do so may undo risks and discredit from the target demographic on a brand. Challenges lie in the collection, storage, and use of consumer data for brands, considering the rigorous enforcement of data privacy regulations like the General Data Protection Regulation (GDPR) according to Ramaswamy & Ozcan (2016, p. 92). Brands should be in front of their transparent and ethically acting data within regulations, aiming only at further establishments and maintaining consumer trust.

First, under the broad scope of technical challenges, it puts algorithmic uncertainties and platform changes. Grand View Research Inc. (2023, p. 16) say that this makes things difficult for brands, as it may have a lot of dynamism inside the algorithms of social media platforms; a single or minor change in the same could. The brand should be in a state that is agile and adaptive enough to change strategies if required by the changing algorithms and platform updates.

Brands, however, have to manage the changing consumer preferences, which follow fast-changing market conditions and technological progressions effectively, if they have to remain in competitive edges note Ramaswamy & Ozcan (2016, p. 78). In the digital age, brands must constantly adapt to the changing needs and expectations of the consumer to keep themselves relevant and engaging.

One of the challenges that brands face in supporting uninterrupted omnichannel experiences is the balancing act between offline and online touchpoints according to Hsieh & Kumar (2023, p. 68). Brands will also have to find a subtlety threshold in touchpoints that would be specific to varying tastes and behaviors of consumers.

Brands will have to engage in a strategic, proactive approach in dealing with these emergent trends and challenges in digital branding. Other key success factors of the brand name to compete in this ever-chaotic, highly dynamic digital environment include: "Innovations, Authenticity, Consumer-centricity."

## 6. CONCLUSION

The transformation of brand-consumer interactions in the era of social networks is the result of a dynamic interplay between emergent trends and confronting challenges, which has influenced the evolution of branding strategies. In order to flourish in a constantly changing ecosystem, brands must maintain agility, innovation, and a consumer-centric focus while navigating the complexities of the digital landscape.

The advent of emerging trends including social commerce, augmented reality (AR) experiences, and personalized content offers brands fresh prospects for innovation and more profound consumer engagement. By adopting these patterns and incorporating nascent technologies like voice search and artificial intelligence (AI), organizations can provide streamlined and customized encounters that deeply connect with customers and stimulate sales.

Nevertheless, despite the potential advantages presented by emerging trends, brands are confronted with an extensive array of obstacles such as excessive content, concerns regarding authenticity, and intricate regulatory frameworks. To surmount these obstacles, brands must maintain a steadfast commitment to transparency, ethical conduct, and consumer confidence, all the while being quick to adjust to regulatory mandates and platform modifications.

In summary, the transformation of branding tactics during the age of social networks emphasizes the criticality for companies to adopt innovative approaches, cultivate genuineness, and place customer involvement at the forefront of their online branding endeavors. The next research agenda should try to investigate the impact of emerging technologies like AR and VR on branding, the effect of AI on personalization, and the effectiveness of influencer marketing. Of particular need for research is how to manage the ever-growing user-generated content, how brands can fit changes in social media algorithms, and what brands can do to remain true and trusted by consumers in a content-overload world.

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# RESEARCH ON CONSUMER ATTITUDES TOWARDS THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN DIGITAL MARKETING

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**Abstract:** Contemporary research and practice indicate a continuous rise in the application of artificial intelligence in the domain of digital marketing within today's dynamic environment. The utilization of artificial intelligence has significantly advanced the field of digital marketing, particularly in the processes of market segmentation and the creation of personalized content, enabling companies to stand out among a plethora of advertisements. Crafting personalized content with recommendations tailored to consumer preferences enhances user experience and can influence purchasing decisions. This study investigates the current state of awareness among the observed population regarding the concept of artificial intelligence in the domestic market, as well as the recognition of its application by companies in terms of personalized advertising. The conducted research involved 202 respondents, residents of major cities within the territory of the Republic of Serbia, who utilize technology daily and self-identify as technologically literate.

**Keywords:** artificial intelligence, digital marketing, personalized advertising

## 1. INTRODUCTION

In today's digital era, consumers are being overly exposed to a multitude of marketing messages (Schiessl et al., 2022). Consequently, companies face the challenge of standing out among the plethora of messages consumers encounter online daily (Liu & Chen, 2021). A study conducted in 2022 revealed that marketing professionals utilize artificial intelligence in digital marketing in over 80% of cases for the purpose of automating consumer interactions, content personalization, automating repetitive tasks, and creating consumer identities (Statista, 2024). Upon reviewing research by authors such as Okorie et al. (2024), Babatunde et al. (2024), Fazla et al. (2021) and Ayinla et al. (2024), it can be observed that there is a lack of studies on consumer behavior in the online environment regarding activities that contribute to artificial intelligence algorithms accessing their preferences and actions. Additionally, a review of previously conducted research indicates a gap in understanding the impact of artificial intelligence on consumer decision-making. The research by the mentioned authors focuses on the benefits that the implementation of artificial intelligence in digital marketing provides to companies in directing personalized messages to end consumers. There is a noticeable lack of research from the perspective of consumers, regarding how much digital marketing supported by artificial intelligence tools positively contributes to them and whether they recognize the activities they undertake to help the artificial intelligence algorithm track and define them more accurately. This research paper aims to analyze the role of artificial intelligence in the domain of digital marketing, with the objective of determining consumer awareness and recognition of the application of artificial intelligence in digital marketing.

## 2. THE ROLE OF ARTIFICIAL INTELLIGENCE IN DIGITAL MARKETING

Due to the remarkable and rapid advancement of artificial intelligence, digital marketing is undergoing various phases of transformation (Schiessl et al., 2022). Significant changes can be observed in the increase of potential opportunities to interact with consumers and tailor advertising to each consumer (Preeti & Park, 2023). Artificial intelligence in digital marketing can be applied for analysing consumer data, personalized marketing messages, and decision-making process automation (Pazzanese, 2020).

According to Bhuvaneswari et al. (2024), key uses of artificial intelligence in digital marketing include: analysis of large datasets and determination of consumer behavior, preferences, and market trends; content

personalization utilizing data to deliver customized content, recommendations, and offers to individual consumers; predictive analytics for forecasting future trends; chatbots and virtual assistants providing real-time customer support; creation of relevant and engaging content for the target audience; advertising optimization through analysis of performance metrics, targeting parameters, and audience behavior; SEO and content optimization for search engines; marketing automation to streamline repetitive tasks.

Artificial intelligence tools in digital marketing enable the identification of content types that will capture users' attention and ensure their return to the company's digital channels (Gkikas & Theodoridis, 2019). Additionally, the application of artificial intelligence can identify users prone to churn, analyze the characteristics of this user group, and factors leading to churn (Chintalapati & Pandey, 2022). Based on these analyses, companies can plan future activities within marketing campaigns and create strategies to encourage users to remain engaged.

### **3. THE CONTRIBUTION OF ARTIFICIAL INTELLIGENCE IN PERSONALIZED ONLINE CONSUMER EXPERIENCE**

The utilization of artificial intelligence in digital marketing has simplified the process of consumer segmentation and understanding consumer journeys (Saura et al., 2021), enabling the creation of personalized content tailored to different consumer profiles across various communication channels (Stalidis et al., 2015). Personalized content emerges as an opportunity for companies to stand out among a large number of advertisements (Babatunde et al., 2024). Unlike traditional marketing approaches, which rely on limited datasets, artificial intelligence algorithms can explore a broad spectrum of data sources, including customer relationship management (CRM) data, purchase history, demographics, and previous interactions, all of which provide invaluable insights into consumer preferences (Hassan et al., 2024). By utilizing this data in digital marketing, personalized messages and campaigns can be created (Floridi et al., 2018).

The combination of AI-driven analytics and personalized advertising leads to significant changes in how companies communicate with their consumers in the online environment (Bashynska, 2023). Using artificial intelligence to analyze large consumer datasets and tailor marketing messages to individual preferences enables companies to achieve more loyal and deeper consumer engagement, which can later translate into positive sales outcomes (Alamsyah & Syahrir, 2024) and a positive brand image growth (Ayinla et al., 2024).

The utilization of artificial intelligence in personalized advertising on social media platforms provides companies with the capability to comprehensively evaluate consumer activity data before guiding them towards offers that match their needs and desires (Dumitriu & Popescu, 2020). Specifically, AI tools enable the prediction of price ranges that will most influence conversions, optimal times for content publication, and headlines that will attract the most user attention (Haleem et al., 2022). In this way, the contribution of artificial intelligence to marketing is reflected in its ability to identify and predict trends (Forrest & Hoanca, 2015), leading to efficient advertising investments.

#### **3.1. Effects of Personalized Advertising on Consumer Behavior**

The complexity of artificial intelligence algorithms presents a challenge for consumers to understand how their data shapes personalized experiences (Bashynska, 2023). This lack of understanding can lead to feelings of doubt and manipulation among consumers (Okorie et al., 2024). According to Preeti & Park (2023), the application of artificial intelligence in creating personalized content with recommendations can influence consumer decision-making. If artificial intelligence algorithms recognize that a consumer has filled their online shopping cart but has not completed the purchase, an action a company can take is to send a coupon or similar incentive to encourage consumers to complete the purchase (Chen et al., 2024).

However, a review of research by authors such as Babatunde et al. (2024), Fazla et al. (2021), Ayinla et al. (2024), and Triberti et al. (2020) highlights the lack of studies on consumer attitudes and how the application of artificial intelligence in digital marketing contributes to their user experience, and whether they consciously choose to be targeted with personalized messages generated with the help of artificial intelligence. This also signifies the initiation of the research conducted in the continuation of this study.

### **4. CONSUMER ATTITUDES RESEARCH**

#### **4.1. Methodological Framework**

Although there is a growing body of scientific works and studies addressing the integration of artificial intelligence into everyday business, a review of the literature and analysis of previously conducted research has revealed a limited availability of works exploring this area in the context of determining consumers'

awareness and recognition of the implementation of artificial intelligence into digital marketing. With the aim of providing insight into the state of the domestic market, a study was conducted through an online survey. The target group of the research consisted of residents of large cities in the territory of the Republic of Serbia (with over 100,000 inhabitants), aged 18 and older, who self-identify as technologically literate, meaning they use computers and information and communication technologies in their daily work. The study involved 202 participants, with 49.8% being female and 50.2% male. Most of the participants were between 25 and 34 years old (45.7%), followed by 23.3% under 24 years old, and 31% aged 35 and older. Regarding educational attainment, 47% of participants completed high school, 32.9% completed college or university, and 20.1% are still in the process of education. In terms of employment status, a significant portion, 71.2%, of participants were employed, 8.6% were unemployed, and 20.1% belonged to the student group. The demographic structure of the surveyed population based on observed demographic characteristics (gender, age, educational attainment, and employment status) was aligned with the results of the study "Usage of Information and Communication Technologies in the Republic of Serbia in 2023," conducted by the Statistical Office of the Republic of Serbia (2023).

## 4.2. Results and Discussion

In response to the question regarding the extent of respondents' familiarity with the concept of artificial intelligence (Table 1), nearly half (49.5%) of the observed population provided an affirmative answer. Significant differences are observed across the observed demographic characteristics. Specifically, precisely two-thirds (66%) of those under the age of 24 reported being familiar with the concepts of artificial intelligence, in contrast to only 16% of those aged 35 and older providing affirmative responses. Significant differences are also noted based on educational attainment, with fewer individuals having completed only high school (39%) being familiar with the concepts of artificial intelligence compared to those with a college or university education (52%).

**Table 1.** How familiar are they with the concept of artificial intelligence

	Total	Gender		Age			Level of education		
		Male	Female	Under 24	25 - 34	35+	High school	College	Ongoing education
N	202	101	100	47	92	63	95	66	41
sig	-	0.66		0.00			0.04		
Not at all	6.7	9	5	-	4	15	12	4	-
Mostly no	13.6	15	13	15	9	20	17	10	11
<b>NO (sum)</b>	<b>20.3</b>	<b>23</b>	<b>17</b>	<b>15</b>	<b>13</b>	<b>35</b>	<b>29</b>	<b>14</b>	<b>11</b>
Both	30.2	29	31	19	23	49	32	34	20
<b>YES (sum)</b>	<b>49.5</b>	<b>47</b>	<b>52</b>	<b>66</b>	<b>64</b>	<b>16</b>	<b>39</b>	<b>52</b>	<b>69</b>
Mostly yes	27.8	24	31	30	37	13	21	32	37
Yes, to a large extent	21.8	23	21	35	27	3	18	21	32
Total	100%								

In total, 29.2% of the observed population utilize artificial intelligence tools, with 15.6% using them frequently, and 13.6% using them daily (Table 2). Similar to the previous question, significant statistical differences are observed across the observed demographic characteristics. There is a significantly higher proportion of users among those under the age of 24 (42%) compared to those aged 35 and older (6%). Additionally, there is a significantly higher proportion of users among those with a college or university education (32%) compared to those with only a high school education (22%). Among artificial intelligence tools, chatbots such as ChatGPT, Copilot, and Bard are the most commonly used.

**Table 2.** How often do they use artificial intelligence tools

	Total	Gender		Age			Level of education		
		Male	Female	Under 24	25 - 34	35+	High school	College	Ongoing education
N	202	101	100	47	92	63	95	66	41
sig	-	0.06		0.00			0.02		
They don't use at all	23.5	29	18	9	12	52	31	19	14
They mostly don't use	25.1	28	22	19	27	27	33	19	16

<b>NO (sum)</b>	<b>48.6</b>	<b>57</b>	<b>40</b>	<b>28</b>	<b>38</b>	<b>79</b>	<b>64</b>	<b>38</b>	<b>30</b>
Rarely / Can't assess	22.2	16	28	30	23	15	14	30	29
<b>YES (sum)</b>	<b>29.2</b>	<b>27</b>	<b>32</b>	<b>42</b>	<b>39</b>	<b>6</b>	<b>22</b>	<b>32</b>	<b>41</b>
They often use	15.6	13	19	26	19	4	12	16	25
They use it daily	13.6	14	13	16	20	2	11	16	16
Total	100%								

In response to the question of whether they recognize being exposed to an advertisement for a product/service immediately after discussing or researching it online (Table 3), a notable 85.4% of respondents recognize it, 7.4% are unsure or haven't thought about it, and only 7.2% provide a negative response.

**Table 3.** Do they recognize being exposed to an advertisement for a product/service immediately after discussing/researching it on the internet

	Total	Gender		Age			Level of education		
		Male	Female	Under 24	25 - 34	35+	High school	College	Ongoing education
N sig	202 -	101 0.07	100	47	92 0.03	63	95	66 0.05	41
Yes	<b>85.4</b>	83	87	86	90	79	80	90	91
No	<b>7.2</b>	11	3	13	4	8	10	3	7
They are not sure	<b>7.4</b>	6	9	1	6	13	11	7	2
Total	100%								

In response to the question of whether they find it advantageous when they receive advertisements for products they have discussed or researched online (Table 4), we observe divided opinions, with approximately half providing a positive response (47.7%) and approximately half (52.3%) providing a negative response. Among those providing a negative response, there is a significantly higher proportion of individuals aged 35 and older (67%) and with only a high school education (57%).

**Table 4.** Do they find it advantageous that they receive advertisements for products they have discussed/researched on the internet

	Total	Gender		Age			Level of education		
		Male	Female	Under 24	25 - 34	35+	High school	College	Ongoing education
N sig	202 -	101 0.07	100	47	92 0.03	63	95	66 0.05	41
Not at all	14.0	20	8	11	9	24	21	10	4
Mostly not	38.3	34	43	35	37	43	36	41	39
<b>NO (sum)</b>	<b>52.3</b>	<b>54</b>	<b>51</b>	<b>46</b>	<b>46</b>	<b>67</b>	<b>57</b>	<b>51</b>	<b>43</b>
<b>YES (sum)</b>	<b>47.7</b>	<b>46</b>	<b>49</b>	<b>55</b>	<b>55</b>	<b>32</b>	<b>43</b>	<b>49</b>	<b>58</b>
Mostly yes	44.7	44	45	50	51	32	43	43	52
Yes, to a large extent	3.0	2	4	5	4	-	-	6	6
Total	100%								

With the following set of questions, attitudes regarding the sharing or usage of personal data for marketing purposes were examined. In response to the question of whether they believe they have control over how their data is used, a notable 81.9% provided a negative response. However, even so, a significant 61.8% stated that they often or always accept cookies when opening various web pages online. The most common reason for accepting cookies is "urgency" or if it's a condition for accessing pages of interest to them.

In response to the question of whether they check the privacy policies or terms of use when consenting to the use of data (Table 6), only 12.3% do so often, with older individuals aged 35 and above being somewhat more cautious. Nearly half of the surveyed population does not worry about this (46.9%), either never checking privacy policies or doing so rarely (40.7%).

**Table 5:** Do they check the privacy policies or terms of use when giving consent to data usage

	Total	Gender		Age			Level of education		
		Male	Female	Under 24	25 - 34	35+	High school	College	Ongoing education
N	202	101	100	47	92	63	95	66	41
sig	-	0.15		0.00			0.44		
Never	<b>46.9</b>	46	48	46	62	25	47	44	50
Rarely	<b>40.7</b>	37	44	37	35	53	37	48	38
Often	<b>12.3</b>	17	8	17	3	22	16	7	12
Total	100%								

## 5. CONCLUSION

The implementation of artificial intelligence into digital marketing is attracting significant attention from leading global companies, academic communities, and researchers. The significant progress in artificial intelligence has resulted in the creation of new models that companies apply in the field of digital marketing daily. In the future, artificial intelligence is expected to assume a progressively significant role in personalized online advertising. The development of artificial intelligence can help companies establish deeper connections with customers, encouraging engagement, loyalty, and sustainable success in the dynamic digital environment. Therefore, the integration of artificial intelligence in digital marketing is crucial for companies operating in the modern, dynamic environment.

The research conducted in this study examined the state of the domestic market concerning the awareness and recognition of the implementation of artificial intelligence in digital marketing by consumers. The research findings revealed that almost half of the respondents are familiar with the concept of artificial intelligence. However, there are significant differences in respondents' answers contingent upon their age and educational attainment, with younger and college-educated respondents being significantly more likely to give an affirmative answer to this question. The frequent use of artificial intelligence was also observed among younger respondents, with ChatGPT, Copilot, and Bard being highlighted as the most used tools. Analysing the results of the entire study, there were no statistically significant differences in attitudes by gender.

As the utilization of artificial intelligence for digital marketing purposes offers the possibility of advertising personalization, the research also examined the recognition of exposure to advertisements for products and services immediately after searching for them online. A high percentage of respondents recognized this phenomenon and believe they have insufficient control over how their data is used for marketing purposes. However, they often accept cookies when opening various web pages without first checking the privacy policies or terms of use when consenting to the use of data.

The research results indicate the potential of applying artificial intelligence in digital marketing and widespread interest in this concept due to the potential value that both companies and consumers can achieve through its application. However, while artificial intelligence holds promise for enhancing customer engagement and personalization in digital marketing, it also engenders ethical concerns regarding consumer privacy and decision-making processes. In line with this, a potential direction for further research could include ethical considerations regarding the use of consumer data for marketing purposes by companies. Additionally, future research could develop towards in-depth interviews and focus groups with employees in marketing agencies regarding the application of artificial intelligence in personalized advertising.

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# HUMANS AND MACHINES: THE FUTURE OF MARKETING COMMUNICATIONS

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**Abstract:** *The primary thesis of this study is the influence and implications of machine versus human intelligence in marketing communications. The technological trends that have assisted with artificial intelligence (AI) have, over the recent years, significantly impacted various industries globally. Advances in technology, with a specific interest in marketing communication, have led to profound impacts on marketing and changed customer relationships. AI and big data are on the verge of revolutionizing the delivery and use of information in marketing efforts. The article reviewed several studies to examine the nuances of the machine versus human debate in marketing communication. The article also delves into the ethical and privacy concerns associated with using machines among consumers. Through the prism of consumer and firm lenses, the article identified two dimensions of AI technologies in marketing: human-machine interaction and automated analysis. Further, the article explores the interaction between the two aspects of AI in shaping marketing communication.*

**Keywords:** *Artificial Intelligence, Human-machine interaction, Automated analysis, Ethics and Privacy*

## 1. INTRODUCTION

The world today is on a fast-paced trajectory towards a digital future over the next years. Much of people's lives today are deeply mired in technology, which is on the verge of becoming integral to humanity's daily interactions. The paradigm shift is due to several factors that drive the change. With customers increasingly becoming tech-savvy, they desire a swift and seamless digital experience and instantaneous solutions to their needs. Firms respond to tech developments by changing how they conduct business by accelerating the utilization of technology and reinventing business models and organizational structures. Communication is a crucial element of any marketing strategy, and such key interactions involving firms and customers will persist via digital media and devices. Several digital media and devices allow businesses and clients to develop, share and analyze several types of content to yield various digital communication objectives. Digital communication occurs through electronic media and transpires between businesses and customers (Shankar et al., 2022). Examples of digital communication include electronic word of mouth (eWOM), mobile communication, search and online display advertising. Digital marketing is fast becoming a mainstay for marketers. Besides selling products and services, digital marketing offers novel means of reaching, engaging, and informing customers. Digital marketing in the current era of technological advances allows firms to employ digital technologies to facilitate communication and collaborate with customers (Kim et al., 2021). With the rise of technology in marketing communication, one trend that stands out is the application of machines that emulate human capabilities. For instance, Artificial Intelligence (AI) uses computerized machinery that copies human capabilities. Following the rapid evolution of technologies in marketing communications, including AI services, virtual reality (VR), augmented reality (AR), and multi-channel networks, the digital marketing communication landscape is now shaped by machines that are slowly replacing human intelligence. The study presents a review that examines the implications and influences of machines in marketing communications. The paper delves into the transformative influence of emerging technologies, particularly AI, on marketing communications. It explores how AI-driven advancements are reshaping the way businesses interact with customers and transforming traditional marketing roles. By examining human-machine interactions, the study highlights the benefits and complexities introduced by these technologies in marketing contexts. Ethical and privacy concerns associated with AI are scrutinized, emphasizing the need for responsible use to maintain consumer trust. The paper also provides practical insights into how businesses can effectively leverage AI to optimize their marketing strategies and enhance customer engagement. Additionally, it forecasts future trends in digital marketing, offering a glimpse into the evolving landscape and identifying new opportunities for businesses to stay ahead. Ultimately, the research underscores the importance of balancing AI-driven innovation with ethical considerations and human oversight, ensuring that the integration of advanced technologies in marketing is both effective and responsible.

## 2. ARTIFICIAL INTELLIGENCE

Academicians have expressed mixed reactions concerning AI for decades. Haenlein and Kaplan (2019) revealed that the 8-week Dartmouth Summer Research Project on AI was the founding event that sparked interest in the technology. AI is among the promising technologies and has features such as algorithms and machines that mimic human intelligence (Rust, 2020). Such technologies often involve machine learning, neural networks, and language processing, which allow machines to have autonomy in sensing, comprehending, and learning through human-machine interaction (Davenport et al., 2020). Over recent years, AI has driven the interest of several marketing scholars. Defining AI in this context now includes its promise and dangers, future projections, and implications on marketing. When AI conducts a task initially done by humans, it displaces human intelligence (HI). The reduction of tasks by HI can also lead to job losses. The situation has contributed to increased concern that AI can lead to significant HI job losses (Rust, 2020). AI is already taking over repetitive and/or physical tasks. An example is where a modern automobile factory often engages robots and fewer human employees than before. Further, telephone automated menus have since replaced several customer service employees who previously answered customer call queries. Estimations point towards significant risk for job losses to humans because of the advancement of AI (Rust, 2020). AI technology involves two primary players: humans and machines. The task of machines is automating and predicting, while humans employ their distinct insights and apply machine-generated predictions as solutions to marketing-related issues efficiently and profitably (Ma & Sun, 2020). For instance, Haenlein et al. (2019) argued that AI and data analytics enable managers to understand customers and have better information about customers. Kopalle et al. (2022) explored AI in marketing by analyzing the nuances of human-machine interactions when deploying AI technologies. Apart from changing human roles, AI technologies also allow automating analysis of videos, images, audio, and text. Automation can potentially foster understanding and predict various customer behaviors (Kopalle et al., 2022).

## 3. HUMAN-MACHINE INTERACTION

Human-machine interaction (HMI) involves several means by which people and automated systems communicate through sensors, voice, and touch. HMI and AI-powered applications include both machines helping humans and humans aiding machines. Cognitive technologies like robotics, speech recognition, natural language processing, and computer vision enhance HMI, and such technologies can increasingly conduct tasks conventionally done by humans. Additionally, AI-powered machines augment human abilities by amplifying their cognitive might and improving their physical skills. Notably, AI systems and humans can coexist, as humans emphasize feeling tasks and the former acts as a tool for allowing humans to make better decisions (Haenlein & Kaplan, 2019). To illustrate this symbiotic relationship, Huang et al. (2019) examined how businesses should decide whether to assign roles to humans or machines and suggest that AI replaces mechanical tasks and then analytical tasks and, ultimately, the intuitive roles simultaneously. Given the capabilities of AI to replace or supplant humans, an increasing number of marketing scholars are expressing concerns about its potential limitations. For instance, both Rai (2020) and Ma & Sun (2020) argued that such technologies lack transparency and interpretability despite the robust nature of machine learning techniques in terms of showing strong predictive performance and processing large data amounts. Similarly, Proserpio et al. (2020) highlighted the significance of human input and insights in AI. According to Davenport et al. (2020), augmenting, rather than replacing human managers, could make AI more effective. For instance, big data and analytics can offer customers relevant product recommendations, demonstrating HMI's value. HMI can also enable businesses to provide tailored, bidirectional, real-time communication with clients using chatbots (Gentsch, 2019). An instance is where eBay's bot for Google Assistant hastens the search process for customers across an array of product categories. Further, a field study by Luo et al. (2019) revealed that AI chatbots are as effective as experienced employees and supersede inexperienced staff four times in engendering customer purchases. AI-driven recommendation systems are developing in marketing communication. Tech firms such as Google, Amazon and Apple are aggressive in launching intelligent personal assistants to expand their services. For instance, Google launched Google Home with Google OK, Facebook's intelligent private secretary, Amazon's Echo, which is based on Alexa, and Apple's Homepod, based on Siri. Such techs are similar to software apps and AI speaker devices. However, each firm attempts to maximize revenue by associating its primary business with AI speakers as intelligent personal assistants. A new market like the mobile app market is on the verge of being established because third-party organizations have introduced novel features for AI speakers (Kim et al., 2021). Google is focusing on online search and advertising with its Google Home AI speakers. Additionally, the company is targeting the mobile market. Next, Amazon's business focus is cloud services and shopping with the Echo AI speakers and it is keen on the home market with its diversified Alexa devices (Kim et al., 2021). The interactivity of AI speakers is growing in search advertising, mobile and social communication, VR apps, shopping, and cloud services. Moreover, AI speakers

can now extend to customer sharing and engagement, including interactions involving heavily customized firm-to-firm searches, shopping, personalized ads, and referrals. While interacting with these consumers, the AI speakers use aspects of the company and can lead consumers to select and share. HMI-related studies also focus on several applications, such as the internet-of-things (IoT), personalization (Tog et al., 2020), collaborative decision-making systems, virtual reality experiences (Kang et al., 2020), and facial recognition. Moreover, extant research examined HMI's ability to offer insights and improve digital interactions between sellers and buyers (Bharadwaj & Shipley, 2020), influence consumer interactions with humanoid service bots (Mende et al., 2019), and impact shopping behaviour with real-time feedback. Other applications of HMI include data-based marketing automation, Business-2-Business (B2B) marketing, improved sales forecast and behavioral research design. Based on Kopalle et al. (2022) review, extant studies on HMI made significant strides across various marketing applications. Kumar et al. (2019) explored how cultural issues affect consumers' views of the human versus robot debate. The article highlighted HMI's role in customized engagement and offered predictions about how the influence of AI in branding and client management practices varies across developed and developing nations.

#### **4. ETHICAL AND PRIVACY CONCERNS ASSOCIATED WITH HIM**

In this section, the study will examine the impacts of ethical and privacy concerns of AI applications based on human-machine interactions. HMI deals with how humans and automated systems communicate. The adoption of AI technologies is under increasing concern regarding their extent of intelligence and autonomy and the degree to which such features can lead to harm (Davenport et al., 2020). For instance, AI technologies can often identify anonymized data, which can lead to algorithmic bias. Additionally, an increasing concern among professionals is that AI can have a less apparent but more malevolent threat to users through reduced autonomy (Kopalle et al., 2022). An example is AI's invisibility and ubiquitous nature, which can subtly encourage humans to delegate decision-making. As AI becomes increasingly ubiquitous and integrated into people's everyday devices, it can potentially make autonomous decisions and prompt human behavior in ways that are barely noticeable (Kopalle et al., 2022). For instance, AI-enabled assistants like Alexa can soon monitor telecommunications patterns and opt to change consumers to inexpensive providers. While such actions may lead to saving money and time, they can also generate concerns about privacy. Apart from challenging human agency, AI can ultimately replace people and conduct tasks that were once meant for humans. Based on a report by McKinsey (2019), AI and automation are poised to drastically change several professions for the next ten years, including several marketing-related roles like customer service and management. Further, Verganti et al. (2020) proposed that AI will soon surpass humans in innovations and design. The study cited various examples, such as Tesla, Netflix, and Airbnb, which demonstrate that it is already occurring. Netflix uses AI to predict and design content that customers prefer. The authors suggested that the role of humans will change to understand the problems to be addressed. The shift from less emphasis on creating new products and more on what the issues such products are designed to address sparks interest in the types of challenges that businesses will attempt to solve. The infringement of AI in tasks initially done by humans can potentially aggravate people's distrust of this novel technology (Davenport et al., 2020). For instance, the growing autonomy of AI can increase alienation and minimize psychological well-being among customers who leave machines to make decisions. While such privacy and ethical concerns attract heightened attention, the extent to which they raise concerns seems to vary globally (Kopalle et al., 2022).

#### **5. AUTOMATED TEXT, IMAGE AND VIDEO ANALYSIS**

Surveys, experiments, and observations are typically the most common forms of primary data collection conducted by marketing scholars and practitioners. While such inquiry methods yield conclusive insights, they have several limitations. To this effect, automated analysis can overcome such challenges. The digital revolution has now availed vast primary data based on scale and scope. For instance, Amazon can access a million reviews from its customers and learn from them. Also, AI's data collection processes are less obtrusive than other inquiry techniques, thereby reducing potential biases. Rather than imposing on clients to respond to a barrage of survey questions, researchers can now obtain voluminous data. AI facilitates gathering data from overlooked sources, which is subsequently consolidated across multiple digital platforms (Du et al., 2021). AI allows the automation of information involving customer conversations on various social media platforms. Automated technologies like computer vision and natural language processing can extract rich insights from data such as video, images or text. Text-based data contains firm-originated and consumer data, such as advertising copy and social media postings. Meanwhile, audio-based data includes examples such as non-text and spoken words, while image data includes various still images and videos. An excellent example of

automated analysis is an in-store virtual assistant designed to detect consumers' emotions by analyzing the speech and body language of shoppers for the purpose of delivering enhanced customer service. Experts projected that the collection, processing and use of such forms of data would be fully automated and would complement human analytical competencies (Kopalle et al., 2022). Therefore, organizations may ultimately be changed into automated units with a nuanced understanding of diverse customers. Additionally, such organizations will be able to customize their products and services by harnessing and acting on data-driven insights with limited or no human intervention. While automated analysis may yield several benefits, the technology can also attract some concerns associated with data. For instance, automating data collection can result in data being distorted. Similarly, such algorithms can develop misleading content, such as fake reviews (Kopalle et al., 2022). To mitigate this challenge, firms like Amazon employ natural language processing to detect and correct the likelihood of data distortion (Proserpio et al., 2020). The automated processing capabilities of AI optimize marketing communication campaigns across several languages. To illustrate, companies like Cogito utilize real-time AI speech analytics to hear conversations involving salespeople and their customers. Also, the technology provides instantaneous feedback on several aspects that may affect firm performance, such as the degree of empathy and speaking tone. Additionally, technologies influenced by AI can assist firms in providing a broad range of services to underserved populations, thus reducing economic inequality. For instance, Google's AI factory in Ghana improved its natural language algorithms after integrating speech and text from more than 2000 African languages (Kopalle et al., 2022). Similarly, Telkomsel and Unilever are collaborating with Indonesia's Kata.ai, a conversational platform, to group and automate over 95% of customer interactions using limited human effort. The autonomous nature of AI's abilities can act as a uniting agent by minimizing differences that exist between the rich and the poor (Kopalle et al., 2022). For instance, several customers in emerging markets may struggle to afford personal computers and, thus, often watch videos using their phones. Speech recognition by AI and speech-to-text (such as Google translate) features can assist emerging markets in navigating the problems associated with low literacy and thus serve the initially underserved populations. Therefore, a successful implementation of AI-based images, text or audio analytics can greatly enhance the lives of people in economically disadvantaged nations. Notably, AI technologies and automation are universal in nature. However, the differences, such as culture and language, make the audio, video, image and text analytics local in nature. For example, most retail purchases occur in physical establishments. Therefore, automating the analysis of customer shopping behaviour will tend to be increasingly local than global. An excellent example is Duplex, an AI assistant that makes local restaurant reservations that are influenced by customer residences (Newcomb, 2019). Therefore, AI-based text and image analytics can potentially succeed if locally applied. In integrated marketing communications (IMC), the same can be true. Previous studies reveal that IMC is likely to succeed if communication activities integrate diversity based on parameters such as socio-demographics or culture (Kopalle et al., 2022). Thus, it is unsurprising that AI apps like chatbot applications, self-service terminals, and natural language processing are largely local and occur across various major languages. The analysis of automated digital-based voice-based assistants like Siri and virtual chatbots can usually employ voice analytics and NLP to communicate with customers. The interactions cover a broad range of marketing roles. To illustrate, YouTube uses NLP's speech recognition software, which translates into several languages. Similarly, Spotify launched a recent campaign dubbed "Only You" that automatically analyses a user's music streaming behavior and generates a user-specific playlist. Generally, automated methods like speech recognition and emotion detection are fast becoming language-specific, thus highlighting a change towards glocalization (Kopalle et al., 2022). Automated analysis should be adapted to match the unique conditions. An excellent example of this form of glocalization is D-Labs, which is a novel AI-inspired product that can extract brand logos from images on Instagram. With regards to the ubiquitous nature of such forms of postings in social media, this automated image analysis can assist marketers in tailoring to local brand needs across various regions. Furthermore, virtual reality (VR) and augmented reality (AR) both utilize AI-based video analytics. Though such technologies are yet to be fully developed, they can provide realistic imagery visualization (Schmitt, 2020). For instance, AR tools like digital mirrors allow customers to try on various forms of eyewear or clothing online. Cultural factors like the extent to which an interaction entails the spheres of collectivism vs. individualism may moderate the efficacy of such automated interactions. In individualistic cultures, such technologies may be favorable since they are self-focused. On the other hand, customers in some cultures may seem uncomfortable with automated interactions such as robot encounters (Schmitt, 2020). In this case, mixed reality-based tech like HoloLens can provide a space to promote greater acceptance of such technologies, especially among consumers who resist them across the world.

## 6. ETHICAL AND PRIVACY CONCERNS

AI-based images, audio and text also generate concerns about ethics and privacy. Automated analysis sparks interest and raises concerns, but the extent may vary across cultures and nations (Davenport et al., 2020). Firstly, automated analysis relies on large datasets of customers that can result in harmful privacy breaches. Privacy breaches are expensive to companies and customers. Though automated analysis cannot often be the cause, its desire for large data sets to feed the machine learning algorithms increasingly exposes firms to data breaches and potentially opens an avenue for the breaches to exist (Kopalle et al., 2022). Mitigating such risks and, at the same time, harnessing the capabilities of automated analysis requires becoming reluctant to deal with individual-level data. Instead, firms should change their focus to meta-data that statistical analysis generates. This approach allows firms to collect customer data, though it allows storing statistical properties instead of raw data. For instance, a firm that employs AI to get individual-level data for predicting customer churn would get to store relevant parameters and discard the individual-level data. Alternatively, data privacy can be protected by ensuring the analysis occurs from the user's side. For instance, a firm can calibrate artificial neural networks through granular individual-level data from the user's phone. However, models using data from this approach will be less robust because the available data will be of a limited size and will be from only one individual. Next, the growth of automated analysis raised concerns about the potential for algorithmic bias. Bias can lead to systematic and repeatable errors, resulting in unfair outcomes. An instance is favoring one group over others. Such biases seem to be higher in homogenous nations (Kopalle et al., 2022). Besides being harmful to some people, such malicious biases can lead to damaging societal effects. While there are several drivers of algorithmic bias, a specific notable reason is the inherent tendency of AI to employ past data when offering recommendations for future actions. Thus, biases in input data can be reflected in rules learned from the data by automated algorithms. Algorithmic bias can lead to bias despite a designer's efforts to reduce or avoid it (Lambrecht & Tucker, 2019). A means of addressing this bias is employing hybrid decision-making systems that allow automated analysis to only suggest decisions to humans, who, in turn, will follow or reject them. Overall, concerns regarding the need to ensure data privacy and minimize algorithmic bias are the results of rising automated analysis, and the extent of such concerns will potentially vary across nations.

## 7. LIMITATIONS AND IMPLICATIONS

While this study offers valuable insights into the role of AI and digital technologies in transforming marketing communications, certain limitations that may affect the scope and applicability of its findings must be acknowledged. One significant limitation is the study's scope and generalizability. The research focuses on specific industries and regions, so the findings might not fully apply across all sectors or geographical areas. As a result, businesses in different contexts may need to consider these variations when using the insights from this study. Additionally, the rapid pace of technological change presents another limitation. The advancements and trends discussed in this study could quickly become outdated as new technologies emerge and evolve. This dynamic nature of the field underscores the need for continuous updates and ongoing research to maintain the relevance of the findings. The study also relies heavily on existing literature and available data, which could limit its comprehensiveness. Data quality and availability variations across different sources may impact the conclusions' robustness. Future research could benefit from more extensive data collection and analysis to provide a more thorough understanding. Moreover, while the study touches on ethical and privacy considerations, it may not fully encompass the breadth and depth of these issues. The moral implications of AI and automated technologies are complex and multifaceted, and a more detailed exploration could enhance the study's contributions to this critical area. Despite these limitations, the study has several important implications for various stakeholders. The research highlights the substantial potential of AI and digital technologies to transform business marketing communications. Companies can leverage these insights to enhance customer engagement, optimize operations, and drive innovation, thereby gaining a competitive edge in the market. Policymakers can also draw valuable lessons from this study. The findings underscore the need for robust policies and regulations to address ethical and privacy concerns associated with AI technologies. Developing comprehensive frameworks will ensure these technologies' responsible and beneficial use, protecting both businesses and consumers. The study's limitations also open avenues for future research. To build on the current findings, subsequent studies could focus on industries, regions, and the evolving technological landscape. This ongoing research will provide a more comprehensive understanding and help adapt to the field's continuous changes. Finally, the implications for education and training are profound. The study suggests the need for updated curricula incorporating the latest technological advancements and their applications. Training programs can help professionals stay abreast of new developments and ethical standards, ensuring they are well-equipped to navigate the evolving landscape of AI and digital technologies.

By addressing these limitations and implications, the study situates its findings within the broader field context. It enhances their relevance and impact, providing a realistic appraisal of the research's contributions and potential applications.

## 8. CONCLUSION

Advancements in technologies are enhancing the capabilities of marketing communications. AI-driven technologies allow firms to gather, store, analyze and use a large array of customer data (Rust, 2020). The review examined the implications and uses of this technological advancement in driving marketing communication by exploring the role of two crucial dimensions of AI- machine interactions and automated analysis focusing on consumers and firms. The increased use of AI-driven technologies has raised consumer concerns about ethics and privacy, leading to increased education, regulation and training. Such worldwide concerns will likely impact the ability of companies to use AI in automating analysis and change the nature of human-machine interactions. Looking forward, there is an expectation that a growing number of companies will shift to artificial intelligence based on the demands of various groups of customers. After the automation of intelligence, robots, machines, and other AI-based machine learning will incorporate existing information management systems to supplement human analytical competencies. When this autonomous state is reached, most firms will change to AI-fueled organizations that utilize human-machine collaboration developed to leverage data-driven insights based on the local group of consumers.

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# **LEAN MANAGEMENT AND ORGANIZATION – PURPOSE, PROCESS, PEOPLE**



# THE IMPORTANCE OF FORMALIZED SELECTION OF BPI METHODOLOGY FOR BPM SUCCESS

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**Abstract:** *The field of business process management (BPM) has witnessed substantial expansion in literature in recent decades. While BPM plays a pivotal role in establishing sustainable competitive advantages, a considerable number of BPM projects still encounter challenges and fail to achieve success. Important part of BPM is selection of business process improvement methodology. The aim of this paper is to examine the relationship between formalization the choice of business process improvement methodology and BPM success. Data were collected from 91 Serbian companies. It was concluded that organizations that lack defined criteria for selecting a BPI methodology tend to experience lower rates of success in BPM success compared to those that employ an analytical approach. Formalizing the selection of a BPI methodology for BPM success holds practical importance because it can boost efficiency, align endeavors with organizational goals, standardize processes, minimize risks, and cultivate a culture of ongoing enhancement.*

**Keywords:** *BPM adoption, process improvement, BPI methodology choice, success, process performance index*

## 1. INTRODUCTION

Frequent market changes and challenging business environments increasingly influence the need for implementing BPM concepts within companies. Therefore, the number of works in the literature addressing challenges in the implementation of BPM concepts is steadily increasing. The BPM concept enables companies to enhance their operational performance and gain a competitive advantage in the market (Hung, 2006, Škrinjar, Bosilj-Vukšić, & Indihar-Štemberger, 2008, Kohlbacher & Reijers, 2013). Also, the firm profitability depends on processes (Lientz & Rea, 2001). Madison (2005) highlights that problem solving within processes and business process improvement (BPI) leads to the increase of operational performance: cycle time, costs, and customer satisfaction. That is why BPM and BPI are core for business improvement (Siha & Saad, 2008).

In many papers, the success, and reasons for failure of BPM projects are discussed (Trkman, 2010, Bai & Sarkis, 2013, Gabryelczyk & Roztock, 2018). Trkman (2010) states the main criticism of BPM implementation is the lack of immediate results and the need for a proper balance between initial quick wins and long-term solutions. It is essential to quickly achieve results to gain management and employee support for further implementation (Jovanović *et al.*, 2023). Škrinjar & Trkman (2013) stated that the main challenge for BPM success is formalization and precise instruction for each step in BPM implementation.

BPI is important element of BPM and demands selecting appropriate BPI methodology. This paper aims to explore the correlation between the formalization of selecting the right BPI methodology and the BPM success.

The structure of the paper is as follows: Theoretical background will offer a literature review on BPM success and BPI methodologies. Section 3 will outline the research methodology employed for this study, while the primary research findings will be presented in Section 4. These findings will be further deliberated upon in Section 5.

## 2. THEORETICAL BACKGROUND

“Business Process Management is an integrated system for managing business performance by managing end-to-end business processes” (Hammer, 2015). Business Process Management (BPM) is the attainment of

organizational goals through the improvement, management, and control of fundamental business processes (Jeston & Nelis, 2006). Many companies encounter challenges when adopting the BPM concept, as its application demands significant resources, both in terms of time and finances, as well as extensive involvement from employees and top management. Therefore, it is important to analyze the main steps of BPM to notice the possibilities for improvement that would increase BPM success.

One potential method for gauging the BPM success is the Process Performance Index (Rummler-Brache Group, 2004). To leverage the benefits of implementing the BPM concept (Szelaḡowski and Berniak-Woḡny, 2024), it is necessary to consistently apply the methodology. In the BPM, the important step in selection of appropriate BPI methodology (Rashid & Ahmad, 2013).

Over the past few years, numerous organizations have adopted various BPI methodologies, categorized broadly as business process reengineering, redesign, or continuous process improvement. Given the abundance of BPI methodologies, organizations may encounter challenges in selecting the most suitable one.

Formalizing the choice of BPI methodology can ensure that resources are allocated efficiently and that the selected approach is effective for specific challenges in the company.

Therefore, it is interesting to investigate how companies in Serbia select BPI methodologies and does the extent of formalization of selecting BPI methodology influence on the BPM adoption.

### 3. METHODOLOGY

A survey instrument was designed to test the theory. The BPTrends survey (Harmon & Garcia, 2020) was used to gather information on respondents and BPM practice. Authors added questions on choice of improvement methods and business process. In 2012, a similar survey instrument was used, along with additional questions about BPI practice, to assess the implementation of BPM in Serbian companies (Stojanović, Simeunović & Tomašević, 2012). There were 28 questions in total, broken down into three categories: (i) basic inquiries concerning the company, the respondents, and their knowledge of business process management; (ii) inquiries concerning process maturity and the PPI; and (iii) inquiries concerning business process improvement.

General managers, functional managers, and process analysts were the only participants in the empirical investigation. Companies that have adopted the ISO standard were among the population in Serbia, and chambers of commerce assisted in defining the first list of possible responders. We have tried to guarantee that responders have at least some BPM experience by taking this action. In Serbia, there were 674 businesses in operation. After this list was reduced to 500 organizations, 91 of them responded to our request, which is sufficient at the 10% confidence interval level, and an 18.6% response rate was obtained from the 91 valid responses that were received.

### 4. RESULTS

Information about respondents is given in the following figures (figure 1-5).



Figure 1. Job function of respondents

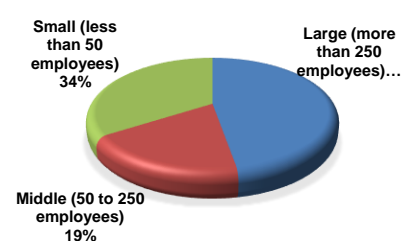


Figure 2. Respondents company size

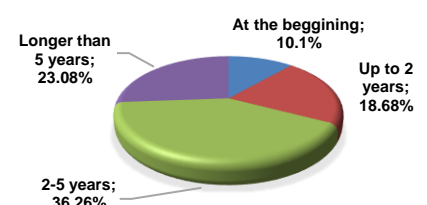


Figure 3. Experience in BPM and BPI

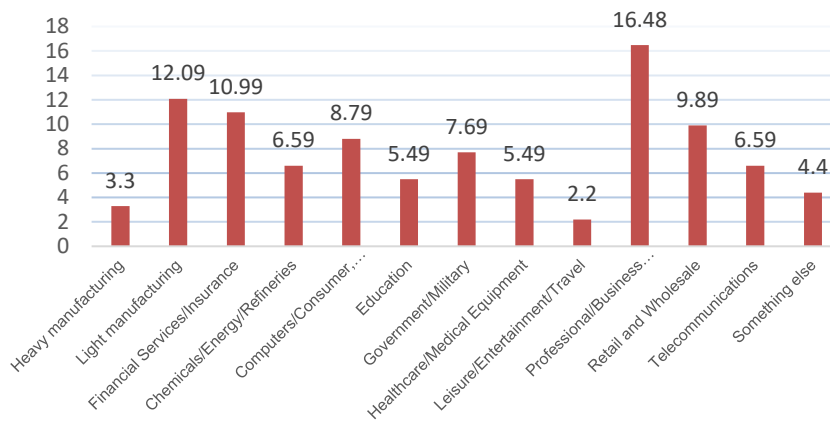


Figure 3. Companies' industry

Most of the workforce seems to be concentrated in the role of Business Function/Department Managers, following closely behind are Process Analysts and Business Analysts, and Consultants at 12.09%, indicating a robust presence of analytical and strategic roles within the organization.

Large enterprises made up most of the respondents and the outcomes of comparable studies are consistent with this finding (Harmon & Garcia, 2020). Experience in BPM shows that respondents have several years of experience in BPM, and this reaffirms the adequacy of the sample size for the study. Most of the companies represented in the study were primarily from the consulting, retail and wholesale, light manufacturing, and financial sectors. BPM is attractive for business consulting sector and light manufacturing and financial services in Serbia.

BPM adoption is evaluated using the Process Performance Index (PPI), with values ranging from 10 to 30 for each company (PPI 91 valid response,  $\bar{X} = 19,57$ , Std = 4,3). Table 2 provides frequencies and percentages of companies corresponding to specific PPI values.

**Table 2:** Frequences and percentage of the companies with specific PPI value

PPI value	Number of companies	%
	[1]	
10	1	9,9
11	2	8,79
12	1	21,99
13	2	13,19
14	2	14,29
15	6	12,09
16	7	8,79
17	8	10,99
18	11	47,25
19	10	18,68
20	10	34,07
21	5	19,78
22	6	59,34
23	1	20,87
24	4	65,93
25	2	24,17
26	3	3,3
27	8	8,8
28	1	1,1
29	1	1,1
Total	91	100,00

Most companies exhibit PPI values falling within the 18-20 range, suggesting a moderate PPI value, and indicating a moderate level of success in BPM adoption within these organizations. This indicates that work must be done to create a more favorable environment for managing business processes in companies in Serbia. Enhancing the conditions for managing business processes would facilitate a more widespread adoption of the concept within companies.

Method of choice of BPI methodology and is independent variable and categorical type, and the PPI is dependent and continuous type variable with normal distribution, so ANOVA (one way of between group ANOVA) will be used. To investigate potential discrepancies in the PPI index between companies with specific

criteria for selection of BPI methodology and those without, an independent sample T-test will be employed. During the first testing of the results, the variable – selection of BPI methodology was observed, which had the value 0 and 1. The value 1 was given if there was no formal approach to selection of BPI methodology, the value 0 was given if there was some form of selection criteria. Table 3 shows the descriptive statistics of the variable choice of BPI methodology and PPI and table 4 shows results of T-test.

**Table 3:** Descriptive statistics of selection of BPI methodology and PPI value

Selection of BPI methodology		Number of companies [1]	Mean	Std. deviation	Std. Error Mean
PPI	0	61	21,11	4,021	,505
	1	30	16,43	2,956	,540

**Table 4:** T-test of selection of BPI methodology and PPI value

		Levene`s test for equality of variances		T-test for equality of means					95% Confidence interval of difference	
		F	Sg.	t	df	Sg (2- tailed)	Mean difference	Std. Error Difference	Lower	Upper
PPI	No equal variance	4,239	,042	5,662	89	,000	4,681	,827	3,039	6,324
	Equal variance			6,277	75,561	,000	4,681	,746	3,196	6,167

A notable contrast emerged between the scores associated with a lack of formal approach to selection of BPI methodology (M=16.43, SD=2.956) and instances where some form of selection criteria was employed (M=21.11, SD=4.021) conditions;  $t(91)=6.277$ ,  $p = 0.000$ ). These results indicates that selection of BPI methodology really does influence PPI, with value of  $\eta^2 = 0,307$  which indicates large effect on difference between the groups and large practical significance (Cohen, 1988).

An analysis was also performed with the grouping of respondents' answers on the method of selection of BPI methodology into the variable "criteria for choosing BPI methodology" which has values 1, 2, 3 and 4. The value 1 means that there are no criteria for the selecting BPI methodology and the answer was: there is no formalized approach to selecting BPI methodology. The value of 2 indicated the use of external criteria, and it consisted of responses such as selecting the methodology used by competitors or planned to be used, and selecting the methodology promoted by a consultant. The value of 3 indicated the use of an analytical approach, comprising responses such as an analytical approach to BPI methodology selection and a process analysis-based approach. The value of 4 was an option for using one's own methodology for improvement. When grouping variables, care was taken to ensure that there were no respondents who provided answers belonging to distinct groups, and this condition was met.

Table 5 provides descriptive statistics of the Process Performance Index by groups for the selection of business processes.

**Table 5:** Descriptive statistics of PPI according to groups for business process selection

Groups	Number of companies [1]	Mean	Std. deviation	Std. Error Mean	95% Confidence interval of difference		Min	Max
					Lower Bound	Upper Bound		
No criteria	30	16,43	2,956	0,540	15,33	17,54	10	22
External criteria	10	19,00	4,028	1,274	16,12	21,88	15	29
Analytical approach	34	22,47	3,510	0,602	21,25	23,70	16	28
Own BPI methodology	17	19,65	4,137	1,003	17,52	21,77	11	27
Total	91	19,57	4,300	0,451	18,68	20,47	10	29

Levene`s test showed that variances are approximately equal. Variance analysis of PPI between groups are given in the Table 6 and shows significant difference between groups.

**Table 6:** Variance analysis of PPI according to groups for choosing BPI methodology

PPI	Sum of Squares	Df	Mean Square	F	Sig.
Between groups	584,566	3	194,855	15,701	,000
Within groups	1079,720	87	12,411		
Total	1664,286	90			

Difference between the four defined groups was founded:  $F(2,91) = 15.701$ ,  $P=0.000$ , Group 1 - no formalized approach for choosing BPI methodology,  $N=30$ ,  $M=16.43$ ; Group 2 - companies that use external criteria for selecting BPI methodology  $N=10$ ,  $M=19.00$ ; Group 3 - companies that use more analytical approach for selecting BPI methodology,  $N=34$ ,  $M=22.47$ , and Group 4 - companies that have their own methodology for BPI,  $N=17$ ,  $M=19.65$ . Group 3 recorded a higher mean ( $M=22.47$ ), and Group 1 a lowest value ( $M=16.43$ ). Then, the Tukey HSD post-test is performed (Table 7).

**Table 7: Tukey HSD post-hoc test of PPI according to groups for choosing BPI methodology**

(I) Selection criteria	(J) Selection criteria	Mean difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-2,567	1,286	0,198	-5,94	0,80
	3	-6,037 <sup>*</sup>	0,882	0,000	-8,35	-3,73
	4	-3,214 <sup>*</sup>	1,069	0,018	-6,02	-0,41
2	1	2,567	1,286	0,198	-0,80	5,94
	3	-3,471 <sup>*</sup>	1,267	0,037	-6,79	-0,15
	4	-0,647	1,404	0,967	-4,32	3,03
3	1	6,037 <sup>*</sup>	0,882	0,000	3,73	8,35
	2	3,471 <sup>*</sup>	1,267	0,037	0,15	6,79
	4	2,824 <sup>*</sup>	1,046	0,041	0,08	5,56
4	1	3,214 <sup>*</sup>	1,069	0,018	0,41	6,02
	2	0,647	1,404	0,967	-3,03	4,32
	3	-2,824 <sup>*</sup>	1,046	0,041	-5,56	-0,08

\*. The mean difference is significant at 0,05.

With Tukey HSD procedure, it was determined that there exists a statistically significant distinction between groups 1 and 3, 1 and 4, 2 and 3, and 3 and 4. Notably, Group 1 exhibited the lowest PPI among all groups, whereas Group 3 highlighted the highest PPI. Additionally, there is no statistically significant difference in PPI between companies in Groups 1 and 2, as well as between Groups 2 and 4.

PPI differs in all four groups, with value of  $\eta^2 = 0,296$  which indicates large effect on difference between the groups and large practical significance (Cohen, 1988).

What is significant to note is a significant difference in PPI between the group that lacks criteria or formalized procedures for selecting improvement methodologies compared to companies that use analyses to make such decisions. Additionally, it is important to highlight that there is no statistically significant difference in PPI between companies that utilize consultants for implementing improvement methodologies and those that use their own improvement methodology.

The post-hoc analysis reveals a statistically significant disparity among groups, particularly highlighting a notable distinction between Group 1 and Groups 3 and 4.

## 5. DISCUSSION AND CONCLUSION

The majority of respondents hold positions as functional or department managers, likely due to the prevalent practice among companies in Serbia of assigning these managers to handle process management issues. A substantial number of process analysts further suggests a widespread awareness of business processes among Serbian companies. The survey findings indicate that companies typically possess over two years of experience in BPM and BPI, aligning with previous observations of process awareness in Serbian companies and affirming the adequacy of the study sample.

To ascertain a correlation between the selection of BPI methodology and the BPM success, an ANOVA test was conducted to assess differences among groups utilizing various selection methods. Subsequently, a post hoc Tukey HSD test was employed to pinpoint specific groups demonstrating divergent levels of BPM success. Notably, organizations lacking specified criteria for selecting BPI methodology exhibited lower rates of BPM adoption success compared to those employing analytical approach.

This analysis validates the hypothesis that there exists a correlation between the selection method of BPI methodology and the BPM success within organizations.

The research may be limited by its focus on Serbia, as practices and attitudes towards BPI methodologies can vary significantly across different geographical regions and cultural contexts, therefore, it would be interesting to apply this research to organizations operating in other countries or regions.

All the above indicates the need to create a model or procedure for selecting BPI methodology that will contain clear selection criteria and an analytical approach. Such a model would enable process analysts and practitioners in the field of business processes to conduct adequate process improvement methodology, thereby influencing the success of their BPM projects positively. The practical significance of formalizing the choice of BPI methodology for BPM success lies in its ability to enhance efficiency, align efforts with organizational objectives, promote standardization and consistency, mitigate risks, facilitate measurement and evaluation, and foster a culture of continuous improvement.

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# AN OVERVIEW OF BPM LIFE CYCLES

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**Abstract:** *The development of Business process management (BPM) has led to the emergence of diverse life cycle models, which have improved organizational efficiency and competitiveness. This research compares and analyzes fourteen BPM life cycles, utilizing the Universal Process Technology (UPT) approach as a reference model. The research reveals similarities and differences among BPM life cycles and systematizes the phases into five categories: strategic planning, process identification and selection, process design, (as-is) modeling and establishing the measurement system, process redesign (to-be), and continuous process improvement (implementation, monitoring and optimization). Observations include the absence of strategic planning as an initial step in most BPM life cycles and inconsistencies when naming the phases. The study underscores the importance of selecting an appropriate BPM life cycle and identifies areas for future BPM life cycle development.*

**Keywords:** *life cycle, Business process management, literature review*

## 1. INTRODUCTION

Every organization is aware of the importance of a understanding and managing their business processes. Ensuring that they consistently provide value is the basis of a company's efficiency and competitiveness (Dumas et al., 2018). In today's business environment, to manage business processes, there are various models that are widely distributed and applied in companies of various activities. The challenge of every company is the choice of an appropriate methodology that will bring the best results in improving business processes, with the aim of enhancing the entire business and increasing value for the customer.

Business process management (BPM) represents a holistic approach which include analysis, design, development, and execution of business processes (Klein et al., 2023; Kohlbacher, 2010) and helps in implementing strategic goals and improving the relationship between process and strategy (Trkman, 2010). BPM strives for continuous process improvements, creating value for customers (Navarro, 2021) and combines methods and tools to increase the effectiveness and efficiency of organizational processes (Beimborn & Joachim, 2011). During the 1990s, BPM research mostly examined technical methods during the process life cycle (Dumas et al., 2013; Klein et al., 2023; Weske, 2007), for example, through process flow modeling and development, process software improvement, or process reengineering. BPM has been more concentrated in information technology since the 2000s, with an emphasis on process improvement and understanding. BPM is a continuous process that is achieved through a life cycle that is divided into phases (Houy et al., 2010). BPM life cycles represent models that systematize the steps and tasks which companies should follow when starting BPM project (Macedo De Morais et al., 2014). According to Dumas et al. (2013), the BPM life cycle includes various tools and methods for process identification and as well as managing individual processes.

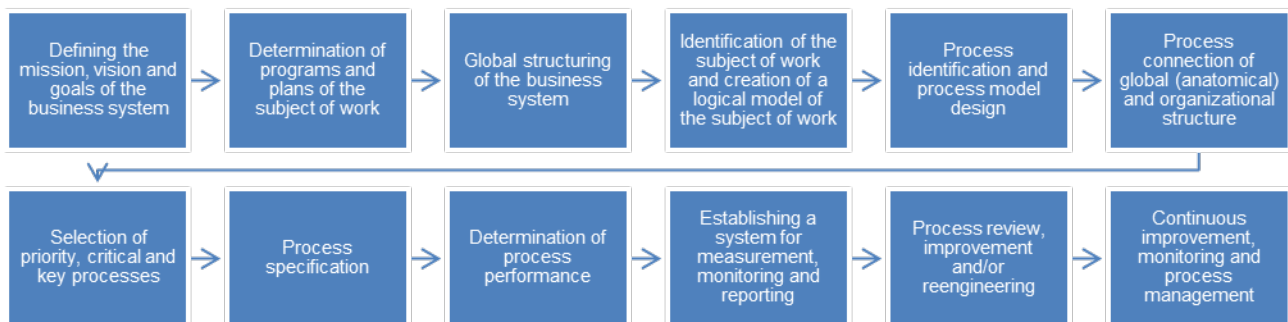
In the literature, there are different models of BPM life cycles, which were created in accordance with the traditional concept of BPM. Theoretical and empirical studies show illustrative approaches to the life cycle of processes in an organization and present them as a series of cyclical phases. However, there are variations in the quantity of steps and tasks required throughout the BPM life cycle and the most common number of stages is four or five. There are researchers who previously deal with the analysis of different life cycles and their evolution (Houy et al., 2010; Macedo De Morais et al., 2014; Szelągowski, 2018). Based on similar research in this area, an overview of existing BPM life cycle models will be given.

## 2. THE DEVELOPMENT OF BPM LIFECYCLES

Hoy (2010) first compares cycles and phases, and proposes his BPM life cycle model. As part of the analysis of the evolutionary development of the BPM cycle, based on a systematic literature review, it compares the BPM cycles that were created between 1990 by Davenport & Short (1990), van der Aalst et al. (2004), Netjes et al. (2006), Zur Muehlen and Ho (2006), until 2008 and the life cycle of Hallerbach et al. (2008). Four years later, the authors Macedo de Morais et al. (2014) compare BPM life cycles and the stages in each. As a

reference model, they use the ABPMP cycle (ABPMP, 2009). The models of life cycles, which were found as a subject of comparison, were also treated by the previous author Hoy. Among them, the life cycle of the author Weske (2007) was added. Macedo de Moraes et al. (2014) propose their BPM framework, which consists of the phases of the ABPMP cycle and the initial planning processes and strategic activities. In this way, they wanted to overcome the identified problems of holistic BPM. Szelągowski (2018) shows the evolution of BPM life cycles and shows the cycles: DMEMO (BPM Resource Center, 2014) and the cycle by Dumas et al. (2013). It states that processes require dynamic management or empowering process owners to make changes to the performance flow itself. Therefore, he proposes a model that compares with the stages of previous models, but states that the stages are interconnected, which means not only the creation of an improvement cycle, but also dynamic management. This means that after the execution and monitoring phase, one can directly move to the (re)design phase, without having to go through the last phase of implementation and adaptation. Like traditional life cycles (ABPMP, 2009; Elzinga et al., 1995; Hoy, 2010) it includes defining goals and preparing for the project, however, Szelągowski does not classify them into four stages of the BPM life cycle. Ubaid & Dweiri (2020) present a comparison of two BPM life cycles and their phases: (1) the BPM methodology (Elzinga et al., 1995) and (2) 7FE framework (Jeston, 2018), to indicate that there is a deficiency in the phases of traditional BPM cycles. The authors compare the stages of quantification and selection of improvement opportunities from Elzinga methodologies and state that they are most similar to the innovation phase from the 7FE framework. In addition, the last two stages (realization of value and sustainable performance) from the 7FE framework are compared to the Elzinga's continuous improvement stage. Based on a critical review, the authors propose a comprehensive BPM life cycle.

As explained, different concepts have been developed for the process approach implementation. At the Faculty of Organizational Sciences, a concept for the implementation of the process approach was created and its application can create a process model as a fundamental business system solution. The Universal process technology approach – UPT approach (Radović et al., 2012) has twelve steps and its adequate implementation can lead to a logical tree or catalog of work items as a basis for process identification and process catalog creation. In this way, the business system is regulated, it is possible to prevent incomplete identification of the process. This life cycle model has precise steps and serves as the foundation for the company's constant state of continuous improvement in effective and efficient way. Figure 1 shows the UPT approach proposed by Radović et al. (2012).



**Figure 1:** The Universal process technology approach – phases (Radović et al., 2012)

Selecting the appropriate BPM life cycle is the important decision when starting a BPM project. The purpose of this research is to analyse the phases of different BPM life cycle models found by literature review, to identify and reveal the variations, similarities and differences between them, using the UPT approach model as a reference model. Based on that, this research systematizes the BPM life cycles phases into adequate categories.

### 3. METHODOLOGY

This study was made according to similar research in this field (Hoy, 2010; Macedo de Moraes et al., 2014; Szelągowski, 2018), with a literature review that observes the guidelines in accordance with Tranfield et al. (2003). The following research questions were formulated to help direct the research:

- Q1: What are the similarities and differences among different BPM life cycles (including the Universal process technology approach) found by literature review?
- Q2: Is it possible to systematize the phases of BPM life cycle based on all BPM life cycles?

A literature review with keyword search and article sourcing in the Scopus database was conducted in March 2024. The data used in this research was collected from the Scopus database, which is the most used citation database. The set of keywords used in the database search procedure was suggested by *Macedo De Moraes*



*et al.* (2014). It resulted in a total of 489 publications. Search was restricted to title, abstract, and keywords of the publications. Conference review, review, short survey was excluded from further analysis. No other restrictions were used during article sourcing, beside English language.

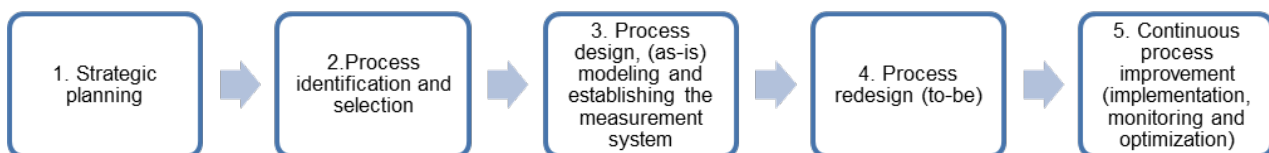
Analysing the titles, abstracts and keywords of 489 publications, the original sample was reduced to fourteen articles because of the exclusion of publications which were not relevant to the proposed research. For the further full-text review and evaluation of the relevant publications, fourteen BPM life cycles were selected: ABPMP (2009), BPM Resource Center (2014), Davenport & Short (1990), Dumas (2013), Elzinga et al. (1995), Hallerbach et al. (2008), Houy et al. (2010), Jeston (2018), Netjes et al. (2006), Pereira et al. (2019), Szelągowski (2018), Van der Aalst (2004), Weske (2007), Zur Muehlen & Ho (2006). The authors and the model names are given in the Table 2.

**Table 1:** Selected BPM life cycles

	Authors	Year	Life cycle title
1.	ABPMP	2009	The BPM life cycle
2.	BPM Resource Center	2014	BPM lifecycle: DMEMO
3.	Davenport and Short	1990	Process Redesign
4.	Dumas	2013	BPM cycle
5.	Elzinga et al.	1995	Continuous Improvement Cycle
6.	Hallerbach et al.	2008	Process life cycle
7.	Houy et al.	2010	BPM-cycle for continuous business process improvement
8.	Jeston	2018	7FE
9.	Netjes et al.	2006	The BPM lifecycle
10.	Pereira et al.	2019	BPM implementation lifecycle
11.	Szelągowski	2018	The BPM lifecycle for dynamic process management
12.	Van der Aalst 2004	2004	The BPM lifecycle
13.	Weske	2007	Business Process Lifecycle
14.	Zur Muehlen & Ho	2006	BPM life cycle

#### 4. RESULTS AND DISCUSSION

By comparing the phases in all BPM life cycles, it was observed that they can be systematized (Figure 2) to make certain categories: (1) Strategic planning, (2) Process identification and selection, (3) Process design, (as-is) modeling and establishing the measurement system, (4) Process redesign (to-be), and (5) Continuous process improvement (implementation, monitoring and optimization).



**Figure 2:** Systematized BPM lifecycle phases

All stages in the life cycles of BPM are compared with UPT and are classified into a certain category. Among the BPM life cycles, a lack of phases of strategic planning, creating a mission and vision, as well as creating a process approach implementation program was observed (Table 3). The initial preparation process represents the first important step of the BPM methodology, because in this way the company prepares for the change of BPM culture (Ubaid & Dweiri, 2020). Strategic planning or preparation for launching a BPM project is modeled by Elzinga et al. (1995), Houy et al. (2010), Jeston (2018), Pereira et al. (2019), Zur Muehlen & Ho (2006).

**Table 3:** Strategic planning

Phases of UPT	BPM life cycles						
Radović et al. (2012)	ABPMP (2009)	Davenport & Short (1990)	Elzinga et al. (1995)	Houy et al. (2010)	Jeston (2018)	Pereira et al. (2019)	Zur Muehlen & Ho (2006)
Defining the mission, vision and goals of the business system	Planning and strategy	Visioning and goal setting	Preparation of BPM	Development of strategy	Foundation and enablement phases People	Process strategy	Specification of objectives and analysis of environment
Determination of programs and plans of the subject of work Global structuring of the business system			Human resource system				

In their life cycles, Elzinga et al. (1995) and Jeston (2018) recognized stages of human resource management (HRM), which do not appear in other models. Ubaid & Dweiri (2020) state that this BPM methodologies are outdated or do not fully cover human interaction with BPM systems. Based on that, the phase of HRM can be

a part of strategic planning when creating a BPM project implementation plan. It is very important to create a group of people who will lead the project, but later explain and spread the results to other employees in the company.

The identification of processes for improvement is recognized in the life cycles of ABPMP (2009), BPM Resource Center (2014), Davenport and Short (1990), and Dumas (2013). The model of Elzinga et al. (1995) also includes the selection phase of the process, while the Jeston (2018) model name this phase as Launch pad. It is one of the most important steps to select the initial critical process for improvement. The details are shown in Table 4.

**Table 4:** Process identification and selection

Phases of UPT	BPM life cycles					
Radović et al. (2012)	ABPMP (2009)	BPM Resource Center (2014)	Davenport & Short (1990)	Dumas (2013)	Elzinga et al. (1995)	Jeston (2018)
Identification and creation of a logical model of the subject of work	Analysis	Define (as is and to be)	Identification of business process	Process identification	Process selection	Launch pad
Process identification and process model design						
Process connection of global (anatomical) and organizational structure						
Selection of priority, critical and key processes						

Design and modeling begin with a process specification (Table 5). The specification phase is addressed in different ways in the models, and can be found under the names: modeling, design, discovery, etc. However, by comparing the description of the phases, it was determined that all models with that phase have a common goal, created: documentation, modeling, design and process decomposition. Also, this category includes establishing a system for measurement, monitoring and reporting. Comparing the phases, it was noticed that models from Davenport and Short (1990), Elzinga et al. (1995) and Hallerbach et al. (2008) recognize this phase with a similar name.

**Table 5:** Process design, (as-is) modeling and establishing the measurement system

Phases of UPT	BPM life cycles												
Radović et al. (2012)	ABPMP (2009)	BPM Resource Center, 2014	Davenport & Short (1990)	Dumas (2013)	Elzinga et al. (1995)	Hallerbach et al. (2008)	Houy et al. (2010)	(Jeston 2018)	Netjes et al. (2006)	Pereira et al. (2019)	Van der Aalst (2004)	Weske (2007)	Zur Muehlen & Ho (2006)
Process specification	Design and modeling	Model		Process discovery	Process description	Modeling	Definition and Modeling	Understand	Design	Process modeling	Design	Design and analysis	Design
Determination of process performance													
Establishing a system for measurement, monitoring and reporting			Understanding the measurement		Process quantification	Frequency and Selection							

Process review, improvement and reengineering includes recording, analysis of the existing state of the process, and the design and implementation of the new state (Table 6). In cycles such as Elzinga et al. (1995), Hallerbach et al. (2008), Houy et al. (2010), the stages of analysis are recognized and are similar to this phase of UTH. It represents the basis for process redesign, and this phase is clearly seen in the models of Dumas (2013), Pereira et al. (2019), Szelagowski (2018).

**Table 6:** Process redesign (to-be)

Phases of UPT	BPM life cycles									
Radović et al. (2012)	Davenport & Short (1990)	Dumas (2013)	Elzinga et al. (1995)	Jeston (2018)	Netjes et al. (2006)	Pereira et al. (2019)	Szelagowski (2018)	Van der Aalst (2004)	Weske (2007)	
Process review, improvement and/or reengineering;	Information technology	Process analysis		Innovate	Configuration			Configuration	Configuration	
	Designing and prototyping the new process	Process redesign	Improvement opportunities selection			Process redesign	The (re)design			

According to UPT, the phases of implementation, monitoring and control can occur as separate phases, but also as grouped phases in the life cycles of BPM (Table 7). Those steps are included in the last phase in UPT - Continuous improvement, monitoring, and process management. That phase is very important, because the success of continuous process improvement depends mostly on the results of the previous phases of applying the process approach (Radović et al., 2012). If the base is set in the right way, the continuous monitoring and improvement of the process will be the final stage that ensures the closure of the BPM life cycle. Also significantly, Continuous monitoring and process improvement relies heavily on tools, such as the Plan-Do-Check-Act methodology (PDCA) and other lean tools, to help improve processes. For most authors, the phase of implementation/execution is isolate from the other phases, but it is the part of the CI, monitoring and process management in UPT. In the end, for the most of BPM life cycles, it is necessary to make a process optimization, maintenance of BPM culture and constant evaluation of system performance.

To compare different phases, it is necessary to analyze how the author defined them. The name of the phase is not enough to conclude about the goals of that phase in every BPM life cycle. For example, the phase such as diagnostics (Netjes et al., 2006; Van der Aalst, 2004), involves providing information to identify opportunities for improvement. It is similar to the optimization in models from BPM Resource Center (2014), Hallerbach et al. (2008), Houy et al. (2010), and the analysis and diagnosis in model from Szelągowski (2018).

**Table 7:** Continuous process improvement (implementation, monitoring and optimization)

Phases of UPT	BPM life cycles														
Radović et al. (2012)	ABPMP (2009)	BPM Resource Center (2014)	Davenport & Short (1990)	Dumas (2013)	Elzinga et al. (1995)	Hallerbach et al. (2008)	Houy et al. (2010)	Jeston (2018)	Netjes et al. (2006)	Pereira et al. (2019)	Szelagowski (2018)	Van der Aalst (2004)	Weske (2007)	Zur Muehlen & Ho (2006)	
CI, monitoring and process management	Implementation	Execute	Implementation	Process implementation	Implementation		Implementation	Implement / Develop			The implementation and adjustment	Execution	Operation	Implementation	
						Execution and monitoring	Execution		Execution						
	Monitoring and control	Monitor		Process monitoring			Monitoring and control		Control	Process monitoring and CI	The execution and monitoring			Monitoring	
	Refining	Optimize			CI cycle	Optimization	Optimization and Improvement	Realize value / Sustainable performance	Diagnosis		The Analysis and diagnosis	Diagnosis	Performance Evaluation	Evaluation	
					Benchmarking										

## 4. CONCLUSION

This research provides an overview of existing BPM life cycles found in literature, with the Universal process technology approach as a reference model. Fourteen BPM life cycles were selected for comparison and compared with UPT. In relation to Q1, this research indicates present differences regarding the number of phases and inconsistency between the names of phases of each BPM life cycle. It was noticed the lack of strategic planning as an initial step in the initiation of BPM projects. Regarding Q2, by comparing the phases in all life cycles, it was noticed that it is possible to systematize the phases of BPM life cycles. Five categories were made: (1) Strategic planning, (2) Process identification and selection, (3) Process design, (as-is) modeling and establishing the measurement system, (4) Process redesign (to-be), and (5) Continuous process improvement (implementation, monitoring and optimization).

Successful companies must operate in dynamic environments and therefore business processes must respond to constant changes. Current BPM practices are not sufficient for companies to respond to dynamic changes in the market. Because of that, BPM needs to move to an upgraded BPM approach, where companies need to use new approaches, principles, and methodologies in BPM projects. Newer methodologies ensure a quick observation of the benefits of implementation and accelerate the implementation of BPM knowledge (Badakhshan et al., 2019). This research observes the shortcomings of the existing traditional BPM life cycles. Beerepoot et al. (2023) recognized a future trend of integrating BPM with multiple disciplines, for improving the phase of redesign and continuous management of business processes. According to this, future research will include the integration of lean management approach in BPM life cycle phases. Regarding the limitations of this research, the literature review can be improved with non-traditional BPM lifecycles, such as comprehensive or agile BPM.

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# COMBINING LEAN AND DISCRETE-EVENT SIMULATION IN MANUFACTURING PROCESSES: A SYSTEMATIC LITERATURE REVIEW

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**Abstract:** *This paper aims to explore current state-of-the-art of combination of Lean and Discrete-Event Simulations (DES) in manufacturing processes. Through systematic literature review of 48 relevant articles from peer-reviewed international journals, four main purposes of combining Lean and DES were identified. Each purpose was explained in terms of how Lean and DES can be combined, illustrating different approaches (ways) followed during implementation. Results demonstrate that combined application of Lean and DES not only excels in process improvements, but DES can also serve as powerful educational tool. This review provides valuable insights in structured way and identifies future research directions for researchers and practitioners seeking to improve manufacturing processes with Lean and DES.*

**Keywords:** *Lean; simulation; DES; manufacturing; review;*

## 1. INTRODUCTION

Lean, originating from Toyota production system, has become a dominant operational excellence paradigm in manufacturing industry, focusing on waste reduction to enhance efficiency and effectiveness of organization through continuous improvements (Tomašević et al., 2021). However, despite significant benefits that Lean offers for system improvement, iterative implementation of Lean concepts, tools, and practices often involves time-consuming trial-and-error steps, potentially contradicting Lean principles and resulting in wasteful processes (Marvel & Standridge, 2009). Furthermore, not considering variations, lacking dynamicity, and inability to evaluate non-existing processes before implementation are argued to be some of main limitations of Lean tools and practices (Uriarte et al., 2015). To tackle these challenges, researchers have proposed supplementing Lean with simulations, emphasizing the complementation and potential benefits of their combination (Robinson et al., 2012; Standridge & Marvel, 2006). Particularly, DES is the most common simulation technique used in design and improvement of manufacturing systems and processes (Jahangirian et al., 2010; Negahban & Smith, 2014). Despite emphasis on significance of their combination to a broad community of researchers and practitioners (Jarkko et al., 2013), and existence of numerous systematic reviews focused on application of simulations in manufacturing (Jahangirian et al., 2010; Negahban & Smith, 2014), none have specifically addressed the combination of DES and Lean. Moreover, there is a gap in literature for comprehensive reviews of their combination within specific application domains, especially those that do not view Lean merely as set of tools and practices (Goienetxea Uriarte et al., 2020). This paper aims to fill the gap by providing comprehensive overview of the combined implementation of Lean and DES in manufacturing processes. By examining existing literature, primarily focusing on field studies, we seek to derive the main purposes and approaches underlying this combination. To the authors' knowledge, this is the first systematic literature review to examine combination of Lean and DES in manufacturing processes. The rest of this paper is structured as follows: Section 2 outlines the review methodology, Section 3 presents the analysis results, followed by discussion and conclusion in Section 4.

## 2. METHODOLOGY

Systematic literature review procedure was followed as defined by Tranfield et al. (2003). Research process stages are outlined in subsections 2.1. to 2.3, covering research question formulation, sourcing, screening, and analysis of the articles.

## 2.1. Research question formulation

This research aims to explore current state-of-the-art of the combination of Lean and DES in manufacturing processes. To achieve that, we asked the following research question:

- What are the main purposes of combining Lean and DES in manufacturing processes, and what are the different ways to achieve these purposes?

The review will primarily focus on field studies in manufacturing processes rather than theoretical or conceptual frameworks. These studies may be conducted in real-world manufacturing systems, where the company and its manufacturing process are described. Alternatively, there may be hypothetical scenarios with a manufacturing process not necessarily derived from real-world systems. Either approach will be included in research scope as long as they provide clear method followed during implementation of Lean and DES. Documents providing theoretical or conceptual frameworks for combined implementation of Lean and DES will not be analyzed unless they are subsequently validated with one of the approaches mentioned before. Other simulation methods (e.g. Agent-Based Modeling or System Dynamics, etc.) or their combinations (e.g. Multi-method or Hybrid Modeling) will not be considered. However, studies integrating some optimization techniques with DES will be included in the review.

## 2.2. Sourcing and screening of the articles

The Scopus bibliographic database was used as the primary source due to its large coverage of important journals in management and engineering (Goienetxea Uriarte et al., 2020). To ensure the quality of the sources search was limited to peer-reviewed international journal articles and articles in press, excluding books, conference papers, and white papers. The initial search conducted in March 2024, using the query "Lean" AND ("Manufacturing" OR "Production") AND ("Discrete Event Simulation" OR "Discrete-Event Simulation") across article titles, abstracts, and keywords, yielded 240 documents. Filters were applied to limit the documents to "articles" written in English, resulting in 96 articles for the initial sample. Reading and analysis of titles, keywords, and abstracts of all 96 articles was done by two researchers independently, to mitigate the possibility of including articles irrelevant to the research question. In case of any doubts, tendency was to include the article in the sample. Accordingly, the sample was reduced to 65 articles. Using several channels, 53 articles were retrieved for full-text screening. After evaluating retrieved articles, 5 were excluded, leaving a final sample of 48 articles for systematic review analysis. The reference list at the end includes only articles directly referred to in the review. The full list of 48 articles can be requested from the corresponding author. The sourcing and screening procedure, with inclusion/exclusion criteria, is summarized in Table 1.

**Table 1** - Articles sourcing and screening procedure

<b>Sourcing</b>	<b>Database</b>	Scopus
	<b>Search string</b>	"Lean" AND ("Manufacturing" OR "Production") AND ("Discrete Event Simulation" OR "Discrete-Event Simulation")
	<b>Search fields</b>	Titles, abstracts, keywords
	<b>Inclusion criteria</b>	<ul style="list-style-type: none"><li>• Articles and articles in press in peer-reviewed international journals</li><li>• Articles written in English</li><li>• All years of publication</li></ul>
<b>Screening</b>	<b>Exclusion criteria</b>	<ul style="list-style-type: none"><li>• Articles with a focus on improving the system's performance with Lean or DES individually</li><li>• Articles marginally addressing Lean or DES</li><li>• Articles using simulation methods other than DES</li><li>• Articles related to non-manufacturing processes</li><li>• Theoretical/conceptual articles (without featuring field studies)</li><li>• Full content access denied</li></ul>

## 2.3. Analysis of the articles

To extract information and reduce subjectivity two researchers reviewed articles and cross-checked the results. Regular meetings were held to address any issues that arose. Two-dimensional matrix in Excel was formed, and questions were asked for each article: How is the combination of Lean and DES implemented in manufacturing process (approach used)? What was the driving purpose behind the combined implementation of Lean and DES?

## 3. RESULTS OF THE ANALYSIS

In response to the question about purposes driving the combined implementation of Lean and DES, existing purposes and ways of combination were reviewed and re-categorized based on our findings. The four proposed purposes are

presented and described in Table 2. The following subsections will address each purpose, explaining ways (approaches used) of combining Lean and DES.

**Table 2 - Purposes of combining Lean and DES**

Purpose	Description
Current state evaluation	Combining Lean tools and practices with DES to evaluate manufacturing processes, identify problems, and determine improvement areas.
Future state evaluation	Using DES to evaluate proposed Lean improvements and validate their feasibility before implementation in real system.
Achievement of Lean objectives through DES	Using DES as Lean tool to achieve Lean objectives (and therefore achieve greater "Leanness"), rather than combining it with other Lean tools and practices.
Education	Utilizing DES to transfer knowledge and stress the importance of Lean manufacturing concepts and practices.

### 3.1. Current state evaluation

To evaluate the current state of a process, articles typically follow two approaches. In the first, evaluation starts with one or more Lean tools and practices. These include: Value Stream Mapping (VSM) (Alzubi et al., 2019; Atieh et al., 2016; J. Maas & R. Standridge, 2015; Poswa et al., 2022; Schmidtke et al., 2014; Sremcev et al., 2019; Stadnicka & Antonelli, 2015; Zhang et al., 2022), Pareto analysis (Alzubi et al., 2019; J. Maas & R. Standridge, 2015), Yamazumi charts (Poswa et al., 2022), and Gemba Walks (Barni et al., 2020; Zhang et al., 2022). As development of DES for manufacturing processes requires list of operations, events, and moveable objects like materials and/or information (Barni et al., 2020), data gathered during the implementation of Lean tools and practices serve as a basis for building current state DES. Conversely, studies following second approach begin by developing the DES model first (Detty & Yingling, 2000; Harish et al., 2023; Makinde et al., 2022; Rane et al., 2017). Additional necessary input data to define stochastic variables (processing times, inter-arrival times, sequencing rules, product demand, number of operations/workstations, type and number of resources assigned to workstations, setup times, changeover times, etc.) are collected through system observation, interviews, workshops, archival documentation, or assumed by researchers. The main limitation of simulation models is related to the extent to which they can be compatible with actual system (Stadnicka & Antonelli, 2015). Therefore, regardless of the approach followed, DES model validation was necessary before continuing with further analysis, to ensure the accurate representation (Atieh et al., 2016). That is achieved by tracing process flow, animation of the model, and comparing simulation results with real-world system data, or data provided by Lean tools (Schmidtke et al., 2014). DES validation is followed by gathering and evaluating simulation results on various performance measures (throughput rate, defects, lead time, takt time, work in process, resource utilization rates, downtimes, idle times, costs, etc.). Additionally, further analysis of findings is done to identify causes of problems and areas for improvement by utilizing Lean tools and practices, including VSM, Kaizen, Ishikawa diagram, 5W1H, Pareto analysis, Bottleneck detection, Overall Equipment Effectiveness analysis, etc. (Alzubi et al., 2019; Harish et al., 2023; Makinde et al., 2022; Nedra et al., 2022).

### 3.2. Future state evaluation

In this context, two different approaches are identified: those building upon current state evaluation and those that do not. In the former, studies extend from current state evaluation by drawing future state VSM and/or utilizing DES to simulate the impact of improvements on performance measures before their implementation. Improvements are based on Lean principles and practices, addressing causes of problems and improvement areas identified in the current state evaluation. In the latter case, initial development of future state VSM and/or DES is followed by their validation (Geraghty & Heavey, 2010; Koulouriotis et al., 2010; Prakash & Chin, 2014). Further steps mentioned hereinafter are common to both approaches. The level of detail when mentioning proposed Lean improvements varies across studies. Some improvements are discussed in general sense, derived from and aligned with Lean manufacturing concepts, but without specific reference to tools or practices employed. For instance, reducing WIP between workstations and improving flow without explicitly stating which just-in-time (JIT) pull-control strategy is used (Detty & Yingling, 2000; Kilic & Erkeyman, 2021), or introducing changes such as adding additional machines/operators to workstations (Atieh et al., 2016; Nedra et al., 2022; Rane et al., 2017), removing non-value added activities (Rane et al., 2017; Sremcev et al., 2019), reducing lot sizes (Detty & Yingling, 2000), modifying process layouts (Nedra et al., 2022; Rane et al., 2017), etc. Conversely, certain studies explicitly name Lean tools and practices implemented, such as supermarkets/Base stock/Kanban/CONWIP/Extended Kanban/Hybrid Kanban-CONWIP (Geraghty & Heavey, 2010; Heravi & Firoozi, 2017; Koulouriotis et al., 2010; Prakash & Chin, 2014; Stadnicka & Antonelli, 2015), Andon system that alerts when problems occur (Detty & Yingling, 2000), reducing setup times with Single-Minute Exchange of Die (Harish et al., 2023; Kiris et al., 2023), optimizing workstation layouts with 5S (Nedra et al., 2022; Sremcev et al., 2019), introducing Poka-Yoke (Harish et al., 2023), incorporating maintenance operations based on Total Productive Maintenance to minimize defects and breakdown times (Barni et al., 2020), etc. Based on proposed improvements,

future state DES is modified or developed. If future state VSM is already developed with different changes integrated within it, future state DES is built based on it. Since VSM is viewed as static, descriptive model that does not include variability, DES can validate future state VSM, ensuring its feasibility and accurate reflection of desired process behavior (J. Maas & R. Standridge, 2015; Sremcevic et al., 2019). Subsequently, improvements are evaluated by running simulations and comparing results of performance measures to determine the most effective solution. Based on obtained results, these steps may involve iterative modifications to the model if desired performance levels are not achieved. Notably, two studies employ Kaizen events to facilitate decision-making in selecting the best solution (Harish et al., 2023; Nedra et al., 2022).

### **3.3. Achievement of Lean objectives through DES**

In this context, DES serves as a tool for achieving Lean objectives, rather than being directly combined with Lean tools and practices. The focus is on designing or improving processes according to Lean manufacturing concepts, thus contributing to the journey of achieving greater "Leanness". There is no specific mention of combining VSM/DES or using Lean tools to analyze or improve the process as in 3.1. or 3.2. Instead, the problem and desired objectives are defined, and then DES is employed to achieve those objectives. Additionally, optimization techniques may be incorporated into DES in this approach to achieve so-called simulation-based optimization (Bocanegra-Herrera & Orejuela-Cabrera, 2016; Saavedra Sueldo et al., 2024). This involves exploring parameter spaces and adjusting input variables or decision parameters within simulation model to find optimal solutions for specific Lean performance measures, such as maximizing throughput or utilization rate, minimizing lead time or work imbalances, optimizing resource allocation or production schedules, etc. For example, Bocanegra-Herrera & Orejuela-Cabrera (2016) designed a cellular manufacturing system with parallel cells considering multiple Lean measures: process performance (measured by WIP, flow time, and cycle time), waste (measured by idle time percentage), and reliability (measured by number of cells). Through optimization, they generated several candidate solutions, which were then evaluated based on Lean measures using DES. Similarly, Saavedra Sueldo et al. (2024) aimed to reduce Lean wastes by targeting transportation, inventory, and idle times. This was achieved by minimizing material handling with simulation-based metaheuristic optimization using DES. Combination of DES and optimization techniques showed successful results without requiring expert knowledge, facilitating implementation of Lean 4.0 concepts. Therefore, DES contributed to the Lean transformation journey by streamlining decision-making to achieve Lean objectives.

### **3.4. Education**

The only article that falls under this purpose is written by Schroer (2004). Unlike previously described purposes, here DES is used to transfer knowledge about Lean manufacturing concepts and practices rather than as an improvement tool. Instead of improving processes through combination of Lean and DES, the objective is to stress the importance of Lean manufacturing concepts through DES. The study describes training simulation of Lean manufacturing concepts on process that produces an electronic device. Key concepts covered include line balancing in relation to takt time, comparison between pull and push manufacturing, implementation of Kanban inventory control policies, and reduction of process variability. Focus is on continuous improvement, variability reduction, and process optimization to enhance productivity and customer satisfaction.

## **4. DISCUSSION AND CONCLUSION**

As highlighted in previous subsections, Lean and DES may be combined for four purposes, each determining possible ways of combination. Proposed purposes differ from those of Robinson et al. (2012) and Uriarte et al. (2015). The reason for this difference is that purposes proposed by those researchers are not based on findings from the literature or results of the review of existing practices but rather serve as conceptual frameworks for how DES can be used over time and in different phases of improvement initiatives. Conversely, our purposes were derived based on systematic research of field studies conducted in manufacturing processes, representing current state-of-the-art and providing insight into common practices. As there was a need to consider the combination of Lean and DES beyond viewing Lean merely as a set of tools that can be combined with DES (Goienetxea Uriarte et al., 2020), purposes given in subsections 3.3. and 3.4. expand the scope of Lean. In subsection 3.3., DES is seen as an independent tool for achieving Lean objectives, contributing to greater "Leanness" of the system. In subsection 3.4., DES serves as an educational tool for teaching Lean concepts and practices. However, despite simulations being highlighted as good educational tool for teaching Lean concepts (Adams et al., 1999), it seems that current state in manufacturing processes is still at level of purposes 3.1. and 3.2. This is evidenced by fact that only one article employs DES for educational purposes. We assume that this disproportion is mainly due to time-consuming validation and selection of right improvements in real processes, as it often requires experimentation with actual system. DES, on the other hand, provides a risk-free environment where proposed improvements can be easily and quickly evaluated in various scenarios before their final implementation in real system. To ensure that simulation results accurately reflect the process performances after the implementation of improvements, proper validation of a DES model is crucial before



proceeding with any further experimentation. Additionally, it is important to note that boundaries between purposes are not fixed, as they are complementary to each other, and there may be certain degree of combination between them. Some studies can satisfy multiple purposes simultaneously by starting with the current state evaluation of the process, followed by simulation-based optimization of process layout and resource allocation. Accepted solutions may serve as a basis for further Lean improvements, such as different JIT pull-control strategies, which are evaluated in the future state evaluation. After implementation, developed DES may be used for training purposes to teach workers about implemented Lean concepts and practices. We believe that such combination is highly desirable, as each purpose represents one piece of the puzzle in achieving greater comprehensiveness in improvement initiatives. For future work, we emphasize the need for articles that will investigate the application potential of DES for educational purposes rather than just for process improvements, as well as for theoretical frameworks and field studies that will further elaborate and integrate mentioned combination of all four purposes.

In response to the need for systematic reviews on combining Lean and simulations with focus on specific types of simulations and specific application domains (Goienetxea Uriarte et al., 2020), this research aimed to explore current state-of-the-art of combining Lean and DES in manufacturing processes. To achieve that, we attempted to answer the question: What are the main purposes of combining Lean and DES in manufacturing processes, and what are the different ways to achieve these purposes? Four purposes were identified: current state evaluation, future state evaluation, achievement of Lean objectives through DES, and education. Each purpose was explained in terms of how Lean and DES can be combined, highlighting common approaches (ways) followed. Moreover, research revealed that the combined application of Lean and DES not only excels in process improvements, but DES can also serve as an educational tool. Managers should consider incorporating DES into training programs to enhance employees' understanding of Lean manufacturing concepts and practices. This research may serve as foundation for organizations to gain detailed insights about possible ways of combining Lean and DES to optimize manufacturing processes. The main limitations of this review are the use of Scopus as a primary database and its focus only on articles published in peer-reviewed international journals. Additionally, as with many systematic reviews, the analysis of articles is quite subjective, although efforts were made to mitigate subjectivity bias by having multiple researchers review the articles.

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# THE CONVERGENCE OF VALUE STREAM MAPPING AND ROBOTIC PROCESS AUTOMATION FOR WASTE ELIMINATION AND COST SAVINGS

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**Abstract:** *This paper examines the symbiotic relationship between Value Stream Mapping (VSM) and Robotic Process Automation (RPA) as a strategic approach for waste reduction and cost optimization. VSM serves as a tool for visualizing and analyzing process flows, enabling the identification of inefficiencies and areas of waste. RPA, on the other hand, automates repetitive tasks, enhancing workflow efficiency and minimizing errors. By using VSM within RPA development, organizations can comprehensively map their processes, identify bottlenecks, and automate routine tasks to improve productivity and reduce costs. This paper explores the principles of VSM and RPA, their complementary nature, and presents case studies illustrating successful implementations in the logistic service company. Additionally, practical guidance is provided for organizations aiming to leverage this convergence to achieve operational excellence, eliminate waste, and realize significant cost savings.*

**Keywords:** *Robot Process Automation, Visual Stream mapping, operational excellence, Lean*

## 1. INTRODUCTION

Although, automation has been around since the early 1920s, it became popular in 1990, particularly in corporate world. A modern technology called robotic process automation (RPA) assists mainly in carrying out tedious manual activities in a computer environment (Kappagantula, 2023). Put another way, RPA is business process automation technology that enables a person or an organization to specify a set of guidelines that will be followed by RPA-designated software (Badgujar et al., 2022). Simple and widely used, RPA has its own market that is predicted to develop at a quick rate each year, from ~2B in 2021 to ~13.4B in 2030 (Dilmegeani, 2024).

RPA offers effective automation solutions for various back-office processes across finance, procurement, supply chain management, accounting, and HR departments. Processes such as invoice processing, customer and contact registration, order registration, and new employee induction prerequisites can be streamlined using RPA technology (Zaharia-Rădulescu et al., 2017). RPA are for systematic automation challenges, providing businesses with a virtual workforce to enhance customer satisfaction and enterprise agility. They significantly improve operational accuracy, execute repeatable tasks precisely and quickly, and offer detailed audit logs for oversight. Moreover, RPA facilitates centralized bot management for easy scaling, leading to cost reductions compared to full-time employees. It boosts productivity by autonomously executing tasks, improves employee morale by relieving them of repetitive tasks, and enhances transparency and compliance through standardized processes and audit trails. RPA also generates valuable data for process optimization and ensures high-quality data for reliable analysis, ultimately improving operational quality and efficiency in the service industry (Devarajan, 2018).

Although RPA offers numerous benefits such as increased efficiency and reduced errors, its implementation can be impeded by factors such as complex unclear processes, resistance to change, and not defined end-to-end processes. Additionally, the costs associated with setup, maintenance, and training, as well as the

need for skilled personnel and adherence to regulatory compliance, pose significant obstacles to successful RPA deployment (Kotb et al, 2018).

The paper will delve into how Value Stream Mapping enhances RPA development by initially visualizing all process steps and subsequently identifying wasteful and value-added/non-value-added tasks. In the introductory section, we will define RPA, enumerate its key benefits, and outline the purpose of this paper. Following that, the subsequent section will provide an overview of relevant literature on the topic. Finally, the third and fourth sections will present a case study.

## **2. THEORETICAL BACKGROUND**

Despite, all its advantages as it was determined, RPA may also have several impediments, such as staff members who are unaware of the potential for automation, poorly stated business requirements, and unclear process stages due to lack of interdepartmental coordination. Challenge that are highlighted is the prospect of automating wasteful or non-value-added processes as a broad picture of the process is frequently overlooked (Prabodha & Liyanage, 2023). Even though, RPA excels at replicating human mechanical tasks so efficiently, it's easy to overlook underlying issues within processes or systems. There's a danger that RPA users might prioritize quick fixes over addressing the root cause of problems (Järvinen, 2021).

Consequently, some of mentioned disadvantage can be overcome by using two methodologies together Lean and RPA, called Lean RPA as authors defined (Mamede et al., 2023). Lean RPA leverages continuous improvement by automating and altering processes beyond what traditional RPA projects would tackle. Processes studied were developed and implemented easily and securely, unlike more complex ones. Lean RPA's affordability, rapid development, and efficacy can transform organizational processes with the right enhancements, leveraging existing internal teams' expertise (Mamede et al., 2023).

Kedziora et al. (2024) explore the concept of "Leanbotics" in their literature review, a service aimed at improving operational efficiencies and fostering organizational acceptance. Drawing from Lean management and Kaizen principles, "Leanbotics" emphasizes continuous process refinement and waste reduction. The authors note parallels between Lean management tools, like current and future state mapping, and RPA's process mapping. This alignment highlights a shared methodology, with Lean management emphasizing visual representations and RPA streamlining processes—a critical aspect in planning new RPA systems. By integrating "Leanbotics", organizations can blend Lean management principles with RPA, empowering citizen developers and accelerating digital transformation while promoting a culture of ongoing improvement (Kedziora et al., 2024).

One of it is Lean RPA framework (Mamede et al., 2023) which describe four phases important for efficient process improvement by combining Lean and RPA:

- Process Selection: Define Value Stream, map processes, identify waste, repeat if not suited for RPA.
- Process Study: Analyze RPA capabilities, define kaizen plans, map future state, set SMART goals.
- RPA Project Development: Develop robot, implement changes, consider standardization.
- Maintenance & Review: Review goals, go live if achieved, iterate for continuous improvement.

It's clear that main tool used in first two phases is Value Stream Mapping (VSM) for purpose of process mapping AS IS state but also for waste identification and TO BE state mapping. Also, it emphasizes the need to integrate a process improvement approach into the RPA lifecycle before implementation. Additionally, it highlights that Value Stream Management steps often overlook opportunities for both robotic and non-cognitive automation (Mamede et al., 2023).

Furthermore, the proposed Lean RPA framework is not a standalone solution, and it is tailor made for bank process that's why authors suggest trying other industries. Every company need their own model regarding project management tool that are used (Mamede et al., 2023).

## **3. RESEARCH DESIGN**

This paper seeks to address the following research question:

- How can we effectively integrate VSM and RPA to optimize costs and eliminate waste in process improvement?"

The following section outlines the research design formulated to address this inquiry. The chosen research design involves a case study methodology as the intention of this research is to explore the phenomenon in a natural setting, i.e., the company (Voss et al., 2002), which involves examining a particular case company in detail and justifies the decision to employ a single case study approach. The research is focused on a single organization that can present two scenarios: one RPA development without fully integrated VSM and another with it.

### 3.1 Case company: description

The focus on internal processes that doesn't require comparisons justifies the use of a single company for this study (Yin, 2018). The company X (real name obscured for confidentiality reasons) is a worldwide company, which provides 4PL, 3PL, and LSP models to a range of clients in the logistics services sector is focus organization for this research. Among it, company is a supply chain operator and logistics company, offering a comprehensive range of services in freight forwarding, contract logistics, and transportation. With a presence in over 120 countries, specializes in providing tailored solutions to meet the complex logistics needs of various industries. The company is known for its innovative approach to logistics, leveraging advanced technology and industry expertise to optimize supply chains and enhance operational efficiency for its clients worldwide. The company's customer-centric approach is reflected in its utilization of tailored processes characterized by numerous manuals, repetitive tasks such as reading PDF documents, generating orders, managing email correspondence, among others. These practices underscore the organization's steadfast commitment to pursuing strategies aimed at enhancing productivity and efficiency and pursuing LEAN and RPA as main tools.

### 3.2 VSM and RPA convergence framework

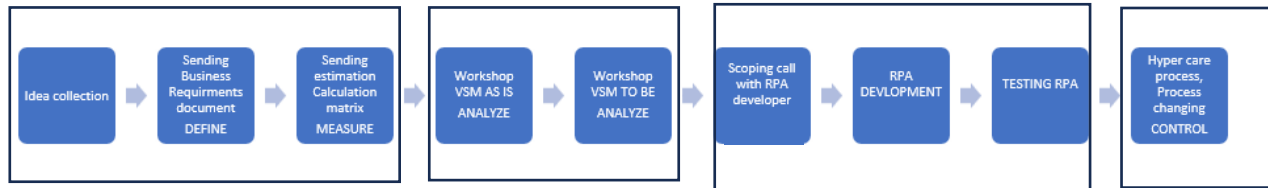
As part of operational efficiency strategy, Lean is established support for Operations team and clients. By embracing Lean methodologies, company aims to streamline operations, reduce waste, and improve overall productivity across its global network. This approach involves continuous improvement efforts, employee involvement in problem-solving, and a focus on delivering value to customers while minimizing costs.

The integration of Robotic Process Automation (RPA) as a tool for process enhancement within the organizational framework followed the initial adoption of Lean principles. Initially, RPA implementation existed as discrete endeavors conducted by disparate teams within the company. However, over time, the necessity for a unified operational model and streamlined project management protocols became apparent. Consequently, a novel procedural framework emerged through collaborative efforts involving the Operations team, the Business Excellence team, and client stakeholders.

This initiative was facilitated through a series of workshops aimed at collectively addressing a central inquiry: "In what manner can potential areas for improvement, process automation opportunities, leading to cost efficiency gains and waste reduction, be identified?"

Figure 1 outlines the framework used for integrating VSM and RPA. After the framework has been created, the training for each team was conducted and procedure designed in order to facilitate the framework implementation.

Process selection	Process study	RPA solution development	Hyper care
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**Figure 1:** Framework for integrating VSM and RPA

The integration framework follows process planning method, as shown in Figure 1, it is divided into four phase and after first two there is need for gates as approval point for project in this case RPA development to be proceeds. The procedural sequence denoted as "Process Selection" initiates with the inception of idea collection, delineating distinct objectives for each team involved. Subsequently, upon the submission of the preliminary iteration of the Business Requirements Document (BRD), inclusive of fundamental information such as process nomenclature, departmental affiliation, FTE allocation, estimated workload and lead times, as well as key performance indicators (KPIs) and problem delineation, the formulation of an estimated calculation matrix ensues, employing a predefined template structure. These two aforementioned documents constitute the requisite components for Gate 1 validation, necessitating approval from the Business Excellence Manager and a Lean expert.

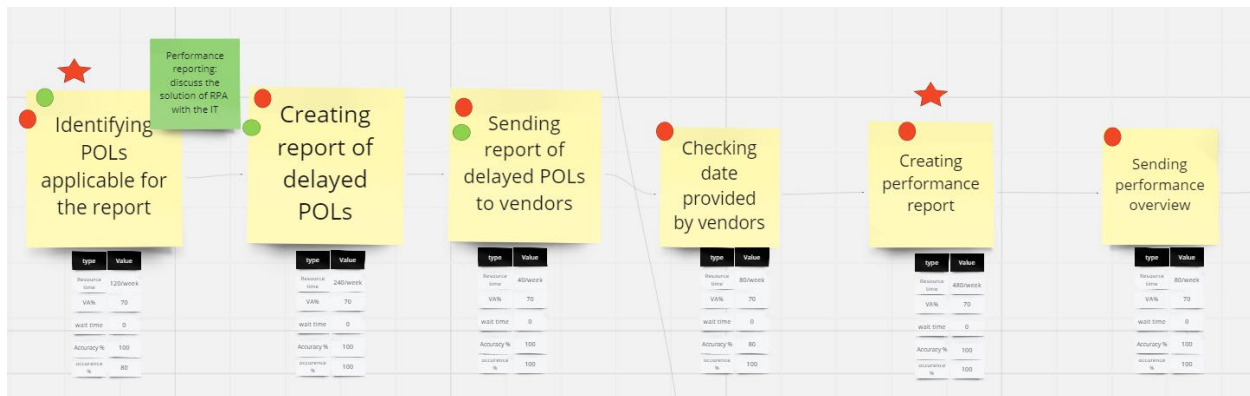
Upon the successful conclusion of Gate 1 deliberations, the VSM methodology is invoked as the principal analytical tool, engaging all relevant stakeholders in a workshop setting, including employees with vested interests, Lean experts, and RPA developers. During this phase, delineation of process steps, identification of value-added and non-value-added activities, as well as the detection of wasteful elements, are undertaken in conjunction with brainstorming sessions. Of paramount significance is the provision for employees to elucidate the existing operational modalities ("AS IS"), thereby enabling RPA developers to discern the cognitive versus repetitive manual nature of tasks and ascertain the presence of pre-established rules and sequential task sequences. The primary objective of the VSM exercise resides in the identification of superfluous process steps within the end-to-end operational framework, thus informing subsequent automation endeavors. The guiding query for the workshop moderator pertains to the customer's willingness to remunerate for the activity in question or the internal customer's cognizance of the temporal investment therein.

Following the VSM phase, the remaining sections of the BRD are comprehensively completed, serving as the foundational basis for Gate 2 validation, contingent upon approval from the IT department. Upon the successful navigation through the initial two gateways, the commencement of RPA development ensues. The culminating phase encompasses Hyper Care and presentation facets, wherein procedural alterations are effectuated, and working instructions are contemporaneously updated to reflect the revised operational paradigm.

#### 4. CASE RESULTS

Scenario 1 describes the integration of VSM and RPA through a framework presented in the previous section. It started as employee's idea to optimize cost and improve process of Vendor management, with a lot of repetitive manual task, low productivity, and same sequence of task. BRD document request as part of Process selection phase had been sent. After approval from Business Excellence manager and Lean expert, as Gate 1, Process Study phase has been initiated. During process design workshop VSM it was discovered that 70% of whole lead time is spent on non-value activities, rest is spent on value added activity which are not going to be scope of RPA project. Also, 5 types of waste were discovered for these activities – waiting, overprocessing, overproduction, defects, and transport (huge number of mails). Usually there were 2 types with the major of tasks – waiting and overprocessing. Overprocessing as waste and non-value-added activity is in the most case source and good candidate for RPA solution. For this project we had two tasks with detected overprocessing (marked with star on figure 2. VSM as part of RPA project), first task was suggested for RPA. Second task "Creating performance report" would be also perfect candidate for RPA in case that this RPA project was done as separated only stand solution or quick win. But in this case of VSM RPA, question was: "Is customer willing to pay for it?" where conclusion done by brainstorming of employees from different department, was that customer has another report on newly

created share where all presented figures can be seen, so action can be eliminated with Key Account approval. After Gate 2, RPA development for one solution started and had been done for 2 weeks, consider that RPA developer was present during two workshop lasting four hours in sum.



**Figure 2:** VSM as part of RPA project

Scenario 2 describes a specific instance of RPA development devoid of VSM workshops, occurring one year prior to Scenario 1. The focal point of this endeavor revolved around the singular task of "Checking date provided with vendors," identified as a prominent time-consuming non-value-added activity, characterized by overprocessing as a form of waste. After the formulation of a Business Requirements Document (BRD), the RPA development initiative garnered approval from the Business Excellence Manager, thereby initiating a three-week development process inclusive of a scoping call, signifying a collaborative alignment between the RPA developer and the Operations team.

**Table 1:** Comparative analysis between Scenario 1 and 2

Scenarios	RPA development hours	NET savings	Value added activity (YES or NO)
Scenario 1 RPA VSM	80hours	0.5	YES
Scenario 2 RPA project	120hours	0.5	NO

Comparative analysis between Scenario 1 and 2 revolves around the RPA developer's time expenditure, which directly correlates with the developmental cost and with operative cost. Despite both scenarios yielding similar Full-Time Equivalent (FTE) savings of approximately 0.5 FTE, the distinction lies in the nature of the automated activity. In Scenario 1, emphasis was placed on automating a value-added activity burdened by clear overprocessing waste, whereas in Scenario 2, the focus shifted towards automating a non-value-added activity. Thus, while savings were achieved in both instances, the selection of the suitable candidate for RPA deployment was pivotal, highlighting the nuanced considerations surrounding process optimization and efficiency enhancement.

## 5. CONCLUSION

The paper explores the integration of VSM and RPA as strategic tools for waste reduction and cost optimization. It emphasizes the symbiotic relationship between these methodologies and their potential to enhance operational efficiency. While RPA offers significant advantages such as improved operational accuracy and efficiency, there are potential obstacles such as inadequate awareness among staff members and the risk of automating wasteful processes. The combination of VSM and RPA emerges as a potential solution to drive continuous improvement and waste reduction.

The case study presented in the paper illustrates the practical application of VSM and RPA integration within a logistics services company. Through workshops and collaborative intradepartmental efforts, the company identified areas of waste and inefficiency within its processes, leading to the development of RPA solutions. By leveraging VSM to visualize process flows and identify waste, the company was able to prioritize RPA

initiatives effectively and achieve significant improvements in operational efficiency, as we can see in Scenarios 1 and 2 where RPA development hours was clearly different, directly influence operative cost.

By combining the analytical capabilities of VSM with the automation capabilities of RPA, organizations can identify and eliminate waste, streamline processes, and enhance operational efficiency. The case study presented in this paper demonstrates the practical application of this approach within a logistics services company, highlighting the benefits of VSM-RPA integration in driving continuous improvement and achieving operational excellence. Moving forward, organizations should consider adopting a Lean RPA framework to maximize the benefits of this convergence and realize significant cost savings.

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# LEAN PROCESS IMPROVEMENT IN HEALTHCARE: A CASE STUDY

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**Abstract:** *In healthcare, the improvement of operational processes remains an ongoing challenge. This paper delves into the vital realm of process improvement methodologies within healthcare institutions, focusing on the transformative potential of lean and Universal process technology approaches. Specifically, it investigates the impact of these methodologies on the critical process of patient examination by general practitioners. Utilizing a comprehensive toolkit including process flow diagrams, Ishikawa diagrams, and value-added analysis, the current state of process is examined with precision. This case study from a health center, offers insights into the application of lean and process methodologies in practice. The results provide an integration of methodologies, such as Training Within Industry (TWI) instructions and process reengineering, further enriching the proposed approach. Consideration of potential effects and challenges represents a significant step towards elevating healthcare operational efficiency, empowering healthcare institutions to navigate the journey of process improvement.*

**Keywords:** *lean, healthcare, case study, process improvement*

## 1. INTRODUCTION

With the increasing notable interest in the application of lean approaches in the healthcare industry, lean healthcare case studies are introduced in a variety of hospital departments, areas, and sub-areas. Staff empowerment and the fundamental lean theory idea of gradual and continuous improvement appear to be the main factors that make lean more suited to healthcare sites than other improvement methodologies. Lean healthcare is thought to be becoming more popular since it produces outcomes that are long-lasting. However, it is still difficult for researchers and professionals to assess lean healthcare from a more critical angle and determine whether it is only a management fad or a worthwhile improvement concept (Brandao de Souza, 2009). This paper explores and discusses how the concept of lean healthcare can be implemented in one large healthcare institution with 785 employees, to improve the identified critical process of patient examination at general practitioners. Process identification is based on the process approach using Universal process technology, to identify the value chain and critical processes that significantly impact the operation of the healthcare institution.

## 2. LEAN APPROACH IN HEALTHCARE

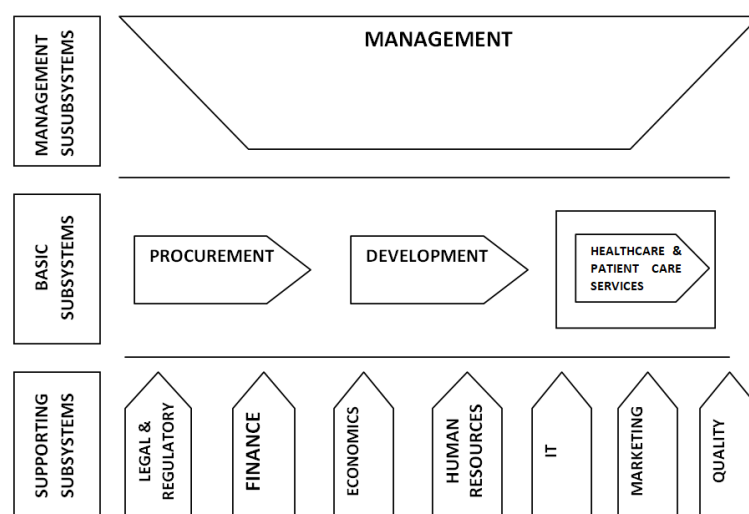
The term “lean” is based on the production method that constantly strives to improve processes, reduce waste when using resources, which affects efficiency, quality and increases profits. This lean philosophy evolved from the Toyota Production System – TPS, as an approach that continuously seeks ways to enhance procedures and reduce waste when utilizing resources, all of which have an impact on productivity, quality, and profitability (Liker & Wu, 2003). Womack et al. (1990) defined lean as “the use of less human effort in the factory, necessary production space, money invested in tooling, spent design hours to develop a new product, which as a result allows for the minimization of inventory and defects, with an increase in the range of products”. The lean approach is introduced in the health system to improve the quality of health services and patient care, better information flow and communication, introduction of IT solutions, finding methods that will help in continuous improvement of patient health, etc. The introduction of a lean approach in healthcare focuses on redesigning and improving ongoing business processes, reducing patient waiting times, and reducing stockpiles of medical supplies and medications (Radnor & Osborne, 2012). Although lean concepts were initially developed to improve production processes, many studies showed that the lean principles could be applied successfully in healthcare organizations (Brandao de Souza, 2009).

From the deployments and findings in the literature, lean healthcare appears to be a useful approach for enhancing healthcare organizations, to reduce the steps that do not add value to the patient, e.g. interruptions, delays, mistakes etc. Brandao de Souza (2009) defines lean healthcare as “an improvement approach that consists of eliminating steps that do not add value to the patients, such as delays, interruptions, mistakes etc., in order to eliminate waste and improve the flow of patients, goods and information”. Many health institutions have already introduced the lean method in their operations, and it helped them to reduce costs caused by duplication of information, unnecessary steps, large number of stocks, lack of staff, etc (Poksinska, Swartling & Drotz, 2013). The lean approach contributed to the reduction of employee dissatisfaction and frustration in the healthcare institutions where it was applied, which were the result of work processes (Mazzocato et al., 2010). According to Proudlove et al. (2008), hospital departments still have a lot of waste to deal with, adding that a deeper understanding of lean may be needed when addressing more complex cross-organizational lean implementations. In their case study, Ben-Tovim et al. (2007) stated that mapping processes across the hospital allowed them to recognise different patient groups, value streams, identify wasteful delays and reduplication along the mapping processes. That was an adequate way to confirm that lean application was useful in core clinical and support services throughout the hospital. Matt et al. (2018) demonstrates how lean, when implemented within the whole supply chain of a healthcare delivery system, can contribute to achieve high staff satisfaction and better process performance. Wackerbarth et al. (2021) state that lean approaches are constantly evolving to meet healthcare needs. Combining tools (DMAIC, VSM, SIPOC, Ishikawa Diagram and 5S), Barros et al. (2021) obtained positive results in time and cost reduction, improvement in the workload and increase in the number of appointments. From these improvements, they concluded that the usage of lean tools and process approach helped in processes improvement in healthcare services.

The process model of the business system constitutes the foundation of any enterprise or institution (Dumas et al., 2018). It serves as the basis for all other business system solutions, including organizational structure, division of labor, authorities and responsibilities, system documentation, cost monitoring, etc. The Universal Process Technology approach (Radović et al., 2012) and its application can create a fundamental business system solution in the form of a process model. Because of that, this approach was used to create a starting point for lean process improvement in healthcare center – the critical process identification. It created the base for the following steps, such as continuous process improvement and implementation of lean approach.

### 3. LEAN PROCESS IMPROVEMENT OF PATIENT EXAMINATION AT A GENERAL PRACTITIONER: A CASE STUDY

This case study provides insight into the successful lean healthcare implementation in one large healthcare center, which provides healthcare services for residents of two municipalities, comprising approximately 220 thousand individuals over an area of about 450 km<sup>2</sup>. The total number of employees is 785, including 193 physicians, 4 pharmacists, 372 nurses, 14 health associates, 27 administrative staff, and 63 technical workers. Additionally, the center employs 41 dentists and 81 dental nurses/dental technicians. The organizational structure of the healthcare center encompasses all organizational units, along with corresponding positions within those units. Following the Universal process technology approach (Radović et al., 2012), the global structuring of the business system, the value chain is depicted. The value chain comprises basic, supporting, and managerial subsystems. The basic subsystem encompasses Personnel, Development, and Core Activity – Healthcare Services and Care (Figure 1).



**Figure 1.** Value chain of the healthcare center

Process identification is one of the most crucial steps in implementing a process-oriented approach. Processes can be categorized as priority, critical, and key processes. It has been determined that several critical processes exist because they influence the achievement of the main goal of the healthcare center, which is to provide quality healthcare and nursing. Improvements can be made to them by applying lean approaches, and one of the critical processes that significantly impacts the operation of the healthcare center is the provision of general practitioner examination services. It is essential to summarize the execution of this process and create an assessment of the current state. Therefore, the process is presented graphically using a process flow and an identification card. This enables further analysis of activities within the process.

### 3.1. Analysis of the current state of the process

Based on the value chain and process identification, the patient examination process at the general practitioner's office has been identified as critical in terms of quality, timeliness, and costs. Several reasons justify this choice, including inconsistent access to electronic health records, unnecessary administrative tasks, time loss during patient admission, poor connectivity between primary, secondary, and tertiary healthcare facilities, among others. Conducting a current state analysis facilitates a deeper understanding of the underlying issues contributing to these problems. It has been recognized that reducing waiting times for appointments with the chosen physician is essential to improve user satisfaction and increase the number of completed examinations. Problems arise during the identification of issues electronically through the patient's e-record due to frequent system failures, power outages, data loss, and the parallel management of both paper-based and electronic patient records. A detailed analysis of the current state of the process involves examining activities that add value (VA), activities that do not add value (NVA), and necessary activities (NVA) that require changes to be eliminated. Details are shown in Table 1.

**Table 1:** Analysis of activities in the process of examining patients at general practitioners

Activity	Duration [min]	Evaluation			Action	Explanation
		VA	NVA	NVAU		
The patient makes an appointment	5			*	Simplify	Transition from phone appointment scheduling to scheduling via website/application.
Arrival of the patient	3			*	Unchanged	This activity cannot be eliminated.
Handing over the health card and inputting into the system	5			*	Simplify	The health card is scanned using a barcode or QR code reader, eliminating manual data entry.
Retrieval of medical records and inputting into the office	4			*	Eliminate	Transitioning to electronic medical records and phasing out paper records eliminates this activity.
Familiarization with medical history	4	*			Simplify	The doctor familiarizes with the medical history before the patient enters.
Patient examination	10	*			Unchanged	The examination must be conducted according to procedures.
Providing diagnosis	5	*			Combine activities	While explaining the diagnosis, the doctor enters the prescribed therapy into the system.
Departure of the patient to the clinic	5			*	Eliminate	Design the layout of the healthcare center so that the clinic is located next to or within the doctor's office.
Administration of injections, inhalations	10	*			Simplify	The nurse in the system views the therapy and prepares it while the patient is still in the doctor's office.
Disposal of medical waste	5		*		Unchanged	Standard procedures are used for disposal.
Patient brings medical records and referral to the counter	5			*	Eliminate	With the transition to electronic records, there is no need for manual data entry.
Nurse enters data and schedules follow-up	5			*	Eliminate	There is no need for data entry; follow-up appointments are scheduled by the doctor or the patient via the application.
Patient goes home	5			*	Simplify	The patient receives their health card upon completion of the doctor's visit and stops by the pharmacy or the laboratory, avoiding waiting at the counter.

Through this analysis, it has been determined that non-value-added activities include: patient appointment scheduling, patient arrival at the healthcare centre, submission of health insurance card and data entry into the system, retrieval of patient records and entry into the examination room, patient transfer to the clinic, patient carrying records and referrals to the counter, and nurse data entry and appointment scheduling. Also, the analysis has revealed a significant problem in this process: poor connectivity of the patient's electronic health record (EHR) with other healthcare institutions. As a result, the physician is compelled to issue a paper referral to the patient for specialist consultation because the specialist does not have access to the patient's EHR. Another issue is the lack of integration between pharmacies and the patient's EHR, preventing pharmacists from accessing the patient's therapy details, even though pharmacists typically conduct a final check before dispensing any medication. Improving healthcare software is necessary to facilitate better communication among staff members and reduce unnecessary time loss.

For the following step of process analysis, an Ishikawa diagram was used as one of the commonly used lean tools. A question was asked about the existing problem and the categories that influence the occurrence of the problem were identified. The problem defined by the Ishikawa diagram, posed in the form of a question, is: "Why does the patient examination take so long?" Potential causes of the problem are identified within different categories using the "5 Whys" method – repeating the question "why" five times until the most probable root cause is reached. The purpose of implementing improvements is to make the job easier, reduce the duration of examinations, increase quality, and lower costs. To achieve this, it is necessary to ensure a state where patient examinations can be conducted without errors, waste, and with the highest possible quality. Therefore, this paper analyzes one of the processes occurring in the healthcare center in detail, through all activities, to identify which activities need to be eliminated or simplified.

### 3.2. Suggestions for process improvement

The proposed measures, presented in the following table, aim to ensure that the process can be carried out as desired and that lean principles are implemented in the healthcare center's operations. Table 2 provides suggestions for lean process improvement, estimated effects and possible challenges in implementing patient examination by general practitioner.

**Table 2:** Suggestions for process improvement, effects and challenges

SUGGESTION FOR IMPROVEMENT	ESTIMATED PROCESS EFFECTS	POSSIBLE IMPLEMENTATION CHALLENGES
Replacement of outdated working materials	More modern materials and equipment for work will further facilitate employees in providing healthcare services (use of digital blood pressure monitors).	Insufficient funds
Introduction of barcode or QR code readers for medical records	It will reduce patient waiting time for the nurse to enter patient data and the possibility of making errors.	Insufficient funds
Connecting healthcare facilities electronically at all levels (health centers connected with pharmacies and hospitals).	If a patient has been examined in location 1 and the doctor has written a referral to a specialist in location 2 along with a report, after the patient goes for the examination in location 2, the specialist will have access to his medical history and all previous therapies, reducing the costs of printing referrals. Currently, electronic healthcare systems are only connected within health centers and pharmacies; it is necessary to connect them with hospitals and specialists in hospitals.	The Ministry of Health and the Health Insurance Fund consider that the existing electronic health record works excellently and do not want to initiate a request for its improvement.
The nurse receives the therapy that she needs to give to the patient before they leave the office.	Integrating systems so that the nurse working in the office is shown which therapy to prepare for each patient, so the therapy will be ready before the patient enters the examination room.	When there are too many patients and only one nurse. She won't be able to prepare all the therapies in time, so some patients will have to wait.
Elimination of the examination completion process, where the patient waits at the counter for a nurse to write all patient's information.	By integrating systems, the doctor would input the referral, diagnosis, and medications, click the finish examination button, and the system would directly record the examination, and prescriptions and referrals would not be issued, as they would be visible in all other institutions by reading the patient's card.	The Ministry refuses to invest money in system improvement.
Introducing TWI instructions.	If TWI instructions can help employees to perform tasks correctly, reduce the possibility of errors or worker injuries, leading to the elimination of waste. Additionally, these instructions will facilitate the work of new employees and prevent them from making mistakes when performing an activity for the first time, as well as assist employees transitioning between positions, particularly those who have not previously performed certain tasks.	It would be beneficial for employees with many years of experience in specific activities to prepare the instructions, with assistance from a process engineering expert.
Training users to transition to a digitized method of scheduling appointments (via	By introducing the MyDoctor application and website, efforts are being made to digitize appointments. It is essential to train people to schedule appointments in this way or through an interactive voice response system, thereby eliminating appointment scheduling via	It is essential to invest in strengthening the information system so that the process can function

SUGGESTION FOR IMPROVEMENT	ESTIMATED PROCESS EFFECTS	POSSIBLE IMPLEMENTATION CHALLENGES
website, application, or interactive voice response system) instead of scheduling via telephone.	telephone. Changing user habits is considered a longer process, as users are generally reluctant to accept changes (especially older citizens who are not up to date with new technologies), but this change will bring significant time savings. Staff who were previously responsible for answering phones throughout the day will be freed from this task and able to perform other duties outlined in their job descriptions, directly addressing the issue of staff shortages. Additionally, alongside digitizing appointment scheduling, information about doctors' shifts should be provided on the website and interactive voice response system, as patients often call to inquire about their doctor's working hours.	flawlessly, but the Ministry is not willing to invest money.
Defining the schedule of appointments throughout the day while leaving space for emergency cases.	One of the problems is the extensive waiting time. This can be addressed by scheduling appointments in advance, while still allowing room for emergency cases at any time. It is necessary to define the number of patients that one doctor can examine during a shift, analyze the average examination time and possible deviations, and schedule appointments within those intervals. If a patient decides to visit the healthcare center on a particular day via the application (or interactive voice response system), they should choose one of the available time slots displayed as free. For emergency cases, there is dedicated time set aside each day. This approach eliminates patient waiting, overcrowding in waiting rooms, and excessive output.	The problems arise with the patients themselves, who are accustomed to the current way of operation at the healthcare center and now need to transition to a different mode of functioning. It is essential to educate people and explain to them why this method is better and the improvements it will bring about.
Phase out the use of physical records and fully transition to electronic records.	In the existing process state, there were 13 activities, and by implementing the lean approach and process improvement, 4 activities have been eliminated, resulting in 9 remaining activities in the process. The activities that have been eliminated include: searching for records and inputting them into the office, patient's visit to the clinic (intervention), patient carrying records and referral to the counter, and the nurse entering data and scheduling follow-up appointments. The removal of physical records from use leads to the elimination of unnecessary activities and time savings previously spent on duplicative record keeping.	Problems may arise at the initial implementation of the new process state because employees need to be trained to work without the activities they previously performed, and to understand how the new technologies work. It is believed that once employees are trained on how the process operates, the process will proceed without issues.
Shortening the duration of appointments with general practitioners from 68 to 30 minutes.	During the analysis of the current state, it was observed that the appointment process with general practitioners lasts a total of 68 minutes. By implementing process improvements, eliminating and simplifying certain activities, the duration of the process has been reduced to approximately 30 minutes, representing a savings and reduction in process time by approximately 55%, which directly addresses patient waiting issues and allows for the processing of a larger number of patients during the working day.	Potential challenges may arise during the implementation of new processes as employees are accustomed to working in a different manner. Therefore, it is essential to train employees and explain to them why this new approach is better and what improvements it brings.

One of the Lean tools that would be beneficial to implement in healthcare institutions is the A3 report, which will assist employees in addressing ongoing issues. It is essential to educate and train employees about the benefits that the A3 report will bring and teach them to apply it in the future. Additionally, as mentioned, using Training Within Industry (TWI) instructions for every activity performed in the process can standardize operations, reducing the possibility of errors during the execution of any activity. It is crucial to create instructions for each activity, as well as for the use of equipment regularly used (such as ultrasound machines, EKG, magnetic resonance imaging, etc.). By creating instructions, each employee will know the exact way to perform a specific activity in the process and will not make mistakes, even if performing that activity for the first time.

#### 4. CONCLUSION AND DISCUSSION

The subject of research in this paper is the improvement of processes in healthcare centers. Therefore, the processes occurring in the observed healthcare center were analyzed to select those critical for operations and goal achievement. The suggestions provided, which should initiate the improvement of business processes, are as follows:

- All examinations should be conducted in a standardized and professional manner, as early detection of any disease can significantly impact patient recovery.
- Introduction of Training Within Industry (TWI) instructions to facilitate daily activities and the use of medical equipment. This would also enable training users on the digitalized appointment scheduling and accessing information about doctor shifts.
- Phasing out physical health records and the manual record-keeping process, transitioning entirely to electronic record-keeping.
- Timely procurement of work materials and equipment to ensure uninterrupted processes.

Integration of healthcare information systems nationwide (currently limited to departmental systems within a single healthcare center and connected to pharmacies), linking the system with all hospitals and healthcare

centers. However, these improvements require significant investment and the engagement of additional funds to secure a better information system and purchase barcode or QR code readers. Yet, in the long run, they bring substantial time and cost savings. It is necessary to engage a team of programmers to work on integrating all healthcare centers, pharmacies and hospitals.

These improvement suggestions should be presented to the healthcare center's director and the Ministry, emphasizing the project's benefits. Initially, employees may express dissatisfaction with this way of working, especially older employees who may not be proficient with new technologies. However, it should be explained to them that these changes will improve and facilitate their work. This project brings many benefits, reducing the possibility of errors, the duration of examinations, increasing patient satisfaction, and employee satisfaction. It is essential to constantly work on the development of healthcare services, keeping pace with technology and improving the provision of all services by following trends in new treatment methods, acquiring new medical equipment, and enhancing employee skills.

As Radnor & Osborne (2012) stated, lean can only succeed when it's seen as a holistic approach that implies a cultural change, rather than being implemented discretely as a set of isolated technical tools. Also, lean requires professionals to share their knowledge with end-users to jointly create value as the only way to fully impact lean application. Without it, the implementation results will not be satisfactory. For future research, it would be useful to examine whether the advantages of proposed applications persist over time and calculate the benefits through different KPIs.

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# RESILIENT STRATEGIES FOR NAVIGATING THE DIGITAL WORK ERA

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**Abstract:** *Digital technologies have profoundly impacted the contemporary work landscape across multiple industries. The onset of artificial intelligence (AI) and automation has brought forth a dual effect where on the one hand, process automation has contributed to redundancy and on the other hand, it has enhanced process efficiency. AI, automation, data analytics, and software as a service (SaaS) infrastructure revolutionize job roles, skills requirements, and workplace dynamics. This study conducts a systematic analysis of the recent literature. It elucidates strategies tailored for policymakers and organizations to effectively navigate the complexities caused by the present-day digital disruption of the workplace.*

**Keywords:** *Automation, artificial intelligence, innovation, sustainability*

## 1. INTRODUCTION

Digital technologies have permeated into the present-day contemporary work landscape, necessitating a paradigm shift by fundamentally changing the way individuals conduct their professional roles, and how organizations operate at large. This paper presents a comprehensive analysis of various resilience strategies that organizations can employ to ensure a pragmatic navigation of the current digital work era. We assess the impact of digital technologies on the work landscape, the challenges brought about by the digital era, opportunities for growth and innovation, and strategies for achieving workplace diversification and sustainability. This thorough analysis provides the reader with a comprehensive understanding of the strategies needed to navigate the digital work era.

## 2. RESEARCH METODOLOGY

The paper delves into the transformative impact of digital technologies, particularly AI and automation, on the modern work landscape, addressing how these advancements reshape job roles, enhance organizational efficiency, and create redundancy. It explores practical strategies for policymakers and organizations to navigate these technological disruptions, highlighting challenges such as operational barriers, the digital divide, and evolving workforce skills requirements. The study also uncovers opportunities for innovation and growth, emphasizing how businesses can leverage digital technologies to foster global collaboration, market expansion, and operational resilience. Additionally, it discusses the ethical and privacy concerns associated with AI, urging the need for robust policies and continuous updates in educational and training programs to maintain relevance in a rapidly changing digital environment. To prepare the essay "Resilient Strategies for Navigating the Digital Work Era," we adopted a meticulous and structured research methodology to ensure the selection of high-quality and relevant sources. We utilized reputable academic databases such as Google Scholar, JSTOR, IEEE Xplore, and PubMed, known for their extensive coverage and credible content. Keywords like "digital transformation," "AI in the workplace," "automation and employment," "resilient strategies," "digital work era," and "technological disruption" were employed to capture a comprehensive range of relevant literature. This approach ensured that our study addressed the profound impacts of digital technologies on the workplace and identified effective strategies for managing these technological disruptions. Our inclusion criteria focused on articles that were directly relevant, published within the last ten years, peer-reviewed, and in English. These criteria ensured that our analysis was both current and reliable, drawing from high-quality sources. We excluded irrelevant articles, outdated studies, and non-peer-reviewed sources to maintain the academic rigor and focus of our research. This careful selection process allowed us to gather a robust collection of literature that directly contributed to our understanding of digital transformations in the workplace.

For analysis, we conducted an initial screening of titles and abstracts, followed by a detailed full-text review of shortlisted articles. We extracted key themes, findings, and methodologies, conducting thematic and comparative analyses to identify recurring patterns and best practices. We also performed a critical appraisal of the studies to ensure high quality and assessed potential biases to maintain objectivity. This systematic

approach allowed us to synthesize the findings into a coherent narrative, providing a comprehensive examination of resilient strategies for naviga

### **3. THE IMPACT OF DIGITAL TECHNOLOGIES ON THE WORK LANDSCAPE**

Automation and artificial intelligence are shaping human roles in various ways. The rapid advancements in artificial intelligence (AI) and process automation technologies have catalyzed immense discussions regarding the future of work, specifically the nature of roles in the workplace. Nedelkoska and Quintini [1] conducted a study that analyzed how AI could reshape job roles and consequently lead to loss of jobs to process automation. The authors used the Program for the International Assessment of Adult Competencies (PIACC) database. They analyzed that 14% of jobs in Organization for Economic Co-operation and Development (OECD) countries are highly susceptible to automation. In the study, Nedelkoska and Quintini [1] confirmed that the ongoing development of AI and process automation is more likely to establish a dynamic that will enhance optimal process productivity at the expense of manual human input. As algorithms and machines take over human roles, there arises a double-sided result where job displacement could be an outcome on the one hand, and the possibilities of new job opportunities on the other. Consequently, Özkiziltan and Hassel, [2] ascertain a high degree of fear among employees regarding the potential loss of their jobs, especially those that entail easily predictable and repetitive tasks. Nonetheless, the changing landscape of workplace roles is not only an avenue for job replacement, but also a creation of new roles that can only be delivered via human input. As Ciarli et al. [3] state, the fields of data analytics, robotics, and AI may replace predictive tasks, but will necessitate the involvement of backend development and human handling and maintenance. These could range from regular bug fixes to creating and developing new improved algorithms. Besides, AI and automation are not entirely replacing human labor, but are also playing an effective complementary role. For instance, Rayhan [4] explains that healthcare, logistics optimization, vehicle monitoring, and supply chain optimization are key processes that cannot be entirely automated, but an interplay between AI, automation, and human handling can significantly improve their efficiency.

Furthermore, developments in AI and automation are changing job landscapes, hence new trends in digital work environments that are largely typified by digital automation. According to Quach et al. [5], the constant need to attain and retain a competitive edge over rival firms has led organizations to redefine their tasks and work culture dynamics in the current rapidly evolving market. As a result, there is also a change in expectations regarding how people work in present day work environments, as well as how well they interact with the technology around them [6]. As a result, companies are quickly adapting to new digital technologies and trends in big data and analytics to ensure that they meet the diverse needs of consumers. This is as evidenced in the reliance on the IoT to offer services as opposed to conventional face to face transactions. Besides, the rise of mobile money and digital currencies has also revolutionized the way organizations optimize payment services for their clients (Ibid). The overall result is that organizations are revolutionizing their workplace environment to suit consumer needs. Besides, the onset of the COVID-19 pandemic raised the value and appreciation of digital work environments, and working from home has grown to become a competitive job proposition in the competition to hire the best talents in the industry [7]. Further, digital platforms have significantly influenced workplace dynamics. Digital technology has completely changed the nature of knowledge employment, including in processes such as coding and programming, by making it easier to offshore such and other similar services. Businesses are offshoring more tasks affiliated with contact centers and IT teams since it is a more cost-effective labor strategy [8]. However, thousands of local employees have lost their jobs as a result of this trend [8]. Therefore, the tendency to offshore highlights a significant drawback of digital platforms in the workplace which essentially draws down to the risk of, or actual job displacement. Furthermore, not all workers have been in favor of the integration of digital technology into the workplace. There is a gap between the capabilities of the workforce today and the expectations of a digitally transformed work environment, as seen by the resistance to these changes that frequently stem from a lack of digital skills or uneasiness with technology [9]. The aforementioned resistance poses a noteworthy obstacle to the smooth integration of digital platforms in the workplace, and further suggests that although digital platforms are intended to improve business efficiency and satisfy changing customer demands, they also present certain challenges that must be tackled in order to realize their potential [9,10] fully.

### **4. CHALLENGES IN THE DIGITAL ERA**

Besides its innumerable advantages, the onset of the digital era has brought with it key challenges that manifest in the quest for organizations to adopt digital technologies, the influence of the digital divide on work inclusivity, and further implications of such technological changes on the requirements for workforce skills.

According to a study by Acemoglu and Restrepo [12], organizations have had to contend with many challenges that entail operational, organizational, and operational barriers.

The correlation between operational, organizational, and operational challenges is intrinsic in that as operational and organizational processes become more complicated as companies adopt new data and



information systems and try to integrate their stakeholders into them. Per Alekseeva et al. [13], the introduction of digital systems such as enterprise systems may often face organizational challenges due to people's resistance to change. As a result, it plausibly becomes challenging for organizations to align their employees and stakeholders into a new organizational culture that is augmented by technology. This, consequently, gives the rise to a need for competency and capacity building which translate to more costs to the affected companies [12]. Besides, operational complexities may emanate from the need to entirely change the existing processes and introduce new digital systems into the organizational workflow without affecting the organization's core values and beliefs (Ibid). From the technological perspective, the present day's rapid pace of innovation demands constant upgrade and replacement of legacy systems, thus further complicating the integration and adoption process [13]. Equally important, such challenges highlight the need for strategic planning, a deep mastery of the digital transformation landscape, and effective change management at the organizational level to ensure a seamless adoption process. Moreover, the digital divide has had its influence on workplace inclusivity. In the broadest sense, the digital divide alludes to societal inequalities of digital capabilities, access, and outcomes [14]. According to data reported by Hanley [15], the average organization in the United States uses more than 130 applications to run its operations. The onset and increase in the reliance on software as a service (SaaS) digital infrastructure has set up a chasm in individual access to IS and individual digital capabilities have influenced workplace inclusivity. This has, therefore, resulted to the demand of the modern-day digital employee who should be universal, rather than exclusive. Therefore, increased engagement, cultural cohesion, and operational efficiency have significantly driven how modern-day companies hire and retain their talent. The gaps created by literacy gaps in technology adoption among employees equally influence their opportunities at work, and also influences their chances for retention or retrenchment [16]. As organizations engrain SaaS infrastructure, incompetent employees are often overlooked and in extreme cases, moved on to facilitate a seamless adoption process. There is, therefore, a need for organizations to evaluate their digital landscape and identify key gaps and areas of improvement that pertain to digital inclusivity; select the right digital platforms that address the unique needs of all employees and not just those with functional email addresses; embody a culture of inclusion that models the use and reliance on inclusive digital inclusive platforms; and establish functional systems and mechanisms for continuous feedback on digital platforms and also adapt them to match the evolving needs of the employees [17]. Consequently, the developments and challenges brought about by rapid technological change have implications on employee skill requirements. First, although technological changes constantly eliminate routine jobs, routine job holders have been compelled to upgrade their skills to stay relevant in the job market [18]. Workers tend to adjust to firm-level organizational and technological change to avoid being redundant. While technological change reduces the firm's proportion of routine jobs, routine job holders have had to go the extra mile to facilitate their personal capacity building to stay at work or avoid facing reduced earnings [18]. However, the skills requirement tends to catch up with workers aged 55 or older, where they often are moved out of the occupation and may lack a chance to move to abstract occupations (Ibid). Also, firms that offer apprenticeship training are more likely to upskill their employees when introducing new changes in their technological infrastructure [18]. Equally important, rapid technological change is shaping the demand for skills in the workplace, thus making traditional hiring requirements that prioritize degrees over practical skills overly obsolete [17]. The evolution in hiring and talent retention practices is testament to the broader trend where companies are compelled to adapt their recruitment methods to stay up to date with practical requirements to innovative approaches.

## 5. OPPORTUNITIES FOR INNOVATION AND GROWTH

While changing trends in the workplace caused by technological changes have resulted in various challenges, the present-day technological revolution also presents multiple opportunities for innovation and growth. This can be analyzed by looking at how firms leverage digital technologies for innovation, creating new business opportunities, and fostering global collaboration and market expansion.

Organizations can leverage digital technologies for innovation and disrupt business models in various ways. According to Hanley [15], firms can reimagine their products, process, and products by adopting machine learning, data analytics, artificial intelligence, and the internet of things.

While striving for innovation, organizations can access a wide pool of digital resources that offer unique pathways to efficiently transform their market approaches and operations at large. In times of crisis, digital transformation has been approved as a key driver for organizational resilience and innovation [7]. For instance, companies can lower their barriers to entry in new markets by leveraging data analytics tools, e-commerce platforms, and social media promotion, thus enabling them to access new markets that would otherwise have been out of reach (Ibid). This approach works by broadening the organization's respective market presence, thus allowing a more efficient and targeted engagement with the target consumer base. Besides, the ability to utilize data analytics is an essential tool that help organizations achieve and maintain their competitive edge in the market. Companies can optimize big data and data analytics to proactively analyze consumer behavior, trends, and preferences thus enabling them to make unique offers for products, services, and collaborations that align them to the ever-evolving consumer demands. Moreover, digital platforms play an integral role in

creating new business opportunities. Digital platforms are growing increasingly useful in creating new business opportunities by introducing a wide range of advanced technologies, including AI, blockchain, and virtual reality [7]. Such technologies don't only make way for highly innovative processes, but also make it possible for businesses to explore fresh market opportunities by identifying untapped niches or markets that may have been previously inaccessible. Nonetheless, through adopting the strategy of growing through innovation, enterprises remain on course towards achieving their respective organizational goals through averaging technological advancements to attain market expansion, strategic partnerships, and innovative accomplishments [12]. This holistic approach makes it possible for organizations to stay updated with current trends and market shifts, and also prime themselves for sustained diversification and growth (Ibid). Also, the digital era can foster global collaboration and market expansion. The onset of the current digital work era has paved way for unpredicted global collaboration while also transforming how individuals interact with their respective work environments. Transformation of this level can be attributed to the strategic partnerships that make it possible for firms to harness the power of technology to innovate and augment their plans to reach new markets in the age of globalization [8]. For instance, the collaboration of Apple and Nike for innovative products such as the Apple Watch Nike+ exemplifies just how the combination of expertise from diverse domains can enhance the creation of innovative products that appeal to the larger global audience [19]. Therefore, such partnerships are key in the identification of new innovative opportunities by leveraging diverse resources and a large pool of expertise. Nonetheless, the implementation of new technologies such as AI, automation, cloud computing, and data analytics play a pivotal role in fueling productivity and efficiency, which are essential for achieving collaboration in the marketplace at a global scale [10]. AI, automation, and cloud computing improve operational capabilities and accelerate the innovation process by helping users tap into a wider pool of knowledge and resources.

## **6. STRATEGIES FOR WORKFORCE SUSTAINABILITY IN THE DIGITAL ERA**

According to Muro et al. [17], an effective model of fostering an innovative culture within an organization entails a multi-dimensional system with key considerations for creating a conducive work environment that enhances experimentation and creativity. This strategy should be grounded on formulating and implementing a comprehensive human resource strategy that focuses on attracting and retaining top talent and regularly engaging employees in key organizational and operational processes [17]. This also entails the recognition of the importance of forward thinking and adaptability in ensuring that the firm does not lose its agility and competitive ability to respond proactively to the ever-changing conditions of the technological market. In addition, organizations can achieve innovation by investing in training and capacity development of their employees, thus responding to the need for having an organization that is proactively adaptive to change. Besides, an investment of this magnitude also touches on hiring new talent equipped with the required skills to thrive and adapt in the digital age, thus equipping the firm with diverse perspectives that are essential for facilitating innovation [7]. Altogether, the elements discussed above highlight the key role played by an effective human resource strategy in establishing an environment that encourages innovation, talent management, and constant upskilling. Moreover, organizations can maximize on opportunities brought about by technological advancements by championing lifelong learning and agile workforce practices. While responding for the challenges caused by automation and AI, Kolade and Owoseni [6] state that organizations should be primed with supporting their talent by developing and implementing workplace systems that encourage agile practices and lifelong learning. The training and capacity development programs at these organizations should be designed at equipping employees with transformational skills that cater to both the need to develop cognitive flexibility and a willingness to try out new things, as well as the need to foster a culture of openness to change and a functional support for continuous learning [7, 13, 17]. Equally this approach is vital in an era characterized by a constantly changing skills landscape, thus making it necessary for talent development to have their priority on the ever-changing demands of the workplace. To add, by incorporating agile workplace practices that work well in developing a culture of adaptability and flexibility, organizations can establish a work environment that is effectively resilient to changes and disruptions brought about by modern-day technology [3, 11]. In essence, the dual focus on fostering agility and lifelong learning is not a countermeasure to the challenges of AI and automation but more of a complimentary strategy to positive advancements in the technology industry. Moreover, organizations can achieve workforce sustainability in the digital era by supporting diversity and inclusivity in digital workplaces. Organizations can improve the levels of inclusivity in their workplaces by entering into global coalitions that facilitate skills-matching and capacity development to bypass the gap caused by skills mismatch in the modern-day labor force [7]. Collaborations work by collectively building environments for professionals from under-represented racial and ethnic minorities, and also catering to the needs of personnel affected by old age. Also, collaborations help the minorities – either by demographics or by skill – by putting in place strategies that make people more adaptive to change, and bridging the gaps on technical expertise.

## **7. LIMITATIONS AND IMPLICATIONS**

While this study offers valuable insights into the transformative impact of digital technologies, particularly AI and automation, on the contemporary work landscape, certain limitations that may affect its scope and applicability must be acknowledged. Firstly, the study's focus on specific industries and regions limits its generalizability. The findings may not fully capture the diverse impacts and challenges all sectors and geographic areas face, thus providing a somewhat narrow view. Additionally, the rapid pace of technological advancements means that some of the discussed trends may quickly become outdated, highlighting the need for continuous updates to maintain relevance. The reliance on existing literature and available data also presents limitations. Data quality and comprehensiveness variations can affect the conclusions' robustness. Furthermore, while ethical and privacy concerns associated with AI and digital technologies are mentioned, the study does not delve deeply into these critical issues, which warrants further exploration. Despite these limitations, the study has significant implications for various stakeholders. For businesses, it provides practical insights into leveraging AI and digital technologies to enhance customer engagement, optimize operations, and drive innovation. Policymakers can use the findings to develop robust policies and regulations addressing ethical and privacy concerns, ensuring the responsible use of digital technologies.

The study also opens avenues for future research, encouraging investigations into different industries, regions, and the evolving technological landscape. This continuous research will help adapt strategies to the dynamic nature of digital transformation. Additionally, the study underscores the importance of updating educational curricula and training programs to incorporate the latest technological advancements, ensuring that professionals remain relevant in a rapidly changing digital environment.

## 8. CONCLUSION

To conclude, understanding the resilient practices for the modern-day digital era needs an analysis of the challenges and opportunities brought about by AI and automation, key trends in the workplace today, opportunities for improvement, and the need to leverage technology to achieve innovation and sustainability. There is an intricate balance between job displacement and the emergence of new job opportunities that need a reevaluation of skills, as well as the development of new skills that are both pragmatic and change-oriented. Integrating AI and automation in the workplace complements operational processes, primes organizations for the development of new products and services and enhances the prospects for global expansion. Organizations should adopt agile workplace practices, and embrace digital solutions to remain competitive in the ever-evolving digital age.

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# **MANAGING HUMAN RESOURCES IN DIGITAL AGE**

# DIGITALIZATION IN HRM IN SERBIA: THE ROLE OF STRATEGIC HRM INVOLVEMENT

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**Abstract:** *The main purpose of this paper is to investigate the level of the usage of digital solutions for human resource management (HRM) processes in companies in Serbia and to explore whether HR strategic issues have effects on the level of the usage of HR digital tools. The research is based on the data gathered from 106 companies that operate in Serbia, by using the Cranet questionnaire in 2021. The authors used descriptive statistics and tests for comparing groups (t-test and ANOVA) to determine the level of the usage and differences in the usage of digital tools for HR processes. The main conclusions are that digitalization is definitively present in HRM in Serbian companies, but that some of the more sophisticated solutions like algorithm-based HR, HRIS, and e-HRM are in the starting phase of the usage. Also, if companies have developed a strategic position of HRM, they use all digital tools to a greater extent than those that are not positioning HR as strategic.*

**Keywords:** *digital transformation, digital HRM, strategic involvement of HR, e-hrm, Serbia, Cranet*

## 1. INTRODUCTION

Digital transformation affects all processes and businesses in the world. HRM processes were also tackled and many of them changed totally due to the strong inflow of digital solutions in HRM and new ways of doing those processes. More and more research are based on this topic, and showing significant effects, mainly positive, on HRM. Digital transformation could be explained as “the use of new digital technologies such as social media, mobile technology, analytics, or embedded devices to enable major business improvements including enhanced customer experiences, streamlined operations, or new business models” (Fitzgerald et al., 2014, p. 2; Kraus et al., 2021, p. 4). When speaking about digitalization in HRM, the digital transformation of the HRM is usually based on the implementation of certain IT solutions and the redesign of the HRM activities to provide new and better services for employees (Berber et al., 2018b). Besides this primary motive to optimize HR procedures, digital transformation in HR brought some other positive effects that are reflected in cost reduction, higher quality of services provided, increase of employees' productivity, and similar (Berber et al., 2018a). Rimon (2017) provides the six most impactful elements of HR's digital transformation:

- The consumerization of HR systems – employees will use HR activities more like real consumers, not just as employees;
- A digital dialogue between employee and manager;
- Learning transformation;
- Changes in goal setting.
- A new way of feedback;
- People analytics (Rimon, 2017, p. 102-103).

Besides the mentioned changes that occurred in HRM due to digital transformation, it is also very important to explore the preconditions needed for the successful integration of digital changes in HRM. Bondarouk et al. (2017) identified 168 factors that affect e-HRM adoption and consequences and classified these factors into technological, organizational, and people (TOP) contexts. Among many (like technological level of development in a company, organizational characteristics, people readiness, and competencies, etc.) strategic orientation of HRM is seen as an important factor when introducing digital HRM (Marler & Parry, 2016). Strategic HRM is “an interdependent bundle of planned or emergent human resource activities that are intended to achieve positive organizational outcomes” (Marler & Fisher, 2013, p. 23). The field of SHRM is concerned with “the determinants of HRM practices, the composition of the HR capital pool, the specification of required behaviors, and the effectiveness of decisions given varying competitive situations and business strategies” (Minbaeva & Navrbjerg, 2023, p. 812). Accordingly, the main purpose of this research was to

investigate the level of the use of digital solutions for HRM processes in companies in Serbia and to explore whether HR strategic issues have effects on the level of the usage of HR digital tools. The research is based on the data gathered from 106 companies from Serbia, by using the Cranet questionnaire in 2021. The authors used descriptive statistics and tests for comparing groups (t-test and ANOVA) to determine the level of the usage and differences in the usage of digital tools for HR processes.

The structure of the paper is the following. Section one presents the introduction, emphasizing the main aim and the purpose of the research. Section two is related to the theoretical background, explaining the effects of digital transformation on HRM and the relations between strategic and digital HRM. The third section represents the methodology of the research, explaining the sample, data collection, and questionnaire. The fourth section are results of data analysis, with discussion, while the fifth obtains conclusions and implications.

## 2. THEORETICAL BACKGROUND

At the very beginning of the paper, it is important to emphasize that transformation in “HR processes is more effective when used as part of a broader employment process” (Vardarlier, 2020, p. 239). Digital HR needs to be understood and applied as a part of the business strategy, not only as a tool to increase the HR performances. Why is that? The integration of digital technologies in HR processes meets challenges such as data privacy concerns, skills gaps among HR professionals, and resistance to change within the organization. Addressing these challenges requires a strategic approach that combines technological innovation with effective change management and continuous learning initiatives.

One of the main problems in the research of SHRM and e-HRM lies in the understanding of which comes first. According to Marler and Parry (2008), one point of view is that “e-HRM can act as a precondition of SHRM, through the freeing up of HR practitioners’ time and the provision of high-quality information that enables them to act more strategically. The alternative view, situated in the literature on contingent strategic HRM, suggests that this relationship is reversed, in that e-HRM is a result of the strategic orientation of the HR function. This view suggests that e-HRM is used as a part of SHRM to achieve the competitive goals of the organization” (p. 40). Although this theme still lacks in its clarity (Marler & Fisher, 2013), several prior research conducted to investigate the relations between SHRM and digital HR.

Parry (2011) investigated the relations between SHRM and digitalization in HRM, most of all in e-HRM. Based on the Cranet data from 2003, in 12 countries, the United Kingdom, USA, Australia, Canada, New Zealand, Germany, Switzerland, the Netherlands, Belgium, Norway, Finland, and Austria, with a total of 2,777 companies, the author analyzed effects of several organizations HRM characteristics on the usage of e-HRM. One of the independent variables in the model was the strategic level of HRM, measured by the existence of HRM strategy in a company, the position of the HR manager on the top management board, and the stage in which an HR manager is involved in the development of the business strategy. The results showed that HR strategic involvement had a significant positive effect on e-HRM use which means that e-HRM is used for a wider range of activities in firms where the HR function plays a more strategic role.

Marler and Parry (2016) also investigated a similar theme, in 2016, using a large survey data set consisting of 5665 companies that are located in 32 different countries, from the Cranet research network. Findings showed that strategic HR involvement and greater e-HRM capability are both directly and reciprocally related to supporting theoretical perspectives (p. 2233) (“which comes first”). According to the authors, e-HRM provides an opportunity to change HRM through business process reengineering, automation, and information sharing; while emphasizing managerial interests and strategic intent before. The relationship between e-HRM and the role of HR in strategic decision-making is not completely independent. Their results showed that “higher support for e-HRM effects on strategic involvement than vice versa - a change in e-HRM capabilities predicted a greater change in HR involvement in strategic decision-making than the other way around” (Marler & Parry, 2016, p. 2236).

Berber et al. (2018a) investigated the level of the use of different digital solutions in HRM (manager and employee self-service systems and e-HRM) in Serbian companies based on the data from the Cranet research in 2015. Results gathered from the sample of 160 companies that operated in Serbia showed that Serbian organizations use e-HRM more when emphasizing they have separate HR departments, written HR, and business strategies. The authors stated that the development of the SHRM process in a company contributes to the understanding and implementation digital approach in the field of HRM.

Most recently, Rimac Bilusic and Pološki Vokić (2023) utilized the Cranet 2021 dataset, with a sample of 4495 organizations from 38 countries worldwide. They used nine indicators of digital HRM (manager and employee self-service, HRIS, algorithm-based HRM, HR analytics, teleworking, e-learning, social media recruitment and

selection) and five indicators of SHRM orientation (HR manager's membership in the management board; involvement of HR manager in the development of business strategy; HRM strategy; HR to employee ratio, the level of HR department performance evaluation). The results showed that HR digitalization has a positive and significant relationship with SHRM orientation. This research showed that digital HRM can be a precondition for SHRM, which is one of the mentioned unknown facts in the field of SHRM and e-HRM research.

Without numbering other similar research, we can state that there is a relation between SHRM and the digitalization of HRM processes, and still, we do not have a clear picture of the dependency between them. However, based on the strategic management perspective, we formulated our research hypothesis:

H1: Companies with strategic involvement of HRM use digital HR processes and tools more than companies without SHRM.

### 3. METHODOLOGY

The analysis was based on worldwide data from the Cranet research network (Cranet, 2024). This international organization, managed by the Center for International Human Resource Studies at Penn State University in the USA, organizes comparative research on the policies and practices of human resource management, using a standardized questionnaire. The CRANET network leads the largest research of HRM practices in the world, based on the well-developed methodology, as a multi-country, multi-time-point survey undertaken regularly over the past 30 years in more than 40 countries (Parry et al., 2021). For the present study, the Cranet database from the 2021/2022 research round was used.

The methodology is based on the questionnaire that is filled out by HR managers in organizations. This means that only one questionnaire is collected from one company. The sample needs to contain organizations with more than 50 employees. The main sections of the questionnaire are HRM activity in the organization, staffing process, career development and training, rewards, employee relations, and communication. "The questionnaire is composed of closed questions, so respondents were asked to select their reply from the sets of alternatives, the preformulated answers essentially covering the specific areas of HRM to be studied" (Szabó et al., 2019). There are no Likert scale questions in the questionnaire. The survey collects "hard" HR data, like percentages, ratios, concrete numbers, and avoids attitudinal information. All participating countries used the same questionnaire, with the application of the translation-retranslation technique in every survey round (Morley et al, 2016). To avoid bias, there are specific approaches for collecting the data and a few country-specific questions.

#### 3.1. Sample

The Faculty of Economics in Subotica, University of Novi Sad, as the official representation of the Republic of Serbia in the CRANET, has participated in an international study on HRM activities since 2008. The sample in the 2021 research round consists of 106 organizations. As mentioned in the previous section, the single-respondent methodology is used. Researchers from the Faculty of Economics in Subotica investigated 106 companies and gathered the data. Data in Table 1 presents the sample.

**Table 1:** The size of the organizations

<b>Organization size (by number of employees)</b>	<b>%</b>
1-249	34.9
250-1000	46.2
1000+	18.9
<b>Total</b>	<b>100.0</b>

Based on the data in Table 1, 65% of analyzed organizations are large companies, while 35% are small and medium-sized companies.

**Table 2:** The sector of the organizations

<b>Sector</b>	<b>%</b>
Public	15.1
Private	84.9
Other	0.0
<b>Total</b>	<b>100.0</b>



Based on the data in Table 2, 85% of organizations work in the private sector and 15% in the public sector. About 55% of responding companies operate in the service sector and 45% in the manufacturing sector. The average number of employees in companies is 975 employees. About 30% of companies are foreign subsidiaries of large international companies, while 22% are headquarters of national companies, and 30% are subsidiaries of national companies.

**Table 3:** The main business markets

The main market for products or services	%
Local	11.3
Regional	22.6
National	20.8
Continent-wide	10.4
Worldwide	34.9
<b>Total</b>	<b>100</b>

Table 3 shows data about the market in which companies operate. The largest share of organizations works on worldwide markets, while 22.6% work on regional and 21% on national markets. Companies that operate on local and continent-wide markets are around 10% for each.

### 3.2. Variables

The authors used the following variables from the CRANET:

- Digital HRM variables were ordinal variables, measured on a scale from 0 = not used at all to 3 = used to a very great extent:
  - use of manager self-service - online tools whereby managers can complete HR processes (Barišić et al., 2019, p. 592),
  - use of employee self-service - online tools whereby employees can access personal information and perform simple HR tasks such as maintaining personal data (Barišić et al., 2019, p. 592),
  - use of HRIS/e-HRM - HRIS refers to systems used within the HR departments to enhance HR processes, while e-HRM is intended to benefit also to non-HRs personnel such as employees and practitioners (De Alwis et al., 2022, p. 5),
  - use of algorithm-based HRM - software algorithms designed to support, automate, and govern HR decisions, activities, and processes (Meijerink et al., 2021, p. 2547),
  - use of HR analytics - an HR practice enabled by information technology that uses descriptive, visual, and statistical analyses of data related to HR processes, human capital, organizational performance, and external economic benchmarks to establish business impact and enable data-driven decision-making (Marler & Boudreau, 2017, p. 13).
- Strategic involvement of HRM:
  - position of HR manager in the top management board (0=no, 1=yes),
  - involvement of HR manager in the development of business strategy (3=from the outset, 0=not consulted),
  - existence of written HRM strategy (0=no, 1=yes).

Owing to the fact that there is still ambiguity about the understanding of digital HRM components presented above, this section brings out definitions of those components intending to make clearer view and to describe closely differences among them.

## 4. RESULTS AND DISCUSSION

Table 4 presents the data about the level of the usage of different HR practices that are affected by the digitalization process. As it is evident, more than 40% of companies in Serbia do not use at all employee self-service and algorithm-based HR processes. About 30% do not use at all manager self-service modules or HR analytics. 24% of companies do not use HRIS and or e-HRM. On the other side, 31% of companies stated that they use HRIS and or e-hrm to a very great extent. All other digital solutions are used in less than 25% of companies on a very high level, and in the case of algorithm-based HR processes is only 7% (about 7 companies).

**Table 4:** The level of the usage of digital solutions for HR in Serbian organizations

Type of practices	The level of the usage (%)			
	Not at all (0)	1	2	To a very great extent (3)

Use of manager self-service	29	19	26	25
Use of employee self-service	43	16	23	18
Use of HRIS /e-HRM	24	18	27	31
Use of algorithm-based HR processes	55	22	17	7
Use of HR analytics	29	14	33	24

However, we need to bear in mind that these data were gathered in 2020 and 2021 when AI was still underrepresented in HRM. Also, according to Jatoba et al. (2019), the period of significant growth in the usage of AI for HRM started in 2018. We expect that the new Cranet research will show larger percentages of companies that use this type of technology for HR processes.

Tables 5, 6, and 7 present the data on the differences in the level of the usage of digital solutions for HRM concerning different HR strategic characteristics (existence of HR strategy, position of HR manager in top management boards, and the level of integration between business and HR strategy).

**Table 5:** The differences in the level of the usage of digital solutions for HR concerning the existence of HR strategy in companies in Serbia

Type of HR practices	Existence of HR strategy	N	Mean	SD	T-test sig. two-tailed
Use of manager self-service	No	31	.94	1.124	p=0.002
	Yes	75	1.71	1.112	
Use of employee self-service	No	31	.45	.810	p=0.000
	Yes	75	1.44	1.177	
Use of HR information systems / e-HRM	No	31	1.06	1.153	p=0.000
	Yes	75	1.91	1.068	
Use of algorithm-based HR processes	No	31	.35	.709	p=0.002
	Yes	75	.92	1.010	
Use of HR analytics	No	31	1.00	1.125	p=0.003
	Yes	75	1.72	1.097	

Table 5 presents the data on the differences in the level of the usage of digital solutions for HRM concerning the existence of HR strategy. Companies that have developed HR strategy showed higher levels of the usage of all digital solutions for HR practices. The differences between those companies are statistically significant in all cases. This test showed companies that possess HR strategy had statistically significantly higher levels of the usage of manager self-service ( $M=1.71$ ;  $SD=1.112$ ) compared to those that do not have such strategy ( $M=0.94$ ;  $SD=1.124$ ),  $t(104)=3.238$ ,  $p=0.002$ . Companies that possess HR strategy had statistically significantly higher levels of the usage of employee self-service, too ( $M=1.44$ ;  $SD=1.117$ ) compared to those that do not have such strategy ( $M=0.45$ ;  $SD=0.810$ ),  $t(104)=4.271$ ,  $p=0.000$ . T-test also showed that companies that possess HR strategy had statistically significantly higher levels of the usage of HRIS and/or e-HRM ( $M=1.91$ ;  $SD=1.068$ ) compared to those that do not have such strategy ( $M=1.06$ ;  $SD=1.153$ ),  $t(104)=3.609$ ,  $p=0.000$ . Companies that possess HR strategy had statistically significantly higher levels of the usage of algorithm-based HR processes ( $M=0.92$ ;  $SD=1.010$ ) compared to those that do not have such strategy ( $M=0.35$ ;  $SD=0.709$ ),  $t(104)=2.863$ ,  $p=0.002$ . In the end, companies that possess HR strategy had statistically significantly higher levels of the usage of HR analytics ( $M=1.72$ ;  $SD=1.097$ ) compared to those that do not have such strategy ( $M=1.00$ ;  $SD=1.125$ ),  $t(104)=3.050$ ,  $p=0.003$ .

**Table 6:** The differences in the level of the usage of digital solutions for HR concerning the position of HR manager in top management boards in companies in Serbia

Type of HR practices	HR manager in top management boards	N	Mean	SD	T-test sig. two-tailed
Use of manager self-service	No	37	1.19	1.126	p=0.058
	Yes	69	1.64	1.163	
Use of employee self-service	No	37	.81	1.076	p=0.028
	Yes	69	1.33	1.184	
Use of HR information systems/e-HRM	No	37	1.19	1.198	p=0.002
	Yes	69	1.91	1.054	
Use of algorithm-based HR processes	No	37	.43	.765	p=0.006
	Yes	69	.93	1.019	
Use of HR analytics	No	37	1.00	1.155	p=0.001
	Yes	69	1.78	1.055	

Table 6 presents the data on the differences in the level of the usage of digital solutions for HRM concerning the position of HR manager in top management boards. It is evident that companies in which the HR manager is a member of the top management board showed a higher level of usage of all digital solutions for HR practices. The differences between those companies are statistically significant in all cases, except in the case of manager self-service. Companies in which the HR manager is a member of the top management board had statistically significantly higher levels of the usage of employee self-service, too ( $M=1.33$ ;  $SD=1.184$ ) compared to those in which the HR manager is not a member ( $M=0.81$ ;  $SD=1.076$ ),  $t(104)=1.913$ ,  $p=0.028$ . T-test also showed that companies in which the HR manager is a member of a top management board had a statistically significantly higher level of the usage of HRIS and/or e-HRM ( $M=1.91$ ;  $SD=1.054$ ) compared to those that do not have an HR manager engaged in boards ( $M=1.19$ ;  $SD=1.198$ ),  $t(104)=3.213$ ,  $p=0.002$ . Companies in which the HR manager is a member of the top management board had statistically significantly higher levels of the usage of algorithm-based HR processes ( $M=0.93$ ;  $SD=1.019$ ) compared to those that it is not ( $M=0.43$ ;  $SD=0.765$ ),  $t(104)=2.587$ ,  $p=0.006$ . Finally, companies in which the HR manager is a member of the top management board had a statistically significantly higher level of the usage of HR analytics ( $M=1.78$ ;  $SD=1.055$ ) compared to those that do not have an HR manager on the top management board ( $M=1.00$ ;  $SD=1.155$ ),  $t(104)=3.521$ ,  $p=0.001$ .

**Table 7:** The differences in the level of the usage of digital solutions for HR concerning the level of integration of HR and business strategies in companies in Serbia

Type of HR practices	The level of integration of HR and business strategies	N	Mean	SD	ANOVA test
Use of manager self-service	Not consulted	9	1.00	1.118	$p=0.271$
	On implementation	9	1.67	1.323	
	Through subsequent consultation	16	1.19	.981	
	From the outset	66	1.64	1.172	
	Total	100	1.51	1.159	
Use of employee self-service	Not consulted	9	.78	1.093	$p=0.552$
	On implementation	9	1.00	1.323	
	Through subsequent consultation	16	1.06	1.124	
	From the outset	66	1.30	1.189	
	Total	100	1.19	1.178	
Use of HR information systems/e-HRM	Not consulted	9	.89	1.167	$p=0.051$
	On implementation	9	1.22	1.093	
	Through subsequent consultation	16	2.06	.772	
	From the outset	66	1.82	1.149	
	Total	100	1.72	1.129	
Use of algorithm-based HR processes	Not consulted	9	.33	.707	$p=0.451$
	On implementation	9	.67	1.118	
	Through subsequent consultation	16	.81	1.047	
	From the outset	66	.88	.969	
	Total	100	.80	.974	
Use of HR analytics	Not consulted	9	.67	1.118	$p=0.071$
	On implementation	9	1.44	1.236	
	Through subsequent consultation	16	1.81	1.047	
	From the outset	66	1.67	1.114	
	Total	100	1.58	1.139	

Table 7 presents the data on the differences in the level of the usage of digital solutions for HRM concerning the level of integration of HR and business strategies in companies in Serbia. It is evident that although companies that involve HR managers in the development of business strategy from the start (from the outset, which means the higher level of integration between HRM and business strategy) showed some higher level of usage of all digital solutions for HR practices, the differences between these types of companies are not statistically significant ( $p>0.05$ ).

Based on the results, hypothesis 1 is partially confirmed, because only two out of three strategic involvement factors showed statistically significant effects on the use of digital HRM in companies in Serbia. Companies use digital HRM to a greater extent if they have HR strategies and HR managers in top management boards. However, the involvement of HR managers in the development of business strategy did not show effects on the use of digital HRM. The results of this research are in line with the previous. Higher strategic involvement of HRM is associated with greater use of e-HRM and other digital HRM processes (Parry, 2011; Marler & Parry, 2016; Berber et al., 2018a).

## 5. CONCLUSION

Digital transformation is “a set of ongoing processes affected in great measure with organizational readiness and digital maturity, where under the term digital maturity is understood (a) digital capabilities, which indicate the intensity of digital initiatives and (b) transformation management capabilities in terms of leadership, culture, change management, governance” (Barišić et al., 2021, p. 359) affects all areas of business and life. HRM as a process of managing organizations human capital is also affected and several positive outcomes occurred due to the digital transformation in HRM. Those are usually seen as enhancing the strategic role of HR in companies since HR can automate some routine tasks and free their time for more important and developmental processes for employees and the company.

The authors of this paper investigated the level of implementation of digital HRM in companies in Serbia and revealed the relations between SHRM and digital HRM. Results showed that most companies in Serbia use self-service and algorithm-based HR processes at a very low level. About 30% do not use at all manager self-service modules or HR analytics. On the other side, companies stated that they use HRIS and or e-hrm to a greater extent. All other digital solutions are used in less than 25% of companies on a very high level, and in the case of algorithm-based HR processes is only 7% (about 7 companies). The authors performed a t-test and ANOVA to investigate whether are there differences in the usage of digital HRM based on the strategic involvement of HR. Based on the results, hypothesis 1 in this research is partially confirmed, because only two out of three strategic involvement factors showed statistically significant effects on the use of digital HRM in companies in Serbia. Companies use digital HRM to a greater extent if they have HR strategies and HR managers in top management boards. However, the involvement of HR managers in the development of business strategy did not show effects on the use of digital HRM.

The implications of this paper lie in the fact that the implementation of digital solutions for HRM should not be separated from broader strategic HR initiatives in a company. The effects of digital HRM would be even higher if a company developed other important processes simultaneously. For example, the use of digital HRM practices impacts HRM effectiveness through the internal consistency of HR practices and external social networking of HR managers with line managers (Wang et al., 2022). Although the authors of this research found that HR managers who make strategic decisions can determine the extent of an organization's e-HRM use, according to Marler and Parry (2016), the deployment of e-HRM has significant effects on the strategic role of HRM in organizations, therefore these two views need to be taken into account together, not isolated.

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# WHAT CAN ORGANIZATIONS DO TO BOOST DIGITAL WORKERS' PERFORMANCE? AN INVESTIGATION INTO FACILITATING FACTORS

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**Abstract:** *Following the effects of digitalization and post-COVID workplace trends, digital work is here to stay. Defined as a professional environment where employees actively use information and communication technology (ICT) to complete their tasks and fulfil organizational objectives, the digital workplace is on the rise. On the managers' side, the focus on how to enhance the performance of the workforce in this setting prevails, motivating the authors to investigate the organizational factors affecting digital workers' performance. This research endeavour is grounded in the development of a multiple linear regression model based on survey data from 153 digital workers. The findings point out that the work environment and the tasks and workload positively and significantly affect performance in digital workplaces. This has twofold implications for both the academic and scientific communities, whose members express an increasing interest in managing the "workplace of tomorrow" and digital workers' quality of outputs.*

**Keywords:** *digital work, performance, factors, multiple linear regression*

## 1. INTRODUCTION

The transformative effects of digitalization and the unprecedented post-COVID workplace trends have accelerated the adoption of digital technologies and remote work practices across industries (Ruiner et al., 2023). As organizations grapple with these new challenges, the concept of the digital workplace has emerged as a focal point for understanding and shaping the future of the workplace as we know it. Defined as an environment where employees utilize information and communication technology (ICT) to perform their tasks and achieve organizational objectives, the digital workplace represents a paradigm shift in how work is conceptualized and executed (Baptista et al., 2020).

In this setting, managers face the need to optimize the performance of their workforce within the digital workplace framework. The ability to effectively manage and enhance performance in this context is paramount for organizations striving to maintain competitiveness, agility, and resilience in an increasingly digitized economy (Vuori et al., 2019). Recognizing the significance of this challenge, we were motivated to carry out this research endeavour, whose primary research objective is to investigate the organizational factors that impact the performance of digital workers.

To fulfil this research objective, we launched a survey for collecting data, which was later analysed and used for developing a multiple linear regression model. Namely, the survey consisted of 18 questions, out of which four were designed to assess the demographic landscape of the sample, including age, gender, organization size, and job position. Then, two questions were put as eliminatory with the aim of preventing respondents from answering the rest of the questions if they did not identify themselves as working in a digital workplace in the country. Because of this, the final sample considered 153 respondents. The rest of the questions related to each of the analysed organizational factors – five questions for measuring the work environment, three for measuring the tasks and workload aspect, and four questions related to the technical infrastructure.

As mentioned, central to this research endeavour is the development of a multiple linear regression model, thanks to survey data collected from 153 digital workers across diverse industries and organizational settings in the Republic of North Macedonia. This research context has been especially of interest as there is a lack of studies concerning the digital workplace in the geographical region. This was confirmed with a detailed

search query in the Scopus database of global, quality research. Namely, we found a low number of studies on the topic, which represented additional motivation for us to carry out the research endeavour.

The findings from this study indicate that the work environment and tasks and workload exert a significant and positive influence on the performance of digital workers in the digital workplace. Furthermore, the results of this research endeavour underscore the multifaceted nature of performance management in the digital era, emphasizing the importance of considering organizational factors as elements that are fully in control of executives and human resource managers in contemporary organizations, which is claimed by other authors, too (Duan et al., 2024).

The implications of these findings extend beyond organizational boundaries, resonating with academic and scientific communities alike. As scholars and practitioners alike grapple with the complexities of managing the so-called workplace of tomorrow, understanding the determinants of performance in digital workplaces assumes heightened relevance. By shedding light on the relations between organizational dynamics and individual performance in digital work environments, this research contributes to a deeper understanding of effective management practices in the digital age.

## 2. THEORETICAL BACKGROUND

In our research endeavour, we refer to a digital worker as an individual who primarily performs tasks and duties within a digital or virtual environment in the broadest sense of this workforce category (Polo & Kantola, 2020). These workers typically engage in various online or computer-based activities to carry out their responsibilities and can include software developers and engineers, digital marketers, data analysts, web developers, virtual assistants, cybersecurity specialists, content creators, and many more (Wibowo et al., 2022). Additionally, this umbrella term can refer to gig workers, freelancers, digital nomads, remote workers, and similar, considering they too mostly rely on using information and communication technology (ICT) (Prester et al., 2023; Waldkirch et al., 2021).

Digital workers often have the flexibility to work remotely, leveraging technology to collaborate with colleagues, access resources, and complete tasks from anywhere with an internet connection (Polo & Kantola, 2020). This flexibility can lead to improved work-life balance and increased performance for individuals who thrive in autonomous environments (Baptista et al., 2020). High digital literacy is often a strong characteristic of these employees who actively operate with digital tools, software applications, and online platforms relevant to their roles (Wibowo et al., 2022).

Besides the increased sense of flexibility and autonomy, digital work often comes with some dark sides in terms of less interpersonal physical communication, which can make decision-making more complex in some instances, while affecting team dynamics (von Thülen & Hartl, 2021). Since digital work is directly affiliated with the use of technology, this can lead to digital fatigue, technostress, and other not-so-good effects (Bondanini et al., 2020). Moreover, with the increasing prevalence of cyber threats and data breaches, cybersecurity takes centre stage in the landscape of digital work, highlighting the need to protect sensitive information and maintain the integrity of digital systems and networks, too (Muthuswamy, 2023).

Considering that performance is at the heart of this research endeavour, from an operational and organizational point of view, it refers to the total outcomes or successes of an employee during concrete periods of professional engagement in comparison to work standards, targets, or other pre-determined and pre-agreed criteria (Diamantidis & Chatzoglou, 2019). Several authors view this concept in relation to work satisfaction and compensation as it is expected of employees to feel content and fulfilled from the results they achieve and be adequately paid for this effort and their performance (Ohunakin & Olugbade, 2022). As such, performance, even in the context of the digital workplace, can be affected by the environment or external factors as well as individual traits, abilities, desires, skills, and abilities (Diamantidis & Chatzoglou, 2019). Having in mind the pronounced competitiveness of digital workplaces, these organizations focus on finding and retaining high achievers (Chatterjee et al., 2023).

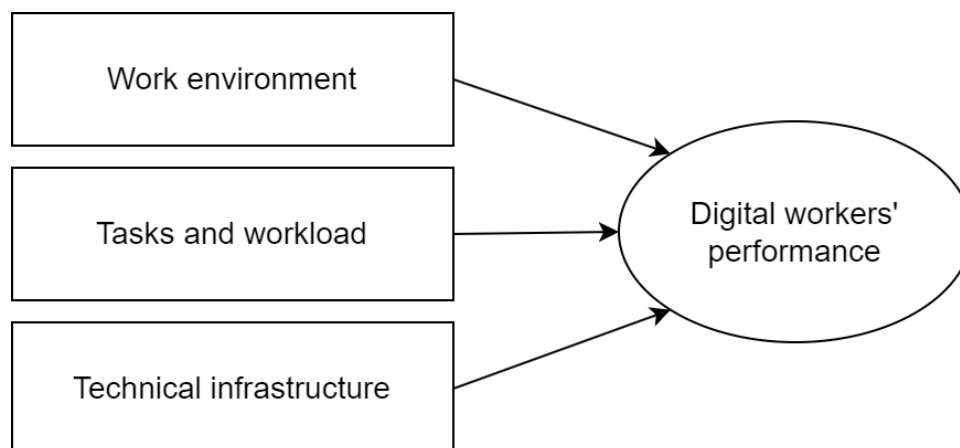
While there are a plethora of factors influencing the performance of digital workers, the subject of this research endeavour focuses on those that are under the direct control of the management or the structural ones tied to the organization, per se. More precisely, we focus on the work environment, tasks and workload, and the technical infrastructure.

We see the *work environment* as the combination of physical, virtual, and organizational drivers that influence the conditions under which digital work is performed, encompassing various elements that shape the experience, performance, and well-being of individuals engaged in digital work settings (Dittes et al.,

2019). This can refer to anything from office layout, ergonomic furniture, lighting, temperature, and other factors up to any potential distractions from colleagues, co-workers, or family and friends (Dittes et al., 2019). Related to this, we believe that a supportive work environment that accepts and welcomes digital workers as an integral part of the organization that does not require direct supervision and micromanagement can positively impact the performance of the so-called digital workers (Meske & Junglas, 2021).

In the context of research involving digital workers, *tasks and workload* can refer to variables that encompass the nature, quantity, complexity, and distribution of work assignments undertaken by digital workers (Baptista et al., 2020). These variables play a significant role in understanding the performance, productivity, and well-being of digital workers, as well as their ability to effectively manage their responsibilities within virtual or distributed work environments by focusing on the task complexity, autonomy, variety, and significance as well as workload distribution, perceived workload, and workload management (Ruiner et al., 2023). Looking at the digital workplace, the tasks and the workload, in general, can become a focal point in how work is done, especially because these employees may not always be under the eye of the supervisor, resulting in too much work or too little (Marsh et al., 2022). As a result, we claim that a workload that is adequate and does not overburden the digital worker can potentially impact their good results.

Eventually, the *technical infrastructure* can be defined as a variable that encompasses the hardware, software, connectivity, and support services that enable individuals to perform their tasks effectively within digital or remote work environments (Gerber & Krzywdzinski, 2019). Having a suitable technical infrastructure in terms of equipment and tools, which is provided by the management or the employer in general can influence how digital workers do their jobs; with better capacities leading to better operational results (Dittes et al., 2019). This gains new meaning as digital workplaces can even transcend physical spaces and take the form of digital platforms (Richardson, 2024). Hence, we hypothesize that a well-established technical infrastructure in the digital workplace can have a positive effect on the performance or outcome of this particular workforce.



**Figure 1:** Conceptual research model of organizational factors influencing the performance in the digital workplace

All of this has led us to define the following research hypotheses as part of the conceptual research model (Figure 1):

H1: A supportive work environment where digital workers operate positively and significantly affects their performance.

H2: A manageable and adequate amount of digital workers' tasks and workload positively and significantly affects their performance.

H3: A well-established technical infrastructure at the digital workplace positively and significantly affects digital workers' performance.

### 3. METHOD

To fulfil the research objective, a quantitative methodological approach was selected which is grounded in data obtained from a survey answered by digital workers who are working in North Macedonia. Due to the specificity of the respondent category, we opted for a purposive sampling technique. For the data analysis, the statistical method of multiple linear regression was used. To develop and test the model, we used the software SPSS.



Moreover, the survey allowed for only anonymous answers in an effort to stimulate more honest and unbiased answers from the respondents. This information was shared with the respondents in the introduction of the survey after which they were asked to provide their consent for participating in the research endeavour.

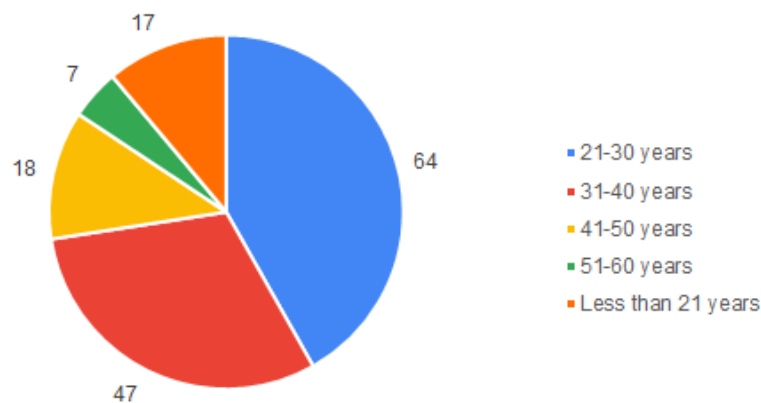
Hence, 18 questions made up the survey, out of which four were designed for assessing the demographics of the sample, focusing on age, gender, organization size, and job position. The foundation of the survey represented the questions or statements relating to the organizational factors affecting the productivity of digital workers, which were 12 in total. These questions were, in fact, statements for measuring the variables of work environment, tasks and workload, and technical infrastructure. Then, two questions were put as eliminatory with the aim of preventing respondents from answering the rest of the questions if they did not identify themselves as working in a digital workplace in the country. Because of this, the final sample consisted of answers from 153 respondents instead of 174 respondents who completed the survey in total but did not consider themselves digital workers. This sample size can be deemed suitable as there should be a ratio of 5:1, i.e., 10:1 between the minimal sample size and the number of analysed variables (Hair et al., 2010). This research endeavour analyses three factors, confirming this statement.

Further, the rest of the questions related to the organizational factors affecting digital workers' performance. Each factor was represented with a set of questions or statements where respondents were asked to provide their level of agreement on a five-point Likert scale with 1 indicating they completely do not agree and 5 indicating they fully agree with the statement.

The measurement scale and factors were adapted per extensive research on the existing literature addressing the topic of interest from Oliveira et al. (2018), Canedo and Santos (2019), and Machuca-Villegas and Gasca-Hurtado (2019). In this sense, the factor of work environment was represented with five statements, the second factor of tasks and workload with three statements, and, lastly, there are four statements for assessing the impact of the factor of technical infrastructure. The survey, which was used for the purposes of this research is provided in the Annex.

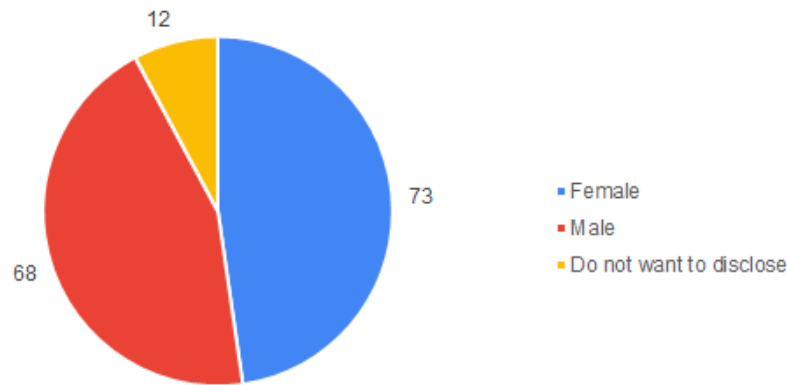
#### 4. RESEARCH RESULTS AND FINDINGS

Before presenting the regression model and the results from this analysis, firstly, we present an overview of the demographics of the sample. To begin with, the majority of the digital workers in the sample can be considered younger with their ages mostly being between 21 years and 40 years. Together they take up almost 73% of the sample (Figure 2). In relation to that, the number of digital workers with fewer years of experience is higher than those with more experience.



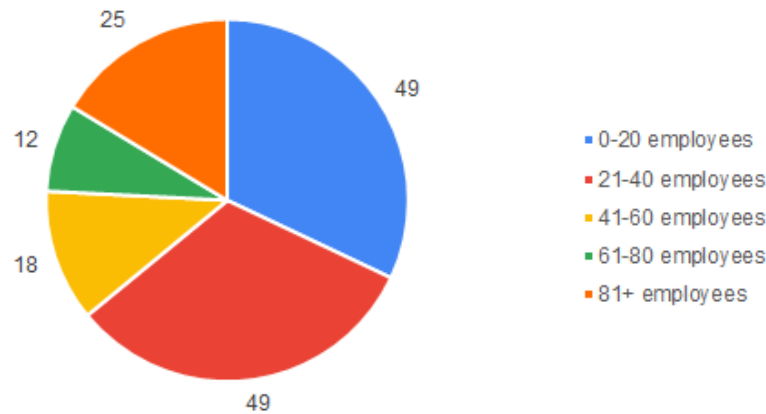
**Figure 2:** Presentation of the sample by age

Namely, the sample has more female digital workers (47.7%), while the sample has 44.4% male counterparts. Additionally, a smaller portion of the respondents did not want to disclose their gender in the survey (Figure 3).



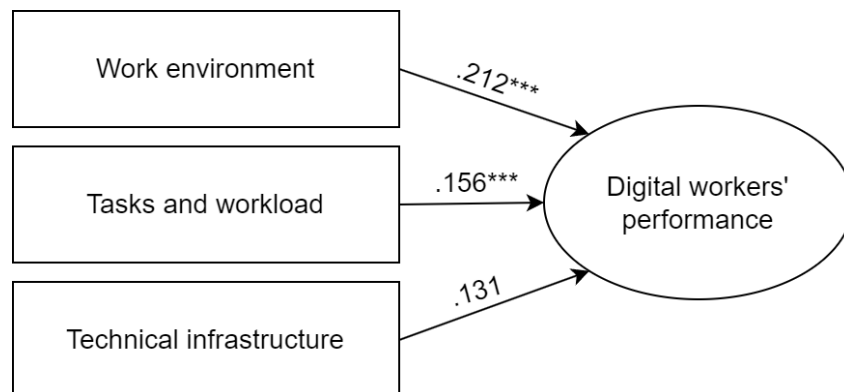
**Figure 3:** Presentation of the sample by gender

Subsequently, respondents provided information about the size of the organizations where they work by the number of employees who work there (Figure 4). Around 65% of them work in micro and small organizations as digital workers, including working as individuals. The least number of respondents are employed in medium-sized organizations. Hence, the belief that digital work is mostly attractive for and applied in startups, lean companies, and among freelancers, remote workers, and digital nomads holds ground.



**Figure 4:** Presentation of the sample by organizational size

Further analysis of the impact of organizational factors on digital workers' performance was done using a multiple linear regression method. We first assessed whether all the prerequisites for this type of analysis were fulfilled. Related to that, it was proven that the model meets the criteria for normality, homoscedasticity, linearity, and multicollinearity. The multicollinearity test factor between the independent variables also known as a variance inflation factor (VIF) shows there is no multicollinearity among these variables. Illustratively, the upper limit of acceptance for this test factor is 10, yet the values of the model presented here are around 2 (Hair et al., 2010). When it comes to the model tolerance, the values in the model are near 0.5, which is deemed satisfactory as researchers recommend a minimal level of 0.2, 0.25, or even 0.1 in some cases (Tabachnick & Fidell, 2012).



**Figure 5:** Model of organizational factors influencing performance in the digital workplace

The research model is presented in Figure 5. A closer look at the standardized beta coefficients shows us that the factor work environment has the most influential positive effect on performance (0.212), while there is a smaller impact of 0.156 prescribed to the factor tasks and workload and the factor technical infrastructure (0.131). These results point to a relation where the performance of digital workers can increase if the workforce has a supportive work environment first and foremost, followed by appropriate tasks and workload as well as a well-established technical infrastructure and suitable equipment. The results from this analysis are overviewed in Table 1.

**Table 1:** Coefficients of the multiple linear regression model

	Standardized coefficients	Sig.	Collinearity statistics	
	Beta		Tolerance	VIF
Constant		.000		
Work environment	.212	.094	.405	2.241
Tasks and workload	.156	.046	.487	2.107
Technical infrastructure	.131	.341	.531	1.938

In addition, we calculated Cronbach's alpha for all variables or factors to prove the reliability of the used scale. The suggested values of this test tend to be between 0.7 and 0.95 (Hair et al., 2010). In our model, they are 0.746 (work environment), 0.788 (tasks and workload), 0.789 (technical infrastructure), and 0.859 (digital workers' performance). As a result, it can be deduced that these criteria are also met.

To demonstrate the (in)dependence between the analysed variables, we conducted a Durbin-Watson test, too, where the test's d value typically goes from 0 until 4; at the same time, the absence of autocorrelation is proven with a value that equals or is close to 2 (Durbin & Watson, 1971). In our model, the d value equals 1.942, which indicates there is no autocorrelation between the organizational factors, which are of interest for this study. Besides this, the  $R^2$  and adjusted  $R^2$  values represent 0.546 and 0.571 respectively. While the recommended values for these indicators vary between types of research endeavours and study fields, for social sciences these values can be between 0.5 and 0.99 (Ozili, 2023). We can interpret these results through the prism that the organizational factors including work environment, tasks and workload, and the technical infrastructure account for 64.6% and 67.1% respectively of the variation in their effect on digital workers' performance. In this vein, we can assume that the rest of the impact can be the result of other factors that are related to the individual characteristics of the employees, the team dynamics, or in other words, their interpersonal and intrapersonal factors, as well as a plethora of factors that are external in nature and exist outside of the organizational context. The values of this model are presented in Table 2 as a summary.

**Table 2:** Regression model summary

$R^2$	Adjusted $R^2$	p-value	Durbin-Watson
.646	.671	.000	1.942

To summarize, we can confirm that the multiple linear regression model, which can be seen in Figure 5, can be considered statistically significant at the 5% significance level with p-value = 0.000 (Table 2). Considering the results of the multiple linear regression explained before, hypotheses H1 and H2 can be confirmed, meaning that the work environment and the tasks and workload positively and significantly affect performance in digital workplaces. However, H3 is rejected due to the results indicating an insignificant relationship between the technical infrastructure and digital workers' performance.

## 5. DISCUSSION

The findings from our research endeavour point out that the work environment and the tasks and workload have a positive and significant impact on the performance of this relatively new type of workforce, which is digital workers. What is more, these findings are in line with other research focusing on this topic, which views the role of the facilitating conditions governed by the organization and the management, itself, as crucial if one wants to boost the performance of the digital workforce (Van Laar et al., 2020).

Moreover, some academics contend that there exists a disparity in the drivers of performance in relation to this aspect between small and large enterprises. In contrast to smaller firms, where these remote work practices are frequently implemented on an as-needed or informal basis, bigger organizations are more likely to have a greater degree of structure (Rainoldi et al., 2024). As a result, they tend to have better control over

the flexible work arrangement, which becomes the fabric of the leadership or management culture (Faisal et al., 2019). The adoption of this kind of work arrangement and new technologies, in general, that foster digital work, in the very structure and strategy decision is of special relevance when it comes to implementing changes and controlling how work is conducted (Bunjak et al., 2021).

Various aspects of the work environment including the light, noise, position, type of office, level of distraction, and similar can impact how digital workers perform regardless of the technology they are using (Rainoldi et al., 2024). Other researchers have noted that the infrastructure that the organization sets up has an important meaning, while in our study it was shown to be insignificant (Gaonkar, 2020). We believe this is likely due to the situation where most digital workers tend to have their own equipment, access to the internet, and the needed tools, so they do not rely on the organization, per se, to provide them. Another factor that can be manageable by the organizations' management is the job design of digital workers or which tasks are delegated to them, thus controlling the level of tasks, too (Piciocchi et al., 2019). Naturally, an increase in tasks when digital worker teams are understaffed or inexperienced can lead to lower performance rates (Piciocchi et al., 2019).

However, the study has several limitations that may be investigated in other studies. Illustratively, additional variables to gauge the impact of organizational factors on the performance of digital workers may be included in future articles, together with features unique to the company where these people work and components from both the wider and more limited environment. Thus, even while the sample size is suitable for the current set of variables, it might be increased to include additional regions or even entire countries. That way, the findings may be compared on a local, national, and international scale.

## 6. CONCLUSION

The objective of this article was to investigate the organizational factors that impact the performance of digital workers as drivers, which are primarily in control of the organizations' management. Through a multiple linear regression model grounded in survey data from digital workers, it was found that the work environment and the tasks and workload positively and significantly affect the performance in digital workplaces, while underlining that the organizations' technical infrastructure does not play a crucial role. The twofold implications of this study are reflected in the theoretical and practical aspects of the research endeavour. Namely, the study presents a novel theoretical model based on prior literature, which can be further tested and scaled up. The practical contributions can be seen in the recommendations that executives and human resource professionals should invest more in custom-tailoring the work environment according to the needs of the members of the digital workplace and ensure the realization of both the personal and professional goals of these individuals. Job design also plays a vital role in the sense of crafting adequate tasks and managing the workload of digital workers who in some cases may not be directly under the eye of the supervisor when they are not working in the office.

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## ANNEX

## Survey questions for data collection

1. What is the type of workplace you work at?
  - Digital workplace
  - A workplace where the employees work from the organization's office spaces
  - Hybrid workplace (in-office work and remote work)
2. In which country do you base your work operations?
3. What is your age?
  - Less than 21
  - 21-30
  - 31-40
  - 41-50
  - 51-60
  - 61+
4. With what gender do you identify?
  - Female
  - Male
  - Do not want to disclose.
5. How many people are employed in the organization you work in?
  - 81+
  - 61-80
  - 41-60
  - 21-40
  - 0-20
6. What is your role in the organization?
7. Indicate the level of agreement related to the following statement: *I don't have too many assignments due at the same time at my digital workplace.* (1 – Strongly Disagree, 5 – Strongly Agree)
8. Indicate the level of agreement related to the following statement: *At my digital workplace, I often work during official working hours and don't work beyond these hours.* (1 – Strongly Disagree, 5 – Strongly Agree)
9. Indicate the level of agreement related to the following statement: *I can experience a shift in my productivity depending on access to tools at my digital workplace.* (1 – Strongly Disagree, 5 – Strongly Agree)
10. Indicate the level of agreement related to the following statement: *The people surrounding me in my work environment can influence me to do better.* (1 – Strongly Disagree, 5 – Strongly Agree)
11. Indicate the level of agreement related to the following statement: *The size of the team can affect my level of productivity.* (1 – Strongly Disagree, 5 – Strongly Agree)
12. Indicate the level of agreement related to the following statement: *My results are better when I am in the work environment I prefer.* (1 – Strongly Disagree, 5 – Strongly Agree)
13. Indicate the level of agreement related to the following statement: *The turnover of employees can impact how I do my job.* (1 – Strongly Disagree, 5 – Strongly Agree)
14. Indicate the level of agreement related to the following statement: *The type of culture and leadership style in my digital workplace influence how productive I am during the day.* (1 – Strongly Disagree, 5 – Strongly Agree)
15. Indicate the level of agreement related to the following statement: *I have the necessary know-how and equipment to work in a digital workplace without disruptions.* (1 – Strongly Disagree, 5 – Strongly Agree)

16. Indicate the level of agreement related to the following statement: *Stakeholders participate in our projects through follow-up emails and remote meetings very often, which helps in my work.* (1 – Strongly Disagree, 5 – Strongly Agree)
17. Indicate the level of agreement related to the following statement: *The communication in my digital workplaces has a smooth flow and doesn't disrupt the work.* (1 – Strongly Disagree, 5 – Strongly Agree)
18. Indicate the level of agreement related to the following statement: *If my organization provides support and help at my digital workplace (such as financial and material help), I believe productivity levels will improve.* (1 – Strongly Disagree, 5 – Strongly Agree)

# DIGITAL LITERACY IN HUMAN RESOURCE MANAGEMENT

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**Abstract:** *In organizations, digitalization and utilize of digital tools are needed. Employees' knowledge and competencies reflect aspects of their mastery and level of proficiency in handling digital tools. Digital literacy and the digital age have given way to the already perceived developed areas of language, numeracy, etc. In what way digital literacy is relevant and necessary for the field of HRM is the question addressed in this paper. In doing so, we aim to highlight the theoretical foundations of digital literacy for the individual functions of HRM and to provide a starting point for future research on digital literacy in the HRM environment. In this paper, we will present the UNESCO model and, on this basis, we will develop a proposal for digital competences for HR.*

**Keywords:** *digitalization, human resource management, digital literacy, HRM processes*

## 1. INTRODUCTION

We live in an environment where, both on an individual level and in terms of organizations, digital is with us at every step. In all organizations, one of the core strategic functions of organizations is undoubtedly HRM. It is a field that deals with the broader space of people management, where the beginning of HRM starts with recruitment and selection, continues into the management of people at work, and at some point, ends with organizations facing the departure of employees, either to retirement or to new work environments. This conclusion does not mean, of course, that the work of HRM stops here, but rather that it is another function that repeatedly encourages HRM to act in an agile way.

To maintain a competitive advantage, companies must focus not on their staff, but on the competency portfolio for different professions, which provides the opportunity to create sets of competencies for specific objectives and projects (Abdrakhmanova et al., 2019)

Digital transformation has forced us to change the way organizations operate to the extent that it has become a fundamental part of companies strategy (Heavin & Power, 2018). We know that the impact of digital transformation is leading to changes in consumer behavior, valuation of services and products, and expectations (Mosca, 2020). To cope with the changes in market behavior, many companies recognize the need to transform their business models to gain a sustainable competitive advantage and keep pace with the digital evolution of their industries.

Digital skills enable the HR manager to be more effective in recruiting and selecting staff, developing staff and ensuring the company's competitive advantage. All this also has an impact on the professionalism of the HR manager (Ponomareva, & Dick, 2020).

From the very beginnings of organizations, when organizations were more concerned with the production process, with efficiency improvements concerning the technical frameworks of organizations, the evolutionary path of organizations has led to the fact that employees are the main pillar of all organizations. Although we see organizations today that are largely digitalized or even robotized, there are still people behind the scenes. The historical trajectory of the development of organizations, which included the behavioral theory of organization development, which specifically touched on the importance of psychology, sociology, and anthropology in organizations, has shown that the synergy of employees in organizations is important for the success and effectiveness of organizations. How do organizations coordinate the work of their employees? How do they motivate them? How do they encourage their achievements? How do they train them? These are all questions that touch on the area of human resources management, which, in conjunction with other strategic functions of organizations, constitutes an important pillar of organizations.

Behavioral theories of organization are a major portion of the field of organizational studies, as behavioral reasoning is found across a range of theoretical approaches (Greve, & Argote, 2015).



Even in the areas of HR traditionally imbued with meaning and cultural significance—recruitment and learning and development—the emphasis has been on productivity and how to measure it. Most human resource managers said they were eager to shift to a model we have come to call “back to human.” The COVID-19 pandemic—which accelerated employee demands on HR to meet physical and mental health needs, as well as intensified moral concerns about a company’s overall impact on society—lent urgency to their view that some core human element has been lost in all these technological advancements (McKinsey, 2021).

Human resources management functions, which are people-oriented, require knowledge and competence in the use of digital tools, given the typical evolution of society. This is precisely the issue that touches on the core areas of HRM and opens opportunities for integrating the "traditional" competencies and skills of the HR manager with digital competencies and skills.

Digital literacy is defined as the knowledge and skills needed to use digital technologies safely and appropriately. It is underpinned by digital competences that enable the use of information and communication technologies to be exploited (Brolpito, 2019).

In recent digitalization and digital literacy studies, it is seen that individuals assume that they are also digitally literate because they can use technology. Thus, the level of using new digital technologies may not show that individuals are digitally literate at the same time. This assumption ignores the factors related to the social effects of societies. In addition, it reduces digital literacy to the level of using only basic information technologies (Öngel, Yavuz, & Tatli, 2022).

In this paper, we will present the theoretical findings of the evidence so far on the development of the level of digital literacy in HRM. The latter will be important for the further research that will be carried out in this area.

## 2. DIGITAL LITERACY

Knowledge is the driving force behind the development and change processes of societies; it is the basis of technological, socio-cultural, political, and economic changes (Öngel, Yavuz, & Tatli, 2022). It is an undeniable fact that human knowledge in society and organizations is at the heart of progress development and innovation in all spectrums of our activities. The concept of the learning organization has been established for decades through knowledge in organizations, which also supports and dictates the trend to promote the knowledge of the organization indirectly for development.

Digital literacy is a concept that emerged with the development and widespread use of the information technology in all areas of daily life as a requirement of the age we live in. However, digital literacy should not be perceived as using a digital platform. Like information literacy, digital literacy refers to individuals' information in digital environments, access, management, evaluation (quality and validity), creation and analysis of new information, and the choice and use of the right platforms that can meet the needs of daily life (Ng, 2012).

The fact that digital literacy has become one of the core competencies of employees in organizations is linked to the development of individuals, groups, and organizations. The UNESCO (2024) definition of literacy is linked to sustainable elements. Literacy is not only the ability to read, write, and count. It is also about recognizing, understanding, interpreting, creating, and communicating in an increasingly digital, textually mediated, information-rich and rapidly changing world. Literacy is the continuous learning and mastery of reading, writing and the use of numbers throughout life and is part of a broader set of skills that include digital skills, media literacy, education for sustainable development and global citizenship, and job-specific skills. Literacy skills themselves are expanding and evolving as people increasingly engage with information and learning through digital technology (UNESCO, 2024).

The areas of competencies covered by Digcomp 2.0 that relate to digital literacy and which will be transferred to HRM in a meaningful way below are (UNESCO, 2024):

**Table 1:** Digital competencies (UNESCO, 2024)

Area of competence	Competence
Information literacy	1.1 Browsing, searching, and filtering data, information, and digital content
	1.2 Evaluating data, information, and digital content
	1.3 Managing data, information, and

	digital content
	2.1 Interacting through digital technologies 2.2 Sharing through digital technologies 2.3 Engaging in citizenship through digital technologies 2.4 Collaborating through digital technologies 2.5 Netiquette 2.6 Managing digital identity
Communication and collaboration	3.1 Developing digital content 3.2 Integrating and re-elaborating digital content 3.3 Copyright and licenses 3.4 Programming
Digital content creation	
	4.1 Protecting devices 4.2 Protecting personal data and privacy 4.3 Protecting health and well-being 4.4 Protecting the environment
Safety	5.1 Solving technical problems 5.2 Identifying needs and technological responses 5.3 Creatively using digital technologies 5.4 Identifying digital competence gaps
Problem - solving	

The Digital Competence Framework for Citizens, identified by its acronym DigComp, was first published in 2013 by the European Commission. It aimed to be a tool to improve digital competence, to help policymakers formulate policies that support digital competence building, and to plan education and training initiatives to improve the digital competence of specific target groups. DigComp also provided a common language on how to identify and describe the key areas of digital competence. Thus offered a common reference at the European level (Vuorikari et al., 2016).

The existing literature on digital literacy, skills, and competencies is rich in definitions and classifications, but there is still no consensus on the major themes and sub-categories of themes (Heitin, 2016). As an example, existing inventories of internet skills are plagued by "incompleteness and oversimplification and conceptual ambiguity" (van Deursen et al., 2015).

Digital literacy, which is one of the challenges of integrating technology into companies (Blau, Shamir-Inbal, and Avdiel, 2020), is defined in the current literature as the competencies needed to navigate a fragmented and complex information ecosystem (Eshet, 2004). Eshet-Alkalai (2012) has designed a "digital literacy framework" consisting of six categories: (a) photo-visual thinking; (b) real-time thinking; (c) information thinking; (d) branching thinking; (e) reproductive thinking; (f) socio-emotional thinking. According to Heitin (2016), digital literacy combines the following strands: (a) finding and consuming digital content; (b) creating digital content; and (c) communicating or sharing digital content. Thus, digital literacy is described in several ways in the literature, as it integrates a set of different technical and non-technical elements.

Digitalization requires changes based on different technological advances and impacts on business strategies (Lipsmeier et al. 2020). Digital transformation has not only had a profound impact on all aspects of our lives but also the processes and roles of human resource management as a strategic business function of companies (Schmid & Pscherer, 2021). The development of new digital technologies has also changed the way HR interacts with information and data. Some HRM processes (Mosca, 2020), such as recruitment, performance appraisal, and HRD, have been fundamentally changed using digital technologies, which improves service delivery to stakeholders.

## 2. DIGITAL LITERACY AND HUMAN RESOURCE MANAGEMENT

HRM is not an isolated strategic function when it comes to technological developments in organizations and society. Its activities, methods, and techniques must undoubtedly adapt and respond appropriately to the opportunities offered by digitalization developments.

Digital human resources management focuses on the digital needs within internal business. This internal focus means that digital transformations in human resource management are considered effective when digital practices raise internally defined employee performance standards (Schneider, 1994). When using internal customers as a valid criterion for assessing the effectiveness of digital HRM practices and processes, employees' feelings and perceptions need to be placed in the context of the logic of customer service quality.

In linking HRM with the elements of digital literacy, which are derived from the general definition as given by UNESCO (2024), we want to present the links to the field of HRM that meaningfully form the spectrum of functions covered by HRM in organizations. In doing so, we have touched upon the following areas:

- (a) Recruitment and selection
- b) Human Resources Development
- c) Rewarding staff

As we said in the initial part of this paper, digitalization and the use of digital tools have a major impact on aspects of our lives, including HR management. In this context, the areas presented in Tables 2 - 4 are highlighted as a starting point for thinking about the treatment of digital literacy for the purposes of future research.

**Table 2.** Digital competencies in HRM functions – Recruitment and selection

HRM function	Area of competence	Competence
Recruitment and selection	Information literacy	Getting HR data, information, and digital content Evaluating job candidate data, information, and digital content Managing candidate data to conduct interviews and interview conclusions
	Communication and collaboration	Communicating with candidates using digital technologies Communicating with candidates via digital technologies Sharing information on vacancies using digital technologies
	Digital content creation	Developing digital content for recruitment and selection
	Safety	Adequate protection of candidates' data and privacy
	Problem-solving	Creative use of digital technologies in recruitment and selection

**Table 3.** Digital competencies in HRM functions – HR development

HRM function	Area of competence	Competence
HR development	Information literacy	Digital data about training and education monitoring the performance of staff training in a digital format
	Communication and collaboration	Communicating with employees using digital technologies for training and education purposes Communicating with

employees via digital technologies  
Enabling training and education for employees online

Digital content creation

Developing digital content for the training and education of employees

Safety

Adequate protection of employees' data and privacy

Problem-solving

Creative use of digital technologies in the training and education of employees

Table 4. Digital competencies in HRM functions – Rewarding

HRM function	Area of competence	Competence
Rewarding	Information literacy	Preparation of HR data and digital content for rewarding system
	Communication and collaboration	Communicating with employees at different stages using digital technologies for rewarding purposes
	Digital content creation	Developing digital content for the reward system
	Safety	Adequate protection of employees' data and privacy
	Problem-solving	Creative use of digital technologies in rewarding

Tables 2 - 4 therefore present the competencies, including digital skills, that we have developed for each HR function. These are a presentation of the individual skills that we intend to explore further to identify, analyze, and evaluate the model we have developed. Given the starting points that theory undoubtedly prescribes for keeping up with the times and the use of digital technologies, the assumed patterns of digital skills are a framework that organizations can follow.

## 4. CONCLUSION

Human resource management must adapt and re-design its practices towards more innovative and creative frameworks and models, due to technological developments in the modern business environment. The same applies to the elements of organizational culture and company structure that are crucial to the success of such initiatives.

The development of skills concerning the assumed model developed at UNESCO (2024) presents us with an opportunity to explore and analyze the reality of HRM in organizations. It is an undeniable fact that digital tools are a necessity and a reality of our time. In principle, the functions of HRM themselves have not changed over the decades. What is changing, however, is how HRM is used, which, with the digital age, offers, on the one hand, a wide range of simplification possibilities and, on the other hand, a degree of caution and manageability on the part of employees.

Even though digital technologies are prevalent in transforming businesses, the role of employees and their digital skills in the process is, to a large extent, neglected. If employees are not ready for this kind of digital technology application, the practices related to employee experience will not create a personalized environment for employees. Employees need to be not only ready for change but also become a part of the change (Dilek, Babak, & Kunio, 2021).

It is one thing to put organizations and employees in the world of digital tools. It is another to recognize that people are still the main capital of organizations, where development and progress take place. With sustainable development in mind, digital tools are also being taken as a knowledge formula together with employees, where organizations must also record productivity on the fact that the knowledge, skills, and abilities of employees are always the treasure on which organizations progress. In the modern environment and society, we live in today, the recognition and awareness of people's skills will be something that needs to be put on the so-called agenda of organizations' daily lives and this paper offers just that - a springboard for further exploration.

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# UNLOCKING HIDDEN POTENTIAL: DEVELOPING LEADERSHIP COMPETENCIES IN THE DIGITAL AGE

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**Abstract:** *The digital age, the uprise of new technologies and contemporary challenges have significantly impacted leaders and their functioning. This paper aims to examine the core competencies leaders have to possess or develop to successfully navigate the digital disruption age. Despite the plethora of noteworthy studies about leadership competencies, there still is a research gap in the context of leadership competencies in a digital age. The article aims to identify the competencies required for leaders to overcome contemporary challenges and successfully navigate new challenges of the digitally disrupted age, drawing on relevant research and respectable articles, and provide a new definition of leadership in the context of the digital age. The findings of this article present six leadership competencies for the digital age and indicate that leaders who understand and embrace new challenges and develop a unique set of competencies will be able to navigate the complexities of the digital age and lead their organisations towards success. This study makes valuable scientific and practical contributions, examining leadership competencies from the perspective of digital-age challenges and providing more fine-grained insight for leaders to enhance their competencies and adapt to the changing landscape of the modern business environment.*

**Keywords:** *leaders, leadership competencies, organisational development, digitally disrupted era, digital business environment*

## 1. INTRODUCTION

The digital era has brought new challenges for businesses and leaders, demanding businesses and leaders to address and explore the key challenges and obtain or develop the skills and competencies required to overcome these challenges. Mirčetić (2018) underlines that digitalisation and the development of new technologies also call for observing leadership from the new perspectives. Digital transformation is not only about digital knowledge but also about the people or the organisation itself. Schiuma and associates (2022) underline that it successfully combines the competencies of employees and organisation.

The digital era, new technologies and globalisation brought many challenges. One of the key challenges of the digital age is the rapid pace of change, leading to the new technologies, such as artificial intelligence, blockchain, the Internet of Things, Society 5.0, but also business models and new challenges at a faster rate than ever before. Digital transformation was boosted during the COVID-19 pandemic (Mirčetić & Mihić, 2022a). Another challenge is the need for digital literacy. New conditions require leaders to adapt to new situations and be agile, which is essential (Bjelica et al., 2020). Another challenge is the existence of a vast amount of data, relevant and irrelevant. Finally, the digital age has also brought about new challenges related to communicating, collaborating and teamwork, such as working remotely or in a hybrid form and virtual collaboration. Given the significant digital transformations in modern society, the leadership competencies deemed sufficient in prior industrial eras have become inadequate (Drucker, 1995). Consequently, there is a pressing need for leaders to obtain competencies that are better adapted to contemporary reality to guarantee organisations' enduring robustness (Longmore et al., 2018).

Recent studies (Guzmán et al., 2020) show that new research on leadership competencies does not have a holistic approach and does not provide a broader picture but primarily focuses on the approach to leadership competencies for a specific business sphere. Additionally, Karaaslan (2015) emphasises that there is still no consensus regarding the competencies needed for modern times and contemporary challenges. Despite the noteworthy research undertaken on leadership competencies, a research gap in the context of leadership competencies in a digital age still exists, which calls for a new study. The paper aims to fill the research gap, identify unique competencies required for leaders to overcome contemporary challenges and thrive in the digitally disrupted era, and propose a new definition of leadership in the digital age.

## 2. THE CHANGING LANDSCAPE OF LEADERSHIP IN THE DIGITAL AGE

The contemporary business environment is dynamic and hypercompetitive with technologies rapidly develop (Mirčetić, 2020). The digital disruption era makes organisations face a dynamic, ambiguous, intricate and complex business environment (O'Connell, 2014). Mirčetić and Mihić (2022b) underline the impact of the crises that periodically occur to the uncertainty. The economy is becoming increasingly globalised (WTO, 2015), and globalisation, followed by the digitalisation of business processes, changes the labour market. Xu and associates (2018) highlighted that the advent of media technologies and technological advancements have led to a notable shift towards digitalisation in the global economy, making the business environment more virtual. As the business world landscape and organisational reality change, the leadership has to change and adapt accordingly (AINuaimi et al., 2022). Shet and Pereira (2021) underline the importance of leaders training to use digital platforms and conduct business in a socially sustainable manner. The increasing focus on sustainable development has necessitated adopting the triple-bottom-line approach by all nations and organisations, thereby compelling business leaders to devise innovative business models, as Roome and Louche (2015) posited. As businesses become more technology-dependent, these skills are beneficial and essential. Leaders need to include the triple bottom line concepts in their activities, minding the business's economic, social and ecological aspects. From the functional skills and concrete skills, they expect to generate organisational reports using different automation tools. Based on their behavioural skills, they need creativity and emotional intelligence while solving complex problems, critically thinking, and making decisions. Also, they need capabilities to lead organisations toward technology-driven changes and more automation.

Technology usage in business is expected to lead to productivity, but it depends on the employees' competencies to use it properly and willingly. The first challenge is technology acceptance. Managers' role in organisations implies that they have to actively embrace technology and create a culture that supports technology adoption and develops suitable attitudes, behaviours, and practices (Frankiewicz & Chamorro-Premuzic, 2020) that will lead toward digital readiness. Digital readiness is based on recognising the opportunities that technology brings and developing relevant knowledge. So, the second role of leaders is not just to enable employees to obtain adequate knowledge but to empower them to do so and facilitate its application. Thus, Schiuma and colleagues (2024) imply that the leadership role has to be redefined according to the new working practices, including structural and cultural changes in the organisational context, along with influencing the appropriate mindset.

In addition to adopting digital technologies to design disruptive business models, digital transformation also encompasses the demonstration of new leadership paradigms (Spremić, 2017). Gimpel and Röglinger (2015) underline that this transformation affects everyone, individuals, organisations, and society as a whole, necessitating the identification of leaders with transformational leadership abilities to spearhead the process of digital transformation and ensure sustained competitiveness in the Industry 4.0 era (Li et al., 2016; Porfirio et al., 2021). Leaders should develop and implement a strategy for upskilling the workforce to actively use digital tools and work efficiently in a digital context, which is seen as one of most demanding tasks for leaders.

## 3. LEADERSHIP COMPETENCIES FOR THE DIGITAL DISRUPTION ERA

Bartram and associates (2002, 7) define competencies as a set of behaviours that are key to achieving desired results or outcomes. Similarly, Lucia and Lepsinger (1999) see competence as a description of knowledge, skills, or characteristics essential for effective business task performance. These diverse perspectives underscore the multifaceted nature of competencies. Competencies represent a set of skills, knowledge, attitudes and abilities that enable an individual to perform job roles (WEF, 2021). Specific authors (Hogan & Kaiser, 2005; Seiler & Pfister, 2009) consider competencies to be part of the theories explaining leadership effectiveness. Seiler and Pfister (2009) state that different leadership competencies, such as professional, strategic, personal, social, and intercultural, are the most important factors defining leadership effectiveness. In the organisational context, the position of the leader is specific and important for an organisation to thrive. D'Este et al. (2012) emphasise that creating a culture of digital transformation is a challenging process influenced by various factors. Leadership is essential for organisations to foster a culture focused on transformation.

Leaders who aim to support and promote digital transformation within their business must possess specific competencies that enable digital knowledge creation, management, and utilisation for ongoing innovation and value creation. This type of leadership demonstrates a digital transformative leader who can create a value-driven and long-lasting organisation by using an entrepreneurial mindset to generate, acquire, and use digital information. Zentner and colleagues (2022) describe leaders as the most important motivational factor in the process of digital transformation. Besides, Mirčetić and colleagues (2019) considers that every leader should motivate followers to optimise the organisational efficiency. Thus, in the pervasiveness of digital transformation, it is crucial to be fully aware of the circumstances and consequences of the current changes and new ways of operating business processes.



### 3.1. Interdependencies of leadership and digital age

Schiuma and colleagues (2024) emphasise the crucial need to combine, absorb, integrate, and employ digital competencies with other complementary knowledge and skills. To create a comprehensive and effective model, classic competency frameworks should be enriched with technological skills (Kovačević & Anđeković Labrović, 2024). In general, leadership competencies for change are based on elements of transformational leadership consisting of the charisma (envision, energise, enable), instrumental (structuring, controlling, rewarding), and institutional skills (risk-taking). In the context of digitalisation, it is about the shift toward digital values and belief in digital transformation (AlNuaimi et al., 2022).

In the current digital landscape, leaders must identify the fundamental leadership qualities required by the changing technical environment. Social and digital technologies significantly transform work dynamics, meaning that this type of awareness is crucial because it demands that leaders adjust their operational approaches accordingly. In addition, successful leadership involves being role models, promoting and maintaining cultural values that encourage a positive attitude towards change, establishing appropriate governance and organisational structures, and ensuring that staff have a deep understanding of digital skills. Additionally, leaders are responsible for removing obstacles to implementing new technology and creating opportunities for employees to interact with them (Bondarouk & Ruël, 2008). Moreover, it is the responsibility of executives to develop new approaches that facilitate a shift towards adaptability, the skilful use of digital tools, and a thoughtful engagement with digital technology (Tarafdar, 2016).

Leaders occupy a strategic position, which means they are responsible for setting the direction and pace of the transformation, and they are role models (Müller et al., 2024). Porfirio and associates (2021) see the leader as the "maestro of the digital orchestra" (p. 611). Sainger (2018) emphasises that digital transformation requires strong leaders to create a common platform that enables different agencies to act accordingly, provides meaning to the technology application process, and leads toward business sustainability. Sustainability is a popular subject for scholars and practitioners in all business spheres (Tornjanski et al., 2023). Sustainability Leaders are responsible for promoting digital mindsets and developing the required agility inside their firms to successfully deal with disruptions caused by digital technology (AlNuaimi et al., 2022).

### 3.2. Identifying and developing leadership competencies for the digital disruption era

The importance of leadership competencies in the organisation is based on their pervasive, both direct and indirect effect on organisational behaviour (Schiuma et al., 2022). In a digitalised organisation, leadership roles require constant capability development, strategic decision-making based on business knowledge, and nurturing interpersonal skills (Porfirio et al., 2021). This aligns with Ghosh's concept (Ghosh et al., 2022) of dynamic capabilities built through continuous learning and unlearning, openness to change, and experimentation. This emphasis on continuous learning and unlearning underscores the dynamic nature of digital competencies and their impact on leadership.

Cameron and Quinn (2006) created a Competing Value Framework which Müller and colleagues (2024) further developed combining leadership competencies and categorising them into four groups based on the dimensions of flexibility/stability and external/internal organisational focus. Implying that there are technical competencies (knowledge of emerging technology), business competencies (visions and strategies), and people-oriented competencies (interactional), they extract four archetypical competency portfolios: the challenger, the bricoleur, the organiser and the competitor with their related competency categories.

One interesting, original conceptualisation is given in Živković's integrative leadership competency framework (2022), covering three dimensions:

1. There is an answer to the question of why, implying vision, innovation, and flexibility.
2. There is a question of what provides an understanding of digital technologies, empowerment, and collaboration.
3. There is a question of how to focus on multiple intelligences, experimentation and continuous learning.

Hargreaves and Fink (2004) concisely summarised sustainable leadership, which encompasses sustainable learning, environmental preservation, and social fairness. Burns and colleagues (2015) investigated sustainable leadership by focusing on the practices of observation and self-awareness, reflection, investigation of ecological and diversity perspectives, and learning from experience and community. Taşçı and Titrek (2019) conducted a study to examine the influence of sustainable leadership on lifelong learning in education. They observed and questioned the enhancement of corporate vision, the implementation of social responsibility, and the establishment of ethical standards. Gitelman and associates (2022) created an instrument for understanding and evaluating managerial competencies by categorising concrete competencies in the well-known digital competencies model (DigComp).

### 3.3. Leadership competencies for the digital era

Deep understanding of the evolving nature of leadership competency, especially with the development of new technologies, is essential. This evolution sees a shift from technical to analytical skills and a greater emphasis on general characteristics such as energy and responsibility (Liu et al., 2022). The future demands for workforce competencies are shifting towards the need to develop digital skills. Embracing new trends, proactive understanding and innovating can assist in preparing for new, virtual, or hybrid working contexts. While it was expected that middle management would be the most tackled with the necessity for developing digital competencies due to their communicative role, research shows that the higher management position requires higher development of digital competencies (Kovačević & Anđelković Labrović, 2024).

Identifying the necessary leadership competencies has become a complex process due to multiple causes. The proliferation of literature on leadership in recent studies has not yet resulted in a consensus on the competencies needed in the present day (Karaaslan, 2015). Furthermore, recent studies on leadership competencies in the twenty-first century tend to focus on a particular industry or setting, lacking a comprehensive vision (đ Guzmán et al., 2020). In addition, there is a discrepancy among authors about the recommended number of leadership competencies needed for the modern era. Regarding business area, different authors propose different number of required key leadership competencies (Higgs, 2003; Van der Merwe & Verwey, 2007; Petrie, 2014).

Leadership competencies in the digital age are only an addition to the essential leadership competencies. Although they can seem similar to the essential leadership competencies, the main difference is that they should be observed and understood in the context of digital transformation and new technologies. Table 1 shows leadership competencies for the digital age with descriptors.

**Table 1:** Leadership Competencies for the Digital Age

Competence	Descriptor
Agility	Adapting to the rapidly evolving environment and making the right decisions promptly to stay ahead of the competition
Collaboration	Being able to foster cross-functional collaboration and the ability to work effectively with diverse teams in person, remotely or in a hybrid form
Data-driven decision-making	Analysing, understanding and interpreting a vast amount of data to make informed decisions
Digital literacy	Having a deep understanding of new technologies, the challenges digital age is bringing and the impact on the business landscape
Effective communication	Being able to communicate effectively and stay connected with followers using different digital tools
Innovative	Ability to drive innovation, create new business models and find new ways to overcome contemporary challenges

Incorporating the findings from this paper's study, this article proposes a new definition of leadership in the context of contemporary challenges in the digital age:

Leadership is a complex and multifaceted process in which an individual establishes twofold relationships with followers, aiming to achieve organisational goals while considering the organisation's needs, changes in the business environment, and challenges of the contemporary digital landscape.

## 4. CONCLUSION

The digital age presents both challenges and opportunities for organisations and leaders. Embracing the existence of necessary changes and a deep understanding of unique challenges and opportunities digital technologies brought, as well as key trends and drivers shaping this landscape, is a prerequisite for successful leadership in the digitally disrupted era. Once embraced, new knowledge should be implemented, which is not the end of the process. Because of the rapid developments in the context of new technologies, a leader must follow key trends, innovate, and adapt already implemented segments to the new tendencies and factual situations. Decisions a leader makes should be driven by data, meaning that the leader analyses, understands and interprets a vast amount of relevant data before making a decision. Leading a successful team means having twofold relationships with the followers and exchanging information about overcoming new challenges. Leaders have to possess specific leadership competencies to drive their organisations' growth and lead them toward success in the digital era. Therefore, leaders have to be agile, collaborative, data-savvy, digitally literate, innovative, and nurture effective communication skills. By embracing new technologies and proposed leadership competencies for the digital era, leaders can unlock the hidden potential of their teams, thrive in the rapidly evolving business landscape of the digital age, and lead their organisations to success.

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# THE IMPACT OF STRATEGIC HRM ON CHANGE MANAGEMENT OUTCOMES

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**Abstract:** *This study provides an overview about the impact of strategic human resources management on change management outcomes, based on the approach and assessment of current strategic trends and available academic literature, with a holistic research approach. It answers the research question about the need for developing a change management model which would be adequate for application in order to ensure successful change management, for the purpose of achieving optimal business results by creating a proper strategic approach. The findings suggest the significant influence of strategic human resources management on change management outcomes, implementation success and sustainable business development, especially considering the balanced influence of Industry 4.0 and Industry 5.0, and the entry of Generation Z into the labour market, while providing guidelines for decision makers and motivating researchers to do further research. The disadvantages of the conducted research are the limited literature and narrative holistic approach.*

**Keywords:** *change management, strategic human resources management, sustainability*

## 1. INTRODUCTION

Today's business faces constant strategic changes of a most diverse spectrum and intensity, such as technological development, artificial intelligence and digitalization development, implementation of innovative solutions, as well as the increasing need for efficient management of crises, which rule the global, social, business, economic and geopolitical scene, thus creating challenging business conditions. Despite all available solutions for efficient change management, business systems face success challenges (Lauer, 2021, p. 3). That being said, the field has been developing further in recent years only to emphasize the importance of people in the form of social responsibility and employee well-being, to establish a balance between the constant strive to achieve competitive advantage and overall enhanced performance and business results, on one side, and the importance of preserving and developing the human capital and talents, on the other side (Machado C. F., Davim J. P., 2023, p. 6, 125). In such a way, organizations can react, operate and adapt to all changes to ensure the existence and sustainable development.

The approach to scientific research in this paper is theoretical, in the form of a holistic analysis of the research subject with a flexible aspect of overall prior knowledge for the purpose of better understanding the concepts, definitions and context of the research subject (Marcyik G., DeMatteo D., Festinger D., 2005, p.9). For that purpose, secondary data sources were used, as well as the interpretative analysis, obtained from scientific journals, articles, course books, the Internet, and materials published by eminent institutions, such as Google Scholar, the International Labour Organization, World Bank and Eurostat. The study is theoretical with the aim of exploring the holistic approach and broader picture of change management and strategic human resources management, especially the impact of strategic human resources management on change management outcomes. The research question can be focused on how to develop a change management model that would be adequate for application to ensure successful change management. The results set the basis for further research.

## 2. LITERATURE REVIEW

### 2.1. Definitions and Significance of Change Management

The dynamics of changes in the business world are at a significantly high level, so each failure to adapt or resistance leads to the inevitable decline of business systems, and one can argue that change management is a complex, strenuous and inevitable process (Asikhia O. U. et al., 2021, p. 78). Notwithstanding the size and

operating level, no organization is immune to changes (Kotter, 1998, p. 5). According to the system theory, organizations operate as open systems, so companies have all options available (Lauer, 2021, p. 13). Constant changes require enterprises to make frequent changes to their corporate strategies, organizational structures and employee competition in order to survive (Jovanović, P., 2006). A change is an unstoppable and inevitable process, part of a company's existence (Jalagat R.C., 2015, p. 1233). Change management skills are crucial for an organization's survival (Kotter, 1998, p. 8). Changes in structure, management, staff, processes, and market are organizational changes (Anderson&Anderson, 2010, p. 5). Cummings and Worley (2009, p. 12) give definitions of organizational changes, relying on the development of an organization, in a way that organizational development includes activities such as outcomes of organizational changes, methods and techniques used for managing changes and overall factors which influence organizational development and, consequently, change management. According to the transformational change approach, Dulanović Ž. and Jaško O. (2008, p. 279) point out that "an organizational change is based on the paradigm of discontinuous development and rational-reactive implementation methodology, which also underlines the necessity for changes, i.e. against the dynamics of the environment, a necessary discontinuity in the form of a rapid and radical change of the structure and functioning of the enterprise". Lauer (2021., p. 4, 32) approaches change management from the standpoint of a special philosophy of corporate management, thus highlighting the importance of the implementation of changes, recognizing the management theory development, which is not correlated with the strategy implementation development, given the widespread opinion that implementation processes are automatic, while the author highlights the importance of implementation, considering the significance of the human factor during that process. Humans have their attitudes, characters, needs, ideas, experiences, emotions, etc. The implementation of changes depends on humans, who are part of social structures not clearly and formally defined. Therefore, the field of change management effects is complex, where a single universal method or technique cannot be applied, so multidimensional perception, a unique choice and authentic adaptation of management methods and techniques are necessary for successful change management. The difference between change management and strategic management lies in the fact that the task of change management is focused on internal optimal adaptation to external changes, which results from strategic management whose task is optimal adaptation to the environment.

A large number of change management models have been developed over the years, which differ according to approaches, steps and factors taken into account. It cannot be said with certainty that a single and unique model is adequate for application in all business situations. However, considering the situational factors and all available models, an optimal decision can be made regarding the appropriate change management model which can be used as framework guidelines when managing and implementing changes (Tornjaski V.Ž., 2019, p. 48). From that aspect, strategic factors are crucial when choosing a change management model, further influencing change outcomes, overall implementation success, and thus sustainable development (Collins D., 1998, p. 62). Relying on the study of the management of planned changes by Stouten et al. (2018, p. 777), Sancak E. (2023, p. 1) suggests a sustainability transformation model, an innovative approach to change management from the sustainability dedication perspective. Sustainable transformation requires dedicated change management through an adequate model, leadership and employee engagement.

## **2.2. Key Factors and Drivers of Change Management**

Drivers of a new business environment may be technology, information revolution, and globalization, together with their implications and critical success factors, such as continuous changes, reduced need for physical assets, overcoming space and time limitations, and vulnerability in the form of exposure to risks. Critical success factors are as follows: the ability to accept changes readily, the ability to be creative and innovative, and the need for the organization and human resource to be at the world level (Coulter M. 2010, p. 100, Kotter 1998, p. 28, Ulrich 2018, p. 15).

Balanced and necessary attention to drivers of internal and external changes is a prerequisite for change management success (Asikhia O. U. et al., 2021, p. 70). The driving forces of changes are new employees, changeable markets, a shorter product life cycle, a change in attitudes towards work, internationalization, globalization, social changes, novel technology, and artificial intelligence (Dulanović Ž., Jaško O. 2008, p. 230). To analyze the external environment, it is recommended to use the PESTLE analysis of the environment, which helps assess the environment based on the following factors: the political, economic, social, technological, legal and ecological environment. Based on the PESTLE environment analysis, which results in a clear overview of trends and scenarios, there is a further possibility of developing the SWOT analysis, which could determine clear chances and threats from the environment, which could further develop strategic plans of necessary changes and development in general (Coulter M., 2010., p. 102). According to Lauer (2021, p. 12) "external changes are subject to the market environment, politics, technology, ecology, the economy as a whole and at the institutional level, as well as the market itself, considering the increasing market competition, and internal changes as human development". To be more precise, various authors and scientists have highlighted the importance of cultural changes as one of the main drivers throughout organizations. On the

other hand, a subsystem change is a change of a smaller extent (Jalagat R. C., 2015, p. 1237). Referring to a statistical finding that 70% of all change attempts had not achieved the expected results in the last two decades, Anderson and Anderson (2010, p. 19) presented IBM's finding, showing a failure in 60% of change processes based on a sample of 1,500 change leaders in a total of 15 different countries. One could argue that the change management failure rate is really high. Three basic factors stand out influencing the change management failure rate, and those are employee resistance forces, inadequate strategies and leadership.

There is a large number of strategic change management factors listed in the literature, with only some being singled out in this paper. From the point of view of organizations, people are the central element (Jaško O., Čudanov et al., 2013, p. 273). The human factor is capable of learning and changing and is characterized by innovative and creative features, which, together with appropriate stimulating methods, enable an organization's sustainable survival (Baron A., Armstrong M., 2007, p. 75). One of the biggest challenges of change management is motivating people to understand that changes are necessary, which is significantly influenced by communication that enables a clear and transparent way of presenting ideas and plans (Kotter 1998, Jaško O., Čudanov et al., 2013, p. 262, Lauer, 2021, p. 6). On the other hand, there is a noticeable influence of strategic aspects of human resource management on change management, especially from the aspect of incorporating completely new human resource management processes and practices, both strategically and functionally, which enable effective and efficient human resource management. Human resource transformation requires, above all, the development of awareness, abilities and skills of experts in human resources. This paper focuses on the element of the human factor of the organization during the change management.

### **2.3. Strategic Human Resource Management Impact on Change Management Outcome**

From the strategic human resource management perspective, policies and practices provide tools for communicating the strategic vision and change management goals (Demo G., Neiva E. R., Nunes I., Rozzett K. 2012, p. 410; Adiguzel Z., Ozcina M. F., Karadal H., 2020, p. 107). Also, strategic human resource management in the function of comprehensive change management, is a driving factor of change and leader of change (Ulrich D., p. 15, Grochowski J., 2018, p.15). Transformative and sustainable human resource management strategies, policies and practices, as well as change leadership, have a positive influence on employee commitment, productivity, welfare, fairness, equality, motivation (Anderson and Anderson 2010, p. 24; Demo G., Neiva E. R., Nunes I., Rozzett K., 2012, p. 415; Yadav R. K., Dabhade N. 2013, p. 60; Hyland M.M., Verreault D.A., 2003, p. 473 ; Kampkötter P., Mohrenweiser J., Sliwka D., Steffes S., Wolter S., 2015, p. 25; Khana Z, Soundararajan V., Wood G., Ahammad M.F., 2020, p. 6; Ulrich D., Grochowski J., 2018 p. 25; Ghulam M., Aamir F. S., 2020, p. 29; Lauer, 2021 p. 421; Dragicevic I., Mihic M. 2020, p. 266). Transformative strategies at the macro level ensure competitive advantage, with the application of the appropriate change management model, particularly from the aspect of readiness for changes and conditions for implementing changes (Alqudah I. H.A, Carballo-Penela A., Rufo-Sanmartín E. 2022, p.6, Bhatia A., Nangia R., 2023, p. 1037; Shrivastava N.A., 2024, p. 9). Strategic human resources management aspects have a crucial role in the digital change management and the creation of adequate strategies and the realization of implementation efficiently and effectively (Junita A., 2020, p. 233). If we take into account the current changes in the past five years, we can see aspects that significantly affect change management from the strategic human resources management point of view, primarily in the form of strategies and working models that are applied, as well as a balanced approach to industry 4.0 and industry 5.0, which further results in the differentiation and diversification of change management strategies (Machado C. F., Davim J. P., 2023, p. 115). Therefore, it can be assumed that resistance to change can be converted in movement forces of change by further development of change management models.

From the other side, the demographic factor stands out for its importance in strategic planning, and thus in change management too, i.e. adequate forecast of changes from the environment from the aspect of workforce and labour market. According to the indicators shown on the Eurostat portal, it is evident that the population is ageing. The EU population decreased, due to the natural population change, with the mortality rate being higher than the birth rate (Eurostat, 2024). The demographic factors are also subject to population migration, which is subject to geopolitical and economic conditions. There is a trend of growing hourly labour costs in the period between 2022 and 2023, equalling 5.3% in the EU, which is subject to not only market disruptions due to the crises but also the strategic changes in the field of labour and workforce. Besides, population migrations have a significant influence, from the strategic aspect of human resources management.

The key demographic changes are population ageing, health and migration, according to the World Health Organization, which thus provides guidelines in the form of facts so that countries can face the challenges and ensure their health and social systems are in accordance with that. By 2050, 80% of elderly people are expected to live in countries with low or middle income. The ageing pace is much faster than before. Between 2015 and 2050, the percentage of the world's population over 60 will have doubled from 12% to 22%. All

countries face a longer population lifespan, and thus an increase in the numbers and proportions of elderly people in the population. By 2030, 1 out of 6 people in the world will be 60 or older. The number of people older than 80 is expected to triple between 2020 and 2050 and thus reach 426 million (WHO, 2024).

Furthermore, the International Labour Organization points out an important strategic aspect which shows that 6% of the global workforce belongs to North, South and West Europe, while 3.9% of the global workforce belongs to East Europe. Also, more than half of the world's workforce is in Asia and the Pacific. The unemployment rate in highly developed countries is 10.4% among youth and 3.8% among adults. In medium-developed countries, the rate for youth ranges between 15.5% and 13.8% and for adults between 4.2% and 3.4%. In underdeveloped countries, it is 9.2% for youth and 4.5% for adults. Globally speaking, the total unemployment rate is 13.3% and 3.9% for youth and adults respectively (ILO, 2024).

The influence of strategic human resources management on change management outcomes is reflected in the influence on both individual and total economic growth. Job creation, employment quality improvement, fair pay, job security, psychological safety at work, gap between the skills and capabilities of the workforce and the needs of employers, technological advancement and green transitions. Labour policies and programs play a key role, designed to protect workers and facilitate labour mobility (World Bank, 2024).

According to the data from the Statistical Office of the Republic of Serbia (2024), the unemployment rate for the last quarter of 2023 was 9.1%, indicating a fall compared to the same quarters in the previous two or more years. Also, the labour market in the Republic of Serbia has seen not only a decline in the unemployment rate but also a constant increase in the average salary and registered employment. The Government of the Republic of Serbia, in collaboration with the International Labour Organization, adopted the Employment Strategy in the Republic of Serbia for the period between 2021 and 2026, which regulates the legal framework and planning documents relevant for the Strategy, as well as the Recommendation on establishing the Youth Guarantee and Employment Support, Quality Framework for Traineeships, integration of the long-term unemployed into the labour market, the European Skills Agenda for sustainable competitiveness, social fairness and resilience. Considering the candidate status, further improvement of the employment policy of the Republic of Serbia is subject to the development of the general European framework of the employment policy, which includes the following: Social Policy and Employment, which was adopted in 2020; Freedom of Movement for Workers, which ensures the freedom of the workforce market. The economic growth of the Republic of Serbia is one of the key strategic, macroeconomic indicators on which sustainable business depends, as well as a sustainable increase in the standard of living, and thus sustainable strategic human resources management.

### **3. CONCLUSION**

The human population, as an essential and strategic factor of strategic human resources management, as well as change management, directs further business adaptation. The development and comprehensive application of artificial intelligence, digitalization, green management, the trend of population ageing, as well as the crises that humanity is facing, from a strategic aspect, affect change management outcomes in several ways, such as the creation of new jobs in the field of artificial intelligence engineering, and many other occupations that are attractive to Generation Z, which, on the other hand, are characterized by changed motivational factors of influence, the necessity of constant care for the workforce, especially from the harder-to-employ categories, which further requires the development of numerous programs to encourage social responsibility and employee care, but also the overall employee well-being.

Considering the expansion and maturation of Industry 4.0, the implementation of Industry 5.0 is under development, striving for a balance in technology management with continuous care for people. In conclusion, green management is closely related to Industry 5.0, considering that the field of change and human resources management has seen a significant emphasis on responsible green behaviour towards employees and continuous care for employee well-being, which further affects sustainable business based on the balanced approach to technology and humans.

By looking at the strategic human resources management aspects in change management, it is possible to answer the research question and conclude that resistance to change can be converted in movement forces of change by further development of change management models to ensure successful change, and thereby take advantage of all the benefits, but also reduce the disadvantages of existing models and use opportunities from the environment, to achieve optimal business results based on overcoming the forces of resistance to change, by creating an adequate strategic change management approach.



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# AN OVERVIEW OF THE FACTORS THAT AFFECT THE CANDIDATE EXPERIENCE DURING SELECTION PROCESS

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**Abstract:** *The purpose of this paper is to highlight the importance that the candidates' experience gained during the selection process has for the employer brand and to identify the most significant factors that shape that experience. Based on the literature review in the field of candidate experience gained during the selection process and surveys conducted by HR platforms most significant factors that influence the candidates' experience were identified as the test relevance, communication with interviewers and information transparency. Based on that, recommendations were given to companies on what they should focus on to ensure a positive candidate experience, and recommendations for further research on this topic were given.*

**Keywords:** candidate experience, selection process, employer brand

## 1. INTRODUCTION

As time passes, organizations begin to understand the importance of human capital and how complex is to study it (Želježić, 2019). The time when candidates fought for the job is long gone. Now the situation is reversed - employers are fighting for potential employees (Miladinović, 2022). For a company to remain competitive in the labor market, it is crucial to manage candidates' perception of a company as an employer (Urmila, Siddharth, & Heena, 2020). Every organization has an employer brand, and whether it owns it or not, it still constantly influences it (Miladinović, 2022). As Theurer and colleagues (2018) emphasize, companies should redirect their resources towards forming employer branding strategies to attract and retain talent, because a developed employer brand suggests that the company is a desirable place to work (Dabirian, Berthon, & Kietzmann, 2019). But organizations must not lose sight of the fact that the employer branding process must continue beyond the recruitment process. All the activities that the organization carries out, all its actions directed towards employees, the environment, society, customers, and thus also candidates, affect the employer's brand (Miladinović, 2022). Therefore, during the implementation of the selection process, companies must take care of how they treat candidates.

It is clear that there is a connection between employer branding and candidate selection (Lloyd, 2002; Ritson 2002; Elving et. al., 2013; Leekha & Sharma, 2014, Grace, D. & Lo, I. J., 2015) – a strong employer brand will attract the best candidates who will enter the selection process, thereby increasing the chances of selecting the best one. However, there is also a significant relationship in the opposite direction – how we conduct the selection process will further reflect on the employer brand.



**Figure 1** – Connection between employer brand and selection process (authors)

According to most researchers, a candidate's experience begins to form long before applying for a job (Miles & McCamey, 2018). Candidates process all the information they have received about the company before, during, and after the selection process, which pertains to the company, and interpret it into a holistic image that encompasses favorable working conditions (McCarthy Julie, et al., 2018). If, as users, we are not aware of the existence of a company or there is a negative experience that we associate with it, we would hardly decide to apply for a job in it. By now, companies have figured the benefits they can have from posting on

social media when it comes to employer branding. But they didn't realize yet that the main part of candidate experience is gained through selection process. Companies should be mapping out every interaction they have with candidates, so they can improve it and deliver a positive candidate experience (Talentegy, 2019). Fundamentally, a candidate's experience is how they perceive an organization, formed by every interaction, procedure, and individual encountered during the hiring process (Miles & McCamey, 2018). This highlights the need for companies to carefully manage each step to ensure a positive candidate experience, because the exchange of their experiences has a strong influence on the employer brand itself, and therefore on the results of the next round of recruitment. McCarthy et al. (2018) argue that organizations prioritizing a high-quality candidate experience are better positioned to attract and engage top talent, thereby increasing brand visibility.

Disappointed applicants are primarily the concern of HR, but it will reflect badly on the entire business – 54.1% of job seekers who had a poor candidate experience stated it would have a negative influence on their decision to purchase a company's products or services or on their brand perception (Talentegy, 2019). British television Virgin Media has quantified the cost of a negative candidate experience at \$6 million in lost value stemming from poor employer branding, lost customers and missed talent from the job market (Miles & McCamey, 2018).

The development of the Internet and social networks has made information spread easily and quickly. Consequently, managing the candidate's experience has become even more crucial, as social reviews can significantly impact a business's reputation both online and offline (Arias-Lopez, 2019). Based on research by CareerArc (2016) – 72% candidates who had poor experience have shared that negative experience online or with someone directly and based on research by Talentegy (2019) – 80% of job seekers rate employer reviews as an important resource in their decision to work for a company.

The purpose of this paper is to highlight the importance of the candidate's experience for companies. Then, on the basis of the research carried out so far, to identify the factors that influence the candidate's experience that was created during the selection process, as well as just before and after the selection process. Based on this, the gap will be determined, and a proposal will be made for further research on this topic.

## **2. METHODOLOGY**

This paper is theoretical. It presents a literature review in the field of candidate experience and the selection process. The search was performed on the websites Google Scholar, Research gate and KoBSON for papers not older than 2015. Keywords that were searched are candidate experience, selection process, selection methods, recruiting process, hiring process, employer attractiveness, employer brand, candidate experience factors, applicant reactions, measuring candidate experience. The study includes journal articles, conference proceedings, dissertations that dealt with this topic. Also, platforms that conduct research in the field of human resources, especially the employer brand, were manually searched – Talentegy, CareerBuilder, CareerArc, SmartRecruiters.

Papers that identified factors influencing the candidate's experience during the selection process (including the activities right before and after the selection (Figure2) were further analyzed. There is no importance if the research was done empirically or through literature analysis. Papers that mainly study the candidate's experience from the recruitment process view were excluded from further analysis.

## **3. RESULTS**

Researchers agreed that candidate experiences have huge impact both on the employer brand (Deloitte, 2018) and on the customer brand (Wojtaszczyk, 2016), which reflects on the entire business (Arias-Lopez, 2019), i.e. the profitability of the company. Now that we recognize the importance of the candidate's experience, it's crucial to identify the factors that shape it and estimate their impact on the employer's brand perception. The aim should be recommendations to companies on how they should design their selection process to ensure that the experience is positive.

Researchers take different approaches when it comes to examining the factors that influence the candidate's experience. Wojtaszczyk (2016) suggests that for the candidate experience to be positive, candidates must be satisfied at all stages of the recruitment process. She based her work on the customer experience model, which she claims is analogous to the candidate experience (Figure 2). Only if both the emotional and physical components of the experience are satisfied, candidates will have positive reactions to the employer.

Example needs	Experience category
Value, pleasure, delight, excitement	Mainly emotional experiences
Confidence, kindness, politeness, care	
Satisfaction, sensitivity, responsibility, resoluteness, comfort, choice, knowledge	Mainly physical experiences
Reliability, availability, security, good value for money, trust	

**Figure 2** - Types of customer experience needs (Wojtaszczyk, 2016)

She agrees with K.W. Grossman (2013) that it is necessary to provide information to candidates about (1) the employer receiving the filled/sent application; (2) hiring/not hiring the candidate; (3) other proposals of employment/cooperation with the organization (or lack of these).

The main recommendations she gives to companies for gaining a positive candidate experience in the selection process are (Wojtaszczyk, 2016):

- 1) Companies should provide detailed information about responsible interviewers and their role, outlining employment conditions, and informing about vacancy filling dates.
- 2) Assignments should be based on work requirements and to refer to concrete situations and candidate behaviors, and should not be discriminatory
- 3) Companies should encourage the applicant to express their mind and ask questions.
- 4) Ensure candidates are comfortable in the interview by asking ice-breaking questions
- 5) Build trust among candidates by evaluating them objectively, according to the set criteria.

Basically, she refers to test's relevance, information transparency, pleasant attitude, objective evaluation.

Hozuri & Mohamed Esmaeili (2023), in addition to the selection and recruitment process, also identified the socialization process as important for gaining candidate experience. Certainly, most of the key factors are found during the selection process, where they highlight adequate selection tools that must be related to the job, informing candidates during the entire process, reducing the number of steps and process duration, and behavior of the company's employees. To these recommendations, Palenius (2021) adds that it is extremely important to give feedback to candidates about their status in the selection, as well as to ask for feedback from them in order to get first-hand recommendations for improving the process (only 1 out of 4 employers regularly request feedback directly from candidates on their experience (CareerArc, 2016)). It should be taken into account that the feedback that the company gives to candidates must be specific and personalized (Talent Board, 2018). Also, according to Palenius (2021) who based her research on the literature review and conducted interviews, online reviews of the company are of great importance to potential applicants for choosing an employer and expectations related to the selection. These claims are supported by the research conducted by Talentegy (2019) where among 4000 candidates, 80% of them confirmed it and according to research by CareerBuilder (2017) where 5016 candidates participated, 81% of them would have a significantly better experience if they were constantly informed about the status of their application.

Miles & McCamey (2018) explain the candidate experience through a multi-stage model that starts with potential talent's career search and ends with both their and company's decision to be employed. When it comes to the selection period, they point out that is necessary to provide applicants realistic job preview, explain in detail the selection process, provide them with a list of contacts for any questions they may have and maintain regular communication. They also point out that it is of crucial importance for the employer's reputation that all candidates are informed in a timely manner about whether they have been accepted or rejected.

McCarthy Julie et al. (2018) showed in their study that informational fairness, social fairness and uncertainty reduction considerably shape the candidate's experience by influencing perceptions of transparency, respect and reassurance and candidate levels of fairness, anxiety and motivation. By informational fairness researchers indicate providing candidates with relevant details about assessments, increasing transparency and perceptions of legitimacy, and by social fairness they emphasize treating candidates warmly and respectfully throughout the testing process, signaling organizational cooperation and consideration. One of the main recommendations for companies to improve the candidate experience based on the results of the Talent Board survey (2018) is to pay attention to how candidates perceive fairness – how fair were the candidates treated during the interview and whether all candidates were given an equal opportunity to show their skills.

**Table 1 – Candidate Experience Factors**

Study	Method/ Sample	Country	CX Factors
(Wojtaszczyk, 2016)	literature reasearch	polish, english literature	<ul style="list-style-type: none"> <li>• test relevance</li> <li>• information transparency</li> <li>• pleasant attitude</li> <li>• objective evaluation</li> </ul>
(CareerArc, 2016)	questionary 826 job seekers 374 HR professionals,	California	<ul style="list-style-type: none"> <li>• communication</li> <li>• interviewer's skills</li> <li>• decrease no. of selection rounds</li> <li>• online user experience</li> <li>• info. about other positions</li> </ul>
(CareerBuilder, 2017)	questionary 5016 candidates, 1500 hiring managers,	United States and Canada	<ul style="list-style-type: none"> <li>• set the expectations</li> <li>• status updates</li> </ul>
(McCarthy Julie, et al., 2018)	2 empirical studies	North America	<ul style="list-style-type: none"> <li>• informational fairness</li> <li>• social fairness</li> <li>• uncertainty reduction</li> </ul>
(Miles & McCamey, 2018)	literature research	English literature	<ul style="list-style-type: none"> <li>• complete and accurate information at each stage</li> <li>• realistic job preview</li> <li>• a list of who to contact</li> <li>• explaining process</li> <li>• selection or denial decision</li> </ul>
(Talent Board, 2018)	questionary 138.000 candidates 180 employers	North America	<ul style="list-style-type: none"> <li>• perceived fairness</li> <li>• interview preparation</li> <li>• informing about next step</li> <li>• giving follow-up</li> <li>• specific feedback</li> </ul>
(Talentegy, 2019)	questionary 4000 job seekers		<ul style="list-style-type: none"> <li>• in person instead online interviews</li> <li>• communication</li> <li>• asking for feedback</li> <li>• technical problems with application</li> </ul>
(Palenius, 2021)	literature reasearch, quality reasearch, 3 interviews	Finland	<ul style="list-style-type: none"> <li>• effective communication</li> <li>• process speed</li> <li>• transparency</li> <li>• online reviews</li> <li>• providing and giving feedback</li> <li>• relevant tests</li> </ul>
(Hozuri & Mohamad Esmaeili, 2023)	quality reasearch, 25 interviews – recruiters and applicants	Iran	<ul style="list-style-type: none"> <li>• adequate selection tools relative to job</li> <li>• informing candidates</li> <li>• reducing steps and duration</li> <li>• employees' behavior</li> </ul>

When we look at all the identified factors of the previously analyzed researches (Table1), we can summarize the main recommendations for companies:

- Companies should maintain clear communication with candidates. (1) to inform them when they receive the application and give them status updates (2) to explain to them who are the responsible persons to contact if they have any questions (3) to be accurate with responding;
- Companies should be transparent with informations. (1) to explain in detail the job description and working conditions (2) to explain how the selection process will proceed and how long it will last (3) to set the expectations - to explain what the selection criteria are;
- Companies should choose only those testing methods and tools that are strictly related to the job requirements. (1) relevant tests (2) specific questions (3) without grounds for discrimination;
- Companies should focus on feedback. (1) the feedback they give to candidates should be timely, personalized and provided to all candidates regardless of whether and in which selection round they were rejected (2) they should inform rejected candidates about other opportunities in company or further (3) they should ask for feedback from candidates in order to get ideas for improvement and to show to the candidates they care about their opinion;
- Companies should prepare well the employees who will be in contact with the candidates. (1) for interviewers to improve their skills (2) for interviewers to have a pleasant attitude towards candidates, to relax them before the interview (3) for other employees who are not testing candidates but should also have a nice behaviour to candidates;
- Companies should take care of the digitalization of the selection process. (1) to ensure that all job seekers are able to submit an application (2) to improve the user experience (3) to give candidates a choice of where they want to be interviewed – online or at the company.

#### 4. DISCUSSION AND CONCLUSION

This paper is focused on finding the factors that shape the candidate's experience during the selection process. Papers from 2015 that investigated this topic through questionnaires or literature review were analyzed. In addition, research by HR platforms conducted on a large sample is also included. The most significant factors that influence the candidate's experience during the selection process were identified. Concrete recommendations that regarding the actions that companies should take to ensure a positive experience for candidates in the selection process are presented.

Considering that a candidate's experience starts with the first contact with the company and ends with the onboarding process, it is certain that it is acquired through many different stages. Since it is in a two-way relation with the employer brand, which is the main tool for attracting talent, for now the greatest emphasis is placed on finding the candidate's experience factor in the recruitment phase. The main thing that is immediately noticeable is that there are not many papers available that investigate the factors that affect candidate experience gained during the selection process. Mostly, we get the most information about the candidate's experience from platforms that offer certain HR services to companies. It is crucial for them to highlight the importance that a bad or good candidate's experience can have on the employer brand and the applicant pool because their profit depends on it, and that is why they conduct research about once a year.

Most research do not distinguish between respondents who got an offer at the end of the selection process and those who were rejected. The assumption is that this would have a significant impact on the results when it comes to candidate satisfaction and perception. According to research by Marysol & Randy (2019), even though they are treated the same way, candidates who are hired will have a more positive experience. This could be a variable to consider when examining other factors in future research.

It is known that candidates from all generation groups prefer live interviews to online/video interviews (Talentegy, 2019) and according to the same study, even half of the respondents answered that they encountered some technical problem when they are filling out online application, which led them to give up applying and never return. Apart from this information, there is not enough data on how the candidates perceive the digitization of the selection process. In the following research, it should be examined how different levels of digitization affect the satisfaction of candidates.

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# THE POWER OF AI ONBOARDING: FOSTERING FAIRNESS, ONBOARDING SUCCESS AND PERFORMANCE IN NEW HIRES

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**Abstract:** *This research investigates the complex interplay between procedural justice, onboarding success, and new hires' performance within AI-powered onboarding processes. Conducted with N=112 new hires in a private sector organization in the EU, it examines how procedural justice affects new hires' perceptions of onboarding success and subsequent performance, as well as the potential mediating role of onboarding success. Mediation analysis revealed that procedural justice exerts both direct and indirect effects on new hires' performance, with onboarding success mediating this relationship. Specifically, higher levels of perceived procedural justice in the AI-powered onboarding process were associated with improved new hire performance, partially attributed to their perception of the onboarding process as successful. This extends understanding of procedural justice in technological onboarding contexts, emphasizing the need for fair processes to enhance performance. The findings inform organizational onboarding practices, highlighting the importance of transparency and fairness for optimal outcomes.*

**Keywords:** *procedural justice, onboarding success, new hire performance, AI-powered onboarding process*

## 1. INTRODUCTION

High performance of new hires is of crucial interest to organizations (Dutta et al., 2024). In the dynamic landscape of modern business, recruiting and integrating new employees are pivotal moments that can significantly impact organizational success. The performance of these new hires carries profound relevance, shaping the trajectory of companies in various sectors. Firstly, the performance of new hires directly influences organizational productivity and efficiency. As they acclimate to their roles and responsibilities, their ability to swiftly grasp tasks, collaborate with colleagues, and contribute meaningfully to projects can either enhance or hinder organizational effectiveness. High-performing new hires can catalyze team productivity and innovation, whereas underperforming individuals may impede progress and strain resources (Chowdhury et al., 2022). In light of these considerations, organizations must prioritize strategies to optimize new hire performance. Effective onboarding programs, mentorship initiatives, and performance feedback mechanisms are instrumental in facilitating new employees' successful integration and development. Additionally, proactive talent management practices, such as robust recruitment processes and talent pipelines, can ensure the acquisition of high-caliber candidates poised to make meaningful contributions from the outset (Bell, 2021).

Once these high-caliber candidates are identified, the journey of integration begins. Effective onboarding processes emerge as the bridge connecting new hires to the organization's heart, shaping their initial performance and laying the groundwork for their long-term success within the company. The onboarding process encompasses a comprehensive set of activities and experiences designed to integrate new employees into an organization, facilitate their socialization, and equip them with the knowledge, skills, and resources needed to succeed in their roles. It involves orientation to organizational culture, job responsibilities, expectations, and opportunities for relationship-building, training, and support (Bauer et al., 2007). Research indicates that well-designed onboarding programs contribute to higher job satisfaction, organizational commitment, and productivity among new hires (Bell, 2021). Furthermore, onboarding facilitates the assimilation of new hires into organizational culture, fostering a sense of belonging and alignment with company values (Chowdhury et al., 2022). Recent studies underscore the importance of tailored onboarding approaches, incorporating mentorship initiatives, performance feedback mechanisms, and proactive talent management practices (Chowdhury et al., 2022). By leveraging these strategies,

organizations can ensure new hires' seamless integration and development, ultimately enhancing their contribution to organizational goals and success.

In addition to traditional onboarding methods, integrating AI-powered onboarding tools and applications has emerged as a transformative approach to enhancing new hire performance. These technologies streamline administrative tasks, deliver personalized training content, and provide real-time feedback, accelerating the learning curve and facilitating the adaptation process for new employees (Gupta & Kumar, 2024). By leveraging AI-driven insights and predictive analytics, organizations can identify potential challenges early on and tailor the onboarding experience to individual needs, optimizing the effectiveness of the onboarding process (Gélinas et. al., 2022).

Amidst this technological revolution, the principle of procedural justice stands firm as a guiding beacon. Procedural justice – the perceived fairness of the procedures used to determine outcomes in organizational contexts – characterized by fairness, transparency, and consistency in organizational processes, has garnered significant attention in organizational psychology literature for its impact on employee attitudes, behaviors, and outcomes (Colquitt et al., 2013). Within the onboarding process, procedural justice emerges as a critical determinant of new hire performance, shaping their perceptions of fairness and organizational commitment. Studies suggest that procedural justice during onboarding positively influences new hires' perceptions of the organization, fostering trust and reducing uncertainty (Jordan et al., 2022). Organizations can instill confidence in new hires by providing transparent and consistent procedures, leading to higher engagement and job satisfaction (Colquitt et al., 2013). Moreover, procedural justice in onboarding contributes to developing a positive organizational climate and promoting cooperation and collaboration among team members (Smith et. al., 2022). Recent research emphasizes the role of specific onboarding practices in enhancing procedural justice and new hire performance. Tailored communication strategies, clear expectations, and opportunities for voice and feedback empower new employees, reinforcing their sense of fairness and belonging within the organization (Korkmaz et al., 2022). Additionally, integrating technology-enabled platforms and AI-driven solutions in the onboarding process offers opportunities to standardize procedures, ensure consistency, and enhance transparency, further bolstering perceptions of procedural justice (Jiang, 2023; Gupta & Kumar, 2024).

The perceptions of new hires regarding the success of their onboarding experiences play a crucial role in shaping their subsequent performance within organizations. Studies indicate that positive perceptions of onboarding success are associated with higher levels of job satisfaction, organizational commitment, and job performance among new employees (Bauer et al., 2007, Zhao et. al., 2023). When new hires perceive their onboarding process as effective and supportive, they are more likely to feel valued, engaged, and motivated to contribute to organizational goals. Recent research underscores the importance of specific factors contributing to new hires' perceptions of onboarding success. Clear communication, adequate training and resources, and meaningful interactions with supervisors and colleagues are crucial elements shaping new hires' onboarding experiences (Sibisi & Kappers, 2022). Additionally, aligning onboarding activities with organizational culture and values enhances new hires' sense of fit and belonging, further bolstering their perceptions of onboarding success (Zhao et al., 2023). Furthermore, the role of technology-enabled solutions in enhancing new hires' perceptions of onboarding success must be noticed. AI-powered platforms, virtual reality simulations, and mobile applications offer opportunities to personalize and enhance the onboarding experience, increasing new hires' satisfaction and confidence in their readiness for their roles (Zhao et al., 2023). Organizations can foster positive perceptions of onboarding success and ultimately enhance new hire performance by leveraging technology to streamline processes, provide timely support, and facilitate connections with colleagues.

Integrating AI-powered onboarding tools and applications represents a paradigm shift in the onboarding process, offering opportunities to enhance procedural justice and shape new hires' perceptions of onboarding success. The interactive and user-centric nature of AI-powered onboarding tools gives new hires greater control over their onboarding experiences, empowering them to voice concerns, seek assistance, and provide feedback (Chowdhury et al., 2022). This participatory approach fosters a sense of inclusion and respect, contributing to positive perceptions of procedural justice and onboarding success.

Recent technological advancements, particularly the integration of AI-powered onboarding tools and applications, offer new avenues for examining the relationship between procedural justice, new hires' perceptions of onboarding success, and their performance. Research suggests that AI-powered onboarding tools can enhance procedural justice by standardizing procedures, ensuring transparency, and providing personalized experiences for new hires (Gupta & Kumar, 2024). By leveraging AI-driven algorithms and data analytics, organizations can tailor onboarding processes to individual needs, fostering perceptions of fairness and equity (Gélinas et. al., 2022). Furthermore, the interactive nature of AI-powered tools gives new hires greater control over their onboarding experiences, empowering them to voice concerns and seek assistance as needed (Chowdhury et al., 2022).

Examining the relationship between procedural justice in AI-powered onboarding tools, new hires' perceptions of onboarding success, and their subsequent performance holds scientific significance for several reasons. Firstly, it provides insights into the mechanisms through which organizational processes influence employee perceptions and behaviors. Secondly, it sheds light on the role of technology in shaping organizational justice perceptions and outcomes. Finally, it offers practical implications for organizations seeking to optimize onboarding practices and enhance employee performance in the digital age. This research aims to enhance our understanding of how procedural justice affects new hires' perceptions of onboarding success and their subsequent performance within the context of AI-powered onboarding processes. Furthermore, it explores whether onboarding success mediates the relationship between procedural justice and new hires' performance.

## 2. METHOD

### 2.1. Participants and Procedure

The data were gathered on N=112 new hires while providing consulting services to a private sector organization in an EU member state. Most of the new hires were men (51%) holding high school degrees (37%) or at least Bachelor's degrees (63%). The organization introduced an AI-powered application to guide the onboarding process for these recruits, aiming to improve its efficiency and enhance the overall experience for the recruits. The AI-powered onboarding process spanned three months (90 days). After this process, the recruits evaluated the fairness of procedures and the success of their onboarding experience using a paper-and-pencil method during final workshops. Additionally, their respective supervisors assessed their performance. The collected data were analyzed using Hayes PROCESS Macro (2018; Model 4) within the IBM SPSS Statistics 25 package.

### 2.2. Instruments

*Procedural justice* was assessed using a five-item procedural justice scale (Jakopec & Sušanj, 2014). The scale was adjusted in order to measure the perceived procedural justice of the AI-powered onboarding process. The example items were: "AI-powered onboarding tool provides me with clear feedback on the quality of my work" and "AI-powered onboarding tool explains me decisions in a clear way and provides additional information when I request it." New hires assessed each item on a five-point Likert scale, ranging from 1 (strongly disagree) to five (strongly agree), with higher scores indicating higher perceived procedural justice. *Onboarding success* was measured by a five-item scale (Sharma & Stol, 2019). The example items were: "The initial orientation program helped me feel less stressed about joining a new workplace" and "I clearly understand the expectations and responsibilities of my job." Items were measured using a five-point Likert ranging from 1 (strongly disagree) to five (strongly agree), with higher scores indicating higher perceived onboarding success. *New hire performance* was evaluated using supervisor ratings of the new hires' work. The performance goals on various criteria were set at the beginning of the onboarding process. At the end of the onboarding process, supervisors rated new hire performance on a five-point scale, namely "unsatisfactory," "requires attention," "satisfactory," "above satisfactory," and "excellent".

## 3. RESULTS AND DISCUSSION

Descriptive statistics and intercorrelations are presented in Table 1.

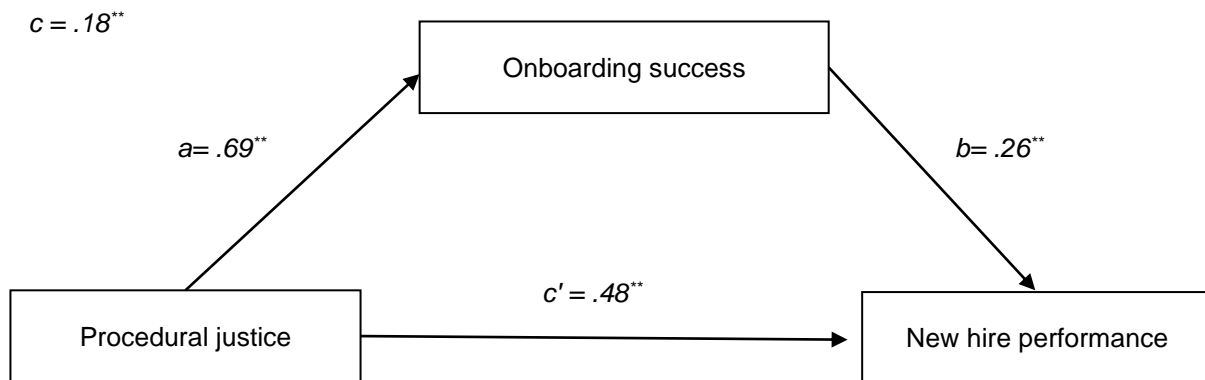
**Table 1.** Descriptive statistics and intercorrelations of all variables measured (N=112).

Variables	Descriptive statistics			Correlations		
	<i>M</i>	<i>SD</i>	<i>α</i>	1	2	3
Procedural justice	4.08	1.13	.94	-	.69**	.66**
Onboarding success	3.42	1.03	.83		-	.59**
New hire performance	4.25	1.02	.88			-

Note: \*\*p<.01

As expected, perceived procedural justice of the AI-powered onboarding process strengthens new hires' evaluations of onboarding success and their performance rated by their superiors. Additionally, onboarding

success leads to higher ratings of new hires' performance. The mediation analysis results (depicted in Figure 1) support the abovementioned.



Note:  $a$ ,  $b$  – standardized regression coefficients;  $c'$  – direct effect;  $c$  – indirect effect;  $^{**}p < .01$

**Figure 1.** Graphic representation of the mediating effect of onboarding success in the relationship between procedural justice and new hire performance (N=112)

Namely, procedural justice both, directly and indirectly – via onboarding success – strengthens new hires' performance. In other words, new hires that perceive higher levels of procedural justice of the AI-powered onboarding process tend to perform better [LLCI 0.2613, ULCI 0.6090], partially because they perceive the onboarding process successful [LLCI 0.0458, ULCI 0.3434]. The tested model explained 68% of the outcome variance ( $p < .001$ ).

This research, conducted in the context of AI-powered onboarding processes, aimed to enhance our understanding of how procedural justice affects new hires' perceptions of onboarding success and their subsequent performance. It also explored whether onboarding success mediates the relationship between procedural justice and new hires' performance. The mediation analysis results confirmed that procedural justice both directly and indirectly – via onboarding success – strengthens new hires' performance. In other words, new hires who perceive higher procedural justice of the AI-powered onboarding process tend to perform better, partially because they perceive the onboarding process as successful. These results align with previous research's results, supporting the notion that perceptions of procedural justice positively influence new hires' performance by enhancing their adjustment and integration into the organization (Bauer et al., 2007). Additionally, this time among new hires, perceptions of onboarding success once again proved to be associated with higher levels of job performance (Badshah & Bulut, 2020).

The scientific value of these research findings lies in their contribution to our understanding of the complex interplay between procedural justice, onboarding success, and new hires' performance within AI-powered onboarding processes. By investigating these relationships, the research sheds light on critical factors affecting new hires' integration and performance in modern organizational settings. Firstly, the research extends our understanding of procedural justice by examining its effect on new hires' perceptions of onboarding success and subsequent performance within AI-powered onboarding processes. This contributes to the broader literature on organizational justice by exploring its relevance in the context of technological advancements in onboarding practices. Secondly, identifying onboarding success as a significant mediator in the relationship between procedural justice and new hires' performance adds nuance to our understanding of these dynamics. By highlighting the indirect effect of procedural justice through onboarding success, the research underscores the importance of ensuring fair and transparent onboarding processes to enhance new hires' performance outcomes.

However, future research should address the existing research limitations. The cross-sectional nature of the data and reliance on correlational analyses preclude causal inferences, and alternative statistical techniques, such as longitudinal or experimental designs, could offer further clarity on the causal mechanisms underlying these relationships. Additionally, reliance on self-report measures for onboarding success may introduce response bias or social desirability effects, potentially influencing the accuracy of the results. Furthermore, the relatively short duration of the AI-powered onboarding process (90 days) may limit the assessment of its long-term impact on new hires' perceptions and performance. Longer-term follow-up assessments could provide a more comprehensive understanding of the sustained effects of the onboarding process.

Finally, these findings have significant practical implications for organizations. They underscore the importance of designing effective onboarding programs that prioritize procedural justice principles, such as transparency and fairness. The use of AI-powered onboarding tools can streamline processes and enhance the overall onboarding experience. Training managers on the significance of procedural justice in the onboarding process can ensure consistent implementation and foster positive perceptions among new hires. Additionally, organizations should prioritize continuous monitoring and evaluation of their onboarding processes to identify areas for improvement and strive for continuous enhancement. By implementing these practical recommendations, organizations can optimize their onboarding practices to facilitate new hires' integration and enhance their performance outcomes. Overall, this research contributes to both theoretical understanding and practical application in the field of organizational behavior and human resource management.

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# SUCCESSION PLANNING AS A WAY OF MANAGING AND RETAINING TALENT

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**Abstract:** *Companies need top talent in key positions to be successful in business. However, many organizations don't think about succession planning until someone in a critical position unexpectedly leaves the organization. This may easily lead to negative consequences for the organization, as it cannot afford to leave a key position vacant for a long time, while filling such position with an inadequate individual may even harm the company's success. Therefore, effective organizations do not passively wait for the future – they decide to invest in planning for potential successors. This paper aims to examine the concept of succession planning and explain its importance for organizations, identify the steps of succession management process, and explore the benefits of implementing an effective succession plan. The paper concludes that a long-term approach to succession planning has become a necessity for contemporary organizations as their survival often depends on their ability to react effectively when an individual in key position exits the organization. Organizations must plan for the future to ensure enough talented individuals are prepared to quickly fill the critical positions when they become vacant.*

**Keywords:** *succession planning, talent management, leadership development, employee retention, human resource management*

## 1. INTRODUCTION

Human resource management aims to obtain and maintain capable, flexible and dedicated people for jobs in the organization (Price, 2007). Companies need top talent to be successful in business. Talent refers to those employees who can have a significant impact on organizational performance. The term refers to a small group of key people in an organization. Individuals are seen as talents when they have great potential and when they are difficult to find and replace (Brewster et al., 2016). They are characterized by skills and abilities that enable them to make a unique contribution and a special value to their work organisation. Today, the term "talent hunting" is often used for the process of acquiring and retaining talented individuals to emphasize the importance of the human factor for achieving company's success.

Since talents are seen as a strategic asset of the company (Brewster et al., 2016), talent management is seen as a strategic process in the organization. The concept of talent management evolved at the end of the 1990s. Talent management includes all organizational activities aimed at attracting, selecting, engaging, developing and retaining talented individuals who will perform strategic roles in the organization (Scullion et al., 2010).

The internal labor supply is constantly changing - new employees enter the organization, existing employees are promoted, retire, etc. The departure of retiring employees and movement of employees to other positions can significantly impact an organization (Hall-Ellis, 2015), especially when it happens in crucial positions. For this reason, organizations must plan for the future to ensure that there are enough qualified and trained individuals who can fill the critical positions when they become vacant. Succession planning is one of many key elements of a successful talent management process aimed at managing and preserving organization's talent pipeline (Bolander et al., 2017) to achieve its strategic goals. Succession planning is a long-term process of identifying critical positions in the organization, selecting key talent and planning their development in order to prepare them to take over those positions in the future. Today, this process is closely related to talent management and the broader processes of human resource planning and development.

In 2021, for example, 1,337 CEOs left their positions, representing an increase of 1.8 percent compared to 2020 (Tyler, 2022a). Many organizations neglect to prepare for an inevitable change (Ritchie, 2020) and don't think about succession planning until someone in a critical position retires or passes away. According to a survey conducted in 2021 by the Society for Human Resource Management (SHRM) which included 580 HR professionals, 56 percent of organizations did not have a succession plan at all (only 21 percent had a formal

succession plan, and 24 percent had an informal succession plan) (Tyler, 2022b). On the other hand, effective organizations do not passively wait for the future (Ibarra, 2005), but invest in planning for potential successors.

This paper represents a theoretical review succession planning. The paper aims to examine the concept of succession planning and explain its importance for organizations, identify the steps of succession management process, and explore the benefits of implementing an effective succession plan.

## **2. SUCCESSION PLANNING**

### **2.1. The concept and significance of succession planning**

Succession planning has become a common practice in organizations worldwide (Fusarelli et al., 2018). It ensures that the organization has the right people in the right jobs today and in the future. Succession planning can be defined as a “systemic, long-term process of determining goals, needs, and roles within an organization and preparing individuals or employee groups for responsibilities relative to work needed within an organization” (Luna, 2012). The goal of succession planning is to enable quick and quality filling of critical positions if the current employee in that position leaves the organization or, for example, is promoted to a higher position. “Sound succession planning is all about picking the right people for the right jobs at the right stage of their personal and professional development” (Tichy, 2014, p. 84). Succession planning should enable business continuity – i.e. when an employee in a key position leaves the company succession plan is expected to ensure that there is another employee who is qualified and ready to take over the role in a short period of time.

Succession planning focuses on key positions and critical roles in the organization. These positions are of the greatest importance for ensuring business continuity and gaining an advantage over the competition, i.e., those positions that, if left vacant for several months or filled by an inadequate individual, would significantly damage the company. Organizations should first identify the critical roles for which they should plan potential successors. These are primarily top management positions (e.g., CEO, CFO, etc.). In addition, succession plans should be made for some non-managerial positions that may be of key importance for the organisation's future, as well as some specific positions that are very difficult to fill if an employee leaves the job. For example, when an HR Assistant leaves the company, finding a replacement and filling the vacant position is usually easy. However, when a company's Vice President of Human Resources (VPHR) leaves the company, the process of replacing the employee can be time-consuming, complex and very expensive, and organizations cannot afford such an important position to be vacant for a long time.

There are two approaches to succession planning. One approach is role-based succession planning. It refers to identifying and developing successors only for specific positions that have been identified as critical. Within this approach, the organization encourages employees to compete for specific roles that are critical to the organization. Bearing in mind that the number of key positions in the organization is not large, organizations in this case consider only a small number of employees in the process of succession planning and plan the development only for those employees. Also, it is important to match the interests of employees with specific critical roles. The other approach to succession planning is aimed at identifying and developing a group of employees with the potential to fill any of the critical positions in the organization. It refers to the planning and development of potential successors for different roles identified as critical in a certain group of jobs that require similar skills with the idea develop a pool of talented individuals who will possess the general skills needed in various critical roles, and who will be flexible and able to fill different positions in the future depending on the needs of the organization.

### **2.2. Succession planning process**

Sobol et al. (2007) have defined a succession planning framework which consists of the following steps: succession, progression, and development. According to Atwood (2020) the succession planning process includes the following stages:

1. Identification of key positions for succession planning
2. Defining the requirements for each key position
3. Identification of potential successors for each key position
4. Talent development
5. Monitoring and periodic revision of the succession plan
6. Making a succession decision.

The first step of succession planning is to identify the key positions that should be included in the process. Afterwards, it is necessary to define the competencies, personal characteristics and other requirements needed for each key position. The focus should be on the competencies that will be needed in the future for

the selected key positions, and not on the current job needs. This step is followed by identifying potential successors for each key position. It is necessary to assess the competences possessed by the individuals based on the defined criteria and available data on their previous performance, skills, competences, leadership abilities, interests and willingness to get involved in the succession planning process. Also, a decision should be made on how many potential successors will be included in the process. For example, grooming just one potential successor of a current senior manager can be risky because the employee may drop out of the succession planning process or prove unsuitable for the position. On the other hand, the number of potential successors should not be large either as it would increase the complexity and the cost of the process; a large number of candidates fighting for the same position in the future can lead to dissatisfaction and mutual conflicts etc.

The next phase of succession planning process is talent development. An individual development plan should be created and implemented for each potential successor. Talent development can be implemented using different methods to enable individuals to gain more experience and develop their leadership skills. These programs may include: job rotation; executive coaching; mentoring; liaising with other managers in different functions, work groups or geographical areas; job tasks; action learning; different types of training; 360-degree performance appraisal etc. (Groves, 2007). Executive coaching refers to one-on-one, goal-oriented, practical learning, usually conducted by a senior manager or an external expert. Mentoring is a development activity based on an employee's advisory relationship with a senior manager, which can be formal or informal. Mentoring programs aim to develop leadership competencies of high-potential employees through coaching, group discussions, career guidance and providing employee visibility to senior managers. Performing job tasks include providing detailed tasks in terms of job role, function or geographical area. They often require skills and knowledge beyond the capabilities of the individual. Action learning usually involves a group of high-potential employees solving existing critical business problems and making recommendations to senior management. Employee performance should be assessed at least on annual basis through 360-performance appraisal and this process should be used for identifying their leadership potential by multiple evaluators (Hall-Ellis, 2015).

The implementation of the created succession plan should be continuously monitored and periodically revised. During its the execution, it is likely that some of the selected individuals will not be successful and therefore excluded from this process. However, even if they are not suitable for the identified critical positions, it is possible that the development programs have prepared them to be excellent candidates for other junior or middle management positions. On the other hand, some talented individuals selected as potential successors will leave the organization, and the organization must be prepared for that possibility. Those who stay in the succession planning process continue with further development programs that should prepare them for future leader roles. They can be assigned complex tasks, take various courses and workshops, or be involved in challenging projects.

Finally, after successful implementation of previous steps, the succession decision is made when an employee in a critical position leaves the organization or the position. Following these steps decreases the risk of assigning an ineffective or inexperienced successor to a critical position when needed. After selecting the individual who will fill the vacant position, an onboarding program should be implemented to enable him/her to adapt to the new position as easily and quickly as possible.

### **2.3. The responsibility for succession planning**

The organizations must have a proactive strategic approach to succession planning. Succession planning should involve the joint efforts of HR professionals, line managers and the company's top management.

The HR department plays an important role in succession planning. When the HR department is aware of employees' development plans, it can direct its activities towards securing the talent needed to achieve organizational goals (Armstrong, 2008). HR professionals perform the following tasks regarding the succession planning:

- Further assessment of the employees identified as potential successors is based on available data on their previous performance, skills, competencies, training, etc.
- participation in the creation and implementation of development programs for the selected employees
- monitoring the progress of the selected employee development program as well as the progress of the succession planning process, and provision of feedback on the progress of these processes
- advising the selected employees regarding their career planning
- assisting in assessment of the selected individuals' developmental needs
- encouraging all employees in the organization to think about their career path and the opportunities for advancement in the organization.



Line managers are in day-to-day contact with their subordinates, and they are familiar with employees' skills, abilities, and potential. For this reason, line managers often identify talents with great potential in the departments or teams they manage. Identification and selection of potential successors can be carried out in various formal and informal ways: through discussions with managers, evaluation of their competencies and skills or based on the performance evaluation results.

In addition, managers at all levels must take the responsibility for building the organization's top talent (Groves, 2007). The organizational culture must support the succession planning process, which can be seen through the strong commitment of the CEO and top management to the development of future leaders. Bearing in mind that succession planning refers to filling the key positions in the organization, the support of the company's top management is necessary to successfully implement this process. Succession planning is not about the skills and competencies the organization currently needs, but about those that will be needed. This significantly complicates the process and emphasizes the need to actively involve the individuals who are well aware of strategic plans for future business development and can predict which skills and competencies will be needed for critical positions in the future.

## **2.4. The benefits of succession planning**

There are many advantages of succession planning. A succession plan reduces business risk and improves an organization's ability to adapt to change by helping the company prepare for what the future holds. It enables immediate reaction to a change and ensures business continuity if an employee in a key position unexpectedly leaves the company. For example, when an unforeseen event happens causing the CEO leaving the organization, an effective succession plan enables that the crucial position is filled within a few hours or a few days (Charan, 2005). On the other hand, the unplanned departure of the CEO can greatly disrupt business continuity if there is no defined succession plan. In this case, the absence of a succession plan can lead to conflicts and power struggles among individuals who hoped to be selected for the position of CEO when it is vacated.

Succession planning mainly refers to developing and promoting existing employees, rather than hiring external candidates for key positions. Given that the focus of succession planning is on internal talent development, this approach reduces the need for external candidate recruitment, which can be extremely complex and expensive for the key positions (Adebola, 2019; Ali & Mehreen, 2019), as it often involves the cost of hiring headhunting agencies in addition to usual recruitment and selection costs.

The existence of succession planning process generates internal capabilities leading to improved performance and organizational competitiveness. Effective succession planning practices ensure that current employees in key positions transfer their knowledge and experience to the selected potential successors through various mentoring programs. In this way the knowledge is not lost when an individual leaves but preserved within the organization (Appelbaum et al., 2012; Atwood, 2020; Hall-Ellis, 2015).

Succession planning reduces turnover intentions (Sweeney, 2013) which have increased immensely since COVID-19 pandemic (Mileva et al., 2022; Tessema et al., 2022). It can be used as a retention strategy which helps the organizations maintain their talent by offering them development opportunities (Ali & Mehreen, 2019; Abbasi & Hollman, 2000). Without a succession plan, organizations risk losing their most valuable individuals (Ritchie, 2020). When a succession planning process exists in an organization, employees perceive that their contributions are recognized, appreciated, and significant (Hall-Ellis, 2015). Employees identified as potential successors for key positions may choose to plan their career path in their organization when they know there is an opportunity for advancement. In this way, succession planning increases employee motivation, engagement, dedication, loyalty and morale (Ali & Mehreen, 2019; Sweeney, 2013).

In addition, organizations can use succession planning for employer branding and improving the company's image, i.e. to create an image of the organization in the public eye as an attractive employer.

## **3. CONCLUSION**

It is crucial for organizations to be able to attract and retain top talent with excellent performance for critical positions. Succession planning is of a huge significance for business continuity (Gilding et al., 2015). It prepares the organization for unexpected events in the future (Butler & Roche-Tarry, 2002) providing a ready source of future leaders. Frequent and significant changes in the labor market, reduced job security, reduced employee loyalty and a high voluntary turnover rate have led many companies to invest more in succession planning.

The devotion to strategic succession planning enables organizations to allocate the necessary time, energy and resources to prepare the selected successors for future roles (Ritchie, 2020). Succession plan should be well-designed and implemented as a continuous process (Atwood, 2020).

However, succession planning frequently encounters tension and indefinite delays (Gilding et al., 2015), and a lot of effort should be invested in making this process successful. Nowadays, organizations may also use the help of software tools to facilitate the process of succession planning.

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# THE IMPACT OF MANUFACTURING EXECUTION SYSTEMS ON OVERALL LABOR EFFECTIVENESS: A CASE STUDY

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**Abstract:** Industry 4.0 is digitization process that enables manufacturing companies to engage in more automated production methods. This is achieved through an integrated infrastructure comprising assets, machines, personnel, mobile devices, and information systems. Manufacturing Execution System (MES) stands out as a pivotal digital technology driving complete digitalization within manufacturing facilities. MES provides real-time information crucial for managing and monitoring the entire manufacturing process, spanning from order inception to product delivery. Therefore, MES enables the process of workforce management, i.e. manages labor resources by tracking employee activities, skills, and productivity metrics. It enables workforce scheduling, task assignment, and performance monitoring to optimize labor utilization and efficiency, and calculation of Overall Labor Effectiveness (OLE) indicator. The behavioral aspect of humans in OLE calculation can influence how labour resources are utilized, measured, and managed in production operations. The paper will illustrate a case study of MES impact on OLE indicator in wet wipes production.

**Keywords:** MES, OLE, Industry 4.0, Human behavior, Human-centered factors

## 1. INTRODUCTION

Since their inception in the mid-1990s, MES has evolved into highly significant software applications for tracking material flows in manufacturing as computer technologies have advanced. The functionality of MES has undergone significant changes, now providing a unique system that supports most production execution processes, from the initiation of a production order to the delivery of finished products.

Lasi, Fettke, Kemper, Feld and Hoffman (2014) discuss the concept of the "smart factory" is fundamental to Industry 4.0, and to realize it, the domain of special information subsystems (which includes innovative MES/ERP approaches) is gaining prominence. According to Almada (2016), Industry 4.0 offers a framework for improving production productivity by meeting the growing demands of customers for faster real-time responses through decentralized production control. MES systems meet these expectations, aiming to enhance performance, quality, and agility for manufacturing companies. According to Deutsche, Wolfgang and Johannes (2013) smart factories are key components of Industry 4.0, facilitating both human and machine tasks through digital production tools such as MES, which monitor material flows in production. MES functions as a factory information system that manages and controls the entire production process, from order placement to finished product delivery, with the goal of achieving high production quality. Overall, MES serves as a central nervous system for manufacturing operations, orchestrating processes, resources, and information flow to achieve operational excellence, improve productivity, and meet customer demands in today's dynamic and competitive manufacturing landscape. Among various attempts to define key structural aspects of production management systems, the ANSI/ISA-95.00.03. (2000) standard has gained popularity among manufacturing practitioners for integrating ERP-to-shop-floor solutions. Alter (1999) described the integration involves mutual reaction and cooperation between different processes, including information sharing, a key aspect addressed by the requirements of the standard. This standard outlines the structure of production operations, divided into four levels: Levels 1 and 2 encompass the process control zone, MES level 3 consists of management and control functions, and Level 4 corresponds to business planning and logistics operations. The goal of the standard is to reduce risks, costs, and errors associated with implementing interfaces between ERP and MES. Braglia, Castellano, Frosolini, Gallo, and Marrazzini, (2021) described that Workforce management process navigates the complex landscape of business operations, one metric that stands out for its comprehensive insight into workforce productivity is Overall Labor Effectiveness (OLE). This powerful measure allows businesses to quantify the effectiveness of their labor force, identifying areas of strength and highlighting opportunities for improvement. By optimizing OLE, organizations can enhance operational efficiency, reduce costs, and improve their bottom line. When measuring organizational effectiveness, most manufacturers recognize the critical role that minimizing machine downtime plays in increasing profits. When your machines are idle, it results in financial losses. Also, the same authors discuss that OLE is a key performance metric in

manufacturing that evaluates the efficiency and productivity of labour resources across the entire production process. OLE encompasses three main components: Availability, Performance, and Quality of human labour. Overall, OLE plays a crucial role in performance management by providing a comprehensive framework for evaluating and optimizing the effectiveness of labour resources in manufacturing operations and has impact on various aspects of manufacturing operations. However, Bommer and Fendley (2016) defined that the human-centred measures bring additional challenges, and many researchers identify a lack of predictability in human performance. Abubakar and Wang (2018) reported that most simulation models simply do not consider human factors, impacting the overall performance of the system. Kong, Ma, Gong and Huai (2016) point out that can be explained by the fact that human performance is hard to estimate due to the complexity of human cognition and behaviour. However, Brabec and Jáčová (2022), point out that the application of the OLE indicator is not very common in practice. In addition to that, this indicator is not of great interest to scientists; its usage was mentioned e.g., by Braglia, Castellano, Frosolini, Gallo and Marrazzini, (2021), or Deepak, Bhaskar, and Balaji, (2021). For this reason, this article has focused on the issue of calculating this indicator and its application in the selected company.

Considering the significant role that human-centred indicators play in the context of Industry 4.0 and the challenges recognized by several authors (Abubakar and Wang (2018), Kong, Ma, Gong and Huai (2016), and Braglia, Castellano, Frosolini, Gallo and Marrazzini, (2021)) in incorporating human factors into prediction, optimization, or simulation models, this paper aims to present the components of the OLE simulation model and the human-centred factors integrated into OLE simulation model to define rewarding simulation model for employees in wet wipes production. To achieve this goal, a paper is conducted to identify human factors and their influence on the OLE simulation model in real production company. More specifically, results of research and case study try to answer the following research questions:

- RQ1: *Is the role of MES software crucial to provide data-driven insights into labour performance?*
- RQ2: *What are the benefits of implementing OLE in production for the humans who are working in manufacturing environment?*

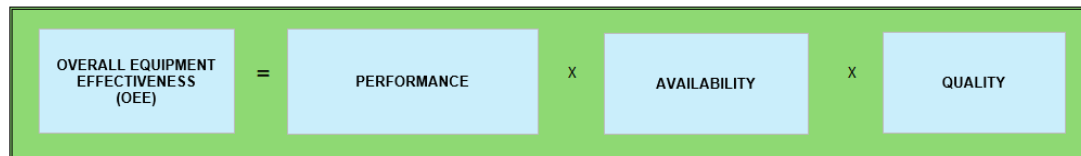
The paper is structured as follows: Section 2 presents the transition concept from OEE to OLE factors. Section 3 presents OLE simulation model for wet wipes production and the paper main findings, and the section 4 concludes the research of the paper.

## 2. TRANSITION OF OEE FACTORS TO OLE FACTORS

However, Brabec, and Jáčová, (2022) stated while many companies routinely measure the productivity of their machines using the Overall Equipment Effectiveness (OEE) metric, just a few apply the same concept to their workforce. Braglia, Castellano, Frosolini, Gallo and Marrazzini (2021) point out that an analogy to OEE indicator exists for processes that rely on human intervention and called Overall Labor Effectiveness (OLE). OLE is a key performance indicator that organizations can use to measure the overall labour productivity of their workforce, particularly where output is dependent on manual labour.

According to Relkar and Nandurkar (2012), OLE has a precursor in a metric known as Overall Equipment Effectiveness (OEE). Designed to ensure maximum output from machines, OEE has been a bellwether of performance for manufacturing managers in asset-intensive industries, such as chemicals and refining. To understand OLE completely we must understand OEE, the relationship between the two, and how they work together to raise overall manufacturing productivity and performance. Kronos Consulting (2021) stated that OEE is a formula that shows the overall performance of a single piece of equipment, or even an entire factory, and is governed by the cumulative effect of three factors: the equipment's availability (percentage of scheduled production time available), performance rate (percentage of parts produced compared to standard), and quality (percentage of saleable parts produced compared to parts started). According to Gallup 2023 Report (2023), OLE is a good tool to measure and improve workforce productivity, especially considering the growing trend of "*quiet quitting*." The majority of the world's employees are "*quiet quitting*" and say: "*I just don't feel like there's a lot of room for me to grow internally.*" Quiet quitting is situation what happens when someone psychologically disengages from work. They may be physically present or logged into their computer, but they don't know what to do or why it matters. They also don't have any supportive bonds with their coworkers, boss or their organization. Nearly six in 10 employees fell into this category. When combined with actively disengaged employees, low engagement costs the USA global economy \$8.8 trillion dollars, or 9% of global GDP. In this context, Renoir Consulting (2024) claims that the OLE serves as a good tool to provide a comprehensive view of direct and indirect labour, enabling companies to effectively strategize for productivity and profitability improvements. By consistently monitoring and acting on OLE metrics, organisations can optimise their current operations and create a culture of continuous improvement, in line with the principles of Lean and Six Sigma methodologies. Any modification to the factors within the OLE equation can have significant impacts on profitability. For example, prioritising quality can affect the speed of production line, potentially affecting output

performance. OLE exposes the interrelationships between these factors so managers need to keep all three in balance. Brabec, and Jáčová, (2022) defined that OEE takes a holistic view, and many managers feel it is the best tool for managing operations in the context of cost- and efficiency-focused manufacturing. OEE is an effective measure, but it doesn't tell the whole story. In today's demand-driven operations, many manufacturing environments no longer place a high value on flat-out volume production. Shorter cycles and more frequent changeovers — which reduce the OEE values — are more important, lessening the value of OEE as an indicator of manufacturing productivity. OEE considers all losses (Stop Time Loss, Speed Loss, and Quality Loss), resulting in a measure of truly productive manufacturing time and OEE is calculated as the ratio of Fully Productive Time to Planned Production Time. In practice, it is calculated as:



**Figure 1:** OEE metrics, Brabec, and Jáčová, (2022)

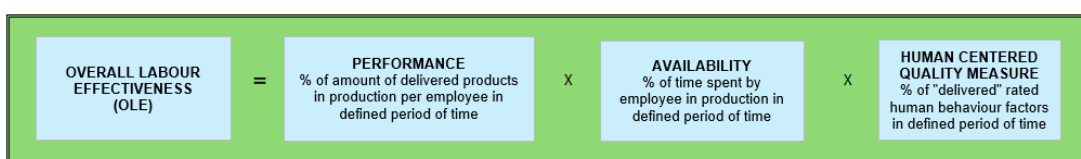
According to Kronos Consulting (2021), OLE can show how assets and employees come together to drive performance. OLE provides the ability to analyze the labor impact at the operator, department, plant, and even corporate levels of the organization. OLE can expose the interaction of interdependent variables. Changes made to improve one area may have a negative impact elsewhere. For example, a process change makes it faster to get parts to the shop floor but complicates warehouse operations. The familiar OEE factors — availability, performance, and quality — are the basic elements used in measuring labor effectiveness. But in measuring the contributions human beings make, it's useful to look deeper and consider additional factors. Braglia, Castellano, Frosolini, Gallo, and Marrazzini, (2021) stated that many companies in the manufacturing industry both abroad are nowadays using the Overall Equipment Effectiveness indicator (OEE) to measure and manage their performance. This indicator has been modified into several so-called derived indicators based on various requirements in the efficiency assessment. One of the derived indicators is the Overall Labor Effectiveness (OLE). OLE is calculated using three main components: Availability, Performance, and Quality. This formula combines the three components to provide a comprehensive measure of labour effectiveness across the entire production process. OLE values typically range from 0% to 100%, with higher values indicating higher overall labour effectiveness. It's important to note that the specific calculation method and parameters may vary depending on the organization's processes, industry standards, and performance measurement requirements. Adjustments or additional factors may be included to tailor the OLE calculation to specific manufacturing contexts and objectives.

### 3. OLE CALCULATION IN WET WIPES PRODUCTION: A CASE STUDY

The company was established in 1993 with the aim of providing consumers with products in the category of personal hygiene and cosmetics for everyday use. The company began implementing the MES system in 2020, by which time it already had clearly defined production facilities: a wet wipes production plant, a paper ready-made production plant, and a plant for cosmetic and personal hygiene product production. At present, the company has implemented the MES system in all three production facilities and stands out in Serbia as one of the first companies to digitize production by implementing the MES system. In the company's production, the MES system enables:

- Complete traceability in production: From raw materials to finished products, facilitating traceability tests to comply with QMS and BRC procedures.
- Real product costing is based on data from work orders containing information about material consumption and labor time.
- Creation of production reports, including planned versus actual production by operations, OEE and OLE, scrap rates, critical control points, and others.

Concerning the process of calculating OLE indicator and its application in the selected company, OLE can be calculated as:



**Figure 2:** OLE factors supported by MES in wet wipes production process

MES enables the collection of data for calculating OLE indicator factors. OLE is calculated monthly and serves as the model for additional rewarding of employees. All OLE factors are calculated for each employee in the production process.

Factor “Availability” measures the actual time that labour resources are available for planned production and compared to the total available production working time per month. The total available production working time per month is the time that labor resources were scheduled to be available for production during a specific period, typically expressed in days.

$$\% \text{ Availability} = (\text{Delivered working time in production per employee} / \text{Total Available Production Working Time}) \times 100 \quad (1)$$

No.	Bussines Unit	Cost center	ID	Surname and Name	Working position,of employee	Delivered working days	Vacation days	Sick leave days	Grand Total	Total working days per month: 19	% Availability
1	Production	049 - Wet wipes	853	Geratović Predrag - 853	362 - Operator I	14	5		19	19	74%
2	Production	50 - Wet wipes	879	Mijatović Petar - 879	363 - Operator I	19			19	19	100%
3	Production	51 - Wet wipes	242	Klipić Nemanja - 242	364 - Operator I	19			19	19	100%
4	Production	52 - Wet wipes	364	Živković Nikola - 364	365 - Operator I	10	4	5	19	19	53%
5	Production	53 - Wet wipes	411	Đurđević Nikola - 411	366 - Operator I	19			19	19	100%
6	Production	54 - Wet wipes	76	Sarić Jovan - 76	367 - Operator I	14	5		19	19	74%

Figure 3: MES report for Availability calculation

Factor “Performance” measures the actual production output per product achieved by labour resources compared to the maximum production output under optimal conditions. The total number of units or products produced during the production period.

$$\% \text{ Performance} = (\text{Total number of units produced per employee per product} / \text{Planned number of units per product}) \times 100 \quad (2)$$

MES ensures that the data from the production process are obtained after each working shift. The MES report is called Planned/Realized production per SKU per day (i.e. per production line and work order)

Date	SKU	Singl/Gra tis	SKU ID	Name of SKU	Production line	Work order	Planned quantity	Produced quantity	% of realization
1.4.2024.	1 Singl		204374	VL.MARAMICA MOJE MARAMICE 15/1	Line 12	R2024301245	56000	5880	1,05
1.4.2024.	1 Singl		204476	VL.MAR.COOP BABY 72/1	Line 14	R2024301242	49275	4992	1,01
1.4.2024.	1 Singl		204710	VL.MAR. BUPI SENSITIVE 56/1 STAMPA T.K.	Line 15	R2024301243	30300	2937	0,97
1.4.2024.	1 Singl		204761	VL.MAR.DIDACO ANTIBAKTERIJAL 15/1	Line 12	R2024301246	28000	2775	0,99
1.4.2024.	4 Gratis		204448	VL.MAR. BABY GAMAR SENSITIVE 80/1 3+1 NEW	Line 8	R2024301230	30028	3030	1,01
1.4.2024.	4 Gratis		204448	VL.MAR. BABY GAMAR SENSITIVE 80/1 3+1 NEW	Line 9	R2024301241	60060	6048	1,01

Figure 4: MES report named as Planned/Realized production per SKU per day

According to MES report Planned/Realized production per SKU per day, the number of ID for each Work Order makes connection to the report % of Realization of production for each operator per SKU in production process.

Date	SKU ID	SKU NAME	Work Order	Line	Shift	Planned quantity	Realized Quantity for I shift	Realized Quantity for II shift	Employee ID	Surname and Name	Working place	% Realization
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	1	56000	42360		1131	Gorica Lončarević	Operator 1	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	1	56000	42360		1347	Katarina Nikolić	Operator 1	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	1	56000	42360		1762	Biljana Kolarić	Operator 1	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	1	56000	42360		1795	Miladinka Todorović	Operator 1	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	1	56000	42360		1863	Dalibor Sibinčić	Operator 2	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	1	56000	42360		1928	Aleksandar Simić	Operator 2	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	2	56000	0		1120	Dragana Mišković	Operator 2	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	2	56000	0		1272	Snežana Nenadović	Operator 2	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	2	56000	0		1782	Milica Kuzmanović	Operator 2	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	2	56000	0		1819	Dragica Oblaković	Operator 2	1,05
1.4.2024.	204374	VL.MARAMICA MOJE MARAMICE 15/1	R2024301245	Line 12	2	56000	0		198	Igor Sedlarević	Operator 2	1,05

Figure 5: MES report named as % of Realization of production for each operator per SKU per day

Factor “Quality” measures the percentage of different human behaviors instances. The model of OLE for the factor “Quality”, includes the performance evaluation table with 12 key criterions of human behavior, which are presenting an employee behavior in the production process. Total employee behavior factor in the production process includes all important instances, i.e. quality of product, competencies of each employee, and human behavior instances of each employee. Each criterion is pondered from 0 to 3.

**Table 1:** Description of ponders of criterions for OLE model

<b>2,6 to 3,0 Good</b>	The employee constantly shows exceptional behavior during the work, which significantly exceeds all expectations for the given position of his/her workplace; The employee communicates and cooperates with other employees in an exceptional way, so that in this domain employee initiates the setting of new standards and rules in the communication; The personal qualities and abilities of the employee significantly exceed the needs for fulfilling work requirements and work procedures far beyond the needs for a given position. Note: The use and assignment of this rating category is RARE and highly limited to a small number of situations and users, only in exceptional situations.
<b>1,5 to 2,5 Satisfies</b>	The employee meets the standards of behavior during work every day; The employee's communication and cooperation with other staff is positively directed and aligned with company rules and standards. The personal characteristics and abilities of the employee in every respect meet the expected needs for the performance of work tasks in the position in which the employee is. Note: This category is often used in the questionnaire to describe the evaluation criteria, i.e. the behavior, personal characteristics, and communication skills of the employee.
<b>0 to 1,4 Not satisfy</b>	During the work, the employee partially meets the set criteria and standards of behavior; The manner and style of communication which the employee uses in the company partially corresponds to the policy, standard procedures and rules of the company; The personal characteristics and abilities of the employee are sometimes below the requirements for the fulfillment of work requirements and work procedures, i.e. below the requirements for a given workplace; The employee's performance in the mentioned domains may be partially unacceptable; There is a need for constant supervision of the employee by superior managers, because most of the problems in this area have a negative impact on the achievement of the goals of the sector; The procedure of introducing corrective measures (additional explanations, courses, additional training and education of the employee) is initiated in order to improve the employee's work performance. Note: The indicated category is used if there is a reduced performance of the employee in a certain time. THIS CATEGORY IS SIGNIFICANTLY USED IN CASE OF CONTINUOUS PROBLEMS AND REDUCED PERFORMANCE IN THE PROCESS.

To comprehensively assess the performance of workers, it has been developed a qualitative questionnaire consisting of 12 criteria. These criteria are evaluated using quantitative grades to ensure a thorough evaluation process. Each criterion is described in detail with additional sentences to ensure the evaluation process remains realistic and objective. The sum of the criterions ponders is divided by the number of criteria (12 criterions) and the obtained amount of percentage presents the % of total behavior factor for each employee for OLE model. It is important to emphasize that the human performances in production process is hard to estimate due to the just quality measures i.e. the percentage of produced units that meet the quality standards or specifications ( $\text{Quality} = (\text{Total Good Units Produced} / \text{Total Units Produced}) \times 100\%$ ). A variety of human factors impacting on the overall performance of the production system. According to previous, that means we cannot only look at one simple human factor named as "Quality". We need to look, at the same time, at several factors of human behaviour, that could extremely affect the working atmosphere in production.

**Table 2:** Performance evaluations criterions for OLE model

No.	Performance criterion	Description of the criterion
1	Level of competencies for operational work	Evaluate the employee's competencies and operational knowledge for completing tasks. The criterion describes the importance of continuous learning in process.
2	Level of understanding of tasks	This criterion assesses the employee's ability to comprehend assigned tasks fully and does employee clearly understand the importance of clarity in task instructions and the necessity of seeking clarification when needed.
3	Level of effort and speed in work	Evaluate the employee's diligence and efficiency in completing tasks and the criterion highlights the significance of timely task completion without sacrificing quality.
4	Level of autonomous quality control of work	This criterion gauges the employee's adaptability to autonomous quality control over the work. The criterion describes an ability of employee to manage quality control tasks independently.
5	Level of motivation for work	Assess the employee's enthusiasm and dedication to their job role. The criterion emphasizes the importance of intrinsic motivation and its impact on overall performance.



6	Quality of work and product (defects units/total units, work failures)	Evaluate the employee's output quality and pay attention to detail. Emphasize the significance of delivering high-quality work that meets or exceeds expectations.
7	Cooperation with other coworkers	Assess the employee's ability to collaborate effectively with colleagues. The criterion describes the importance of teamwork and communication skills in achieving collective goals.
8	Employee attitude towards managers	Evaluate the employee's attitude and respect towards supervisors. Emphasize the importance of maintaining professional relationships and open communication channels with superiors.
9	Acceptance of criticism and suggestions at work	Assess the employee's receptiveness to feedback and willingness to improve and criterion highlights the importance of constructive criticism in personal and professional development.
10	Ability to work independently without constant control	Evaluate the employee's ability to work autonomously and make decisions when necessary and the criterion describes the importance of self-reliance and initiative in achieving objectives.
11	Compliance with work and hygiene procedures	Assess the employee's adherence to company policies and procedures and criterion emphasizes the significance of established guidelines for efficient and compliant work.
12	Maintaining personal hygiene	Evaluate the employee's adherence to cleanliness standards in the workplace and the criterion describes the importance of maintaining a clean and organized work environment for health, safety, and productivity.

The performance evaluation for each employee in production is conducted monthly to facilitate additional rewards for the workers. Team leaders, recognized as the top performers, assess the workers within their respective groups. With detailed descriptions of all evaluated criteria, each team leader can easily conduct individual evaluations of their team members. This revised OLE indicator sounds like a comprehensive human centred approach to evaluating worker performance. So, incorporating both qualitative criteria and quantitative grades, we can indeed provide a more holistic assessment to human behaviour in production process. As follows from OLE calculation, at first step of calculation the OLE indicator is obtained and in the second step of calculation the performance bonus amount is obtained from the table of min. and max. value of bonuses.

No.	Bussines unit	Cost center	ID	Surname nad name	Workplace (working position)	Performance %	Availability %	Human behaviour %	OLE INDICATOR %	Performance bonus amount
1:10 - Production	049 - Wet wipes	853	Geratović Predrag - 853	Operator I	0,97	0,74	1,00	71,1%	12.471 RSD	
2:11 - Production	50 - Wet wipes	879	Mijatović Petar - 879	Operator I	0,97	1,00	0,90	86,9%	14.235 RSD	
3:12 - Production	51 - Wet wipes	242	Kipić Nemanja - 242	Operator I	0,98	1,00	0,93	91,0%	14.824 RSD	
4:13 - Production	52 - Wet wipes	364	Živković Nikola - 364	Operator I	0,97	0,53	0,88	44,6%	0 RSD	
5:14 - Production	53 - Wet wipes	411	Đurđević Nikola - 411	Operator I	0,98	1,00	0,93	91,1%	14.824 RSD	

**Figure 6:** OLE indicator and performance bonus amount calculation

The bonus table, see picture below, shows the range of bonuses per workplace, and the linear distribution of the bonus amount between the minimum and maximum bonus values. As follows, rewarding employees starts from 50% to 100% of the OLE indicator, according to the defined workplace.

Step %:	1%	Workplace	Production manager	Operator I	Packaging technician
Start %:	50%		Team leader	Operator II	Packaging assistant technician : Packaging worker
No. Rows	50	Min. Amount	12.000 RSD	10.000 RSD	6.000 RSD
		Max. Amount	18.000 RSD	16.000 RSD	11.000 RSD
		Diff.	6.000 RSD	6.000 RSD	5.000 RSD
		Linear trend step:	120 RSD	120 RSD	100 RSD
			1	2	3
			4	5	
		OLE %:	Bonus 1	Bonus 2	Bonus 3
		50%	12.000 RSD	10.000 RSD	6.000 RSD
		51%	12.120 RSD	10.120 RSD	6.100 RSD
		52%	12.240 RSD	10.240 RSD	6.200 RSD
		...	...	...	...
		97%	17.640 RSD	15.640 RSD	10.700 RSD
		98%	17.760 RSD	15.760 RSD	10.800 RSD
		99%	17.880 RSD	15.880 RSD	10.900 RSD
		100%	18.000 RSD	16.000 RSD	11.000 RSD
			Bonus 4		
			4.000 RSD		
			4.080 RSD		
			4.160 RSD		
			...		
			7.760 RSD		
			7.840 RSD		
			7.920 RSD		
			8.000 RSD		

**Figure 7:** Bonus scale for OLE indicator scheme from 50% to 100%



### 3. CONCLUSION

According to RQ (1), the impact of MES on OLE can be significant, as MES plays a crucial role in optimizing labour resources, streamlining production processes, and improving operational efficiency. Overall, the impact of MES on OLE is multifaceted and encompasses various aspects of labour management, production optimization, and performance improvement. By leveraging MES capabilities to optimize labour resources, streamline production processes, and drive continuous improvement, organizations can enhance OLE and achieve greater efficiency, productivity, and competitiveness in manufacturing operations.

According to RQ (2), implementing OLE provides several benefits for humans working in manufacturing environments. Overall, implementing OLE in production can benefit humans working in manufacturing environments by providing clear performance expectations, recognition and reward opportunities, skill development and training opportunities, empowerment and autonomy, improved work-life balance, job security and stability, health, and safety enhancements, and fostering a culture of continuous improvement and innovation. The performed research study is not comparable with the studies of other authors due to different human-centered factors implemented into simulation model for analyzed company.

The directions of further development of OLE indicators refer to the further development of human-centered factors in MES systems to develop additional decision-making tools in highly dynamic situations when reacting to unforeseen changes in production. The author would like to continue with research by preparing a questionnaire survey, which would focus on companies with the same field of business as the analysed company.

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# IMPLICATIONS OF UNDERSTANDING GEN-Z VALUES FOR HUMAN RESOURCE MANAGEMENT

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**Abstract:** *For affective human resource management, it is important to understand the values, that employees in your organization hold. Values are also depending on the generation, that a person is born in. Gen-Z, as the generation currently entering the workforce, have their own values. In our paper we ask ourselves the research question of which values does Gen-Z have. Our research is based on a survey among 51 students from Slovenia. Data collection took place in October 2022. Through the analysis of collected data, based on students' responses, we determine their values – Apollonian and Dionysian. We conclude the paper by giving our opinions based on the findings of the research. We present the implications for human resource management in the future through understanding Gen-Z values.*

**Keywords:** *human resource management, Gen-Z, management, organization, students.*

## 1. INTRODUCTION

Values are an important part of every leader's daily life, as they are present throughout the whole daily cycle, which means that they influence the individual's various elements of their life (Jones, 2012). Values are fundamental principles, beliefs and ideals that shape our perception, decisions and behaviour. They reflect what we consider important, desirable or correct in life and work, help us understand what is important to us and set priorities in all areas of life (Zapata-Cantu, Sanguino, Barroso & Nicola-Gavrilă, 2023). There are two known groups that form life values: Dionysian and Apollonian values (Musek, 2015). These two groups of life values are further divided into two types: Dionysian values into the hedonic type and the potency type; and Apollo values into the moral type and the fulfilment type.

As in other developed countries, value orientations in Slovenia also change with age (Marinčič, Đurica & Marič, 2023). This research is important, because it builds upon the understanding of Gen-Z. In the era of globalization and technological progress, understanding different generations becomes crucial for efficient human resource management. It is especially challenging to understand Generation Z, which enters the labour market with a unique set of values and expectations. Understanding the values of Generation Z will not only help organizations to better adapt their human resource management strategies, but will also enable better integration of these young talents into the work environment (Janssen & Carradini, 2021).

Knowing the values helps us to identify the priorities of Generation Z, then it helps to understand how this generation identifies itself and how it wants to be perceived in society. Also, based on discovering the values that are important to them, we can come to the conclusion of what inspires and motivates them to achieve the set goals (Maloney, Hiatt & Campbell, 2019). In essence, recognizing the values of Generation Z is key to understanding their priorities, identities, motivations and behaviours, which helps us to better communicate and collaborate with this generation in different contexts.

Our research relies on quantitative methods to measure and analyse the values of Generation Z, using questionnaires that assess a wide range of values, from hedonic to moral. The results of the survey provide insight into the highest and lowest rated values, as well as those that occupy the middle positions, offering a complex picture of the priorities that drive this generation.

## 2. LITERATURE REVIEW

Differences in values and views are perceived through the generations (Marinčič, Đurica & Marič, 2023). This paper studies the values of Generation Z (Gen-Z). As each generation has their own values, which they hold dear, so does the Gen-Z, which is currently beginning to enter the workforce.

In this chapter, we will focus on defining “values”. There are many of them, but they can be broadly defined as some conception and belief or motives and interests of each individual (Zander, Jonsen & Mockaitis, 2016). Values are also our orientations and relatively lasting understanding of an individual's goals, which are highly valued and respected by the individual. They dictate the lifestyle or behaviour of each individual; the individual's values develop and change throughout the life span (Meglino & Ravlin, 1998).

Values represent what we consider important, desirable or valuable in life. Values can be different for each individual, depending on their life experiences, culture, education and other factors. Value perception is the process of recognizing, understanding and giving importance to values in our life. This process includes introspection, self-evaluation and contextualization of values in our environment (Ormiston & Seymour, 2011). Our perception of value can change over time, as we are exposed to new experiences and information that can influence our priorities and beliefs.

It is important to recognize the values that are important to the individual because it contributes to their sense of identity, authenticity and self-confidence. Through the process of self-recognition of values, young people become aware of their priorities, desires and goals, which helps them direct their actions and decisions in accordance with their deeper beliefs (Scholtens & Dam, 2007).

When they are aligned with their values, people are more likely to be motivated, engaged and successful in what they do. For example, if someone values the value of justice, they are likely to engage in activities or work that promote justice and equality. The sense of authenticity that comes from living up to one's values can increase young people's self-confidence and sense of meaning (Schwartz, 2005). When young people are aware of their values, they can better understand why some situations or events affect them more than others, enabling them to manage their emotions and behaviour more effectively.

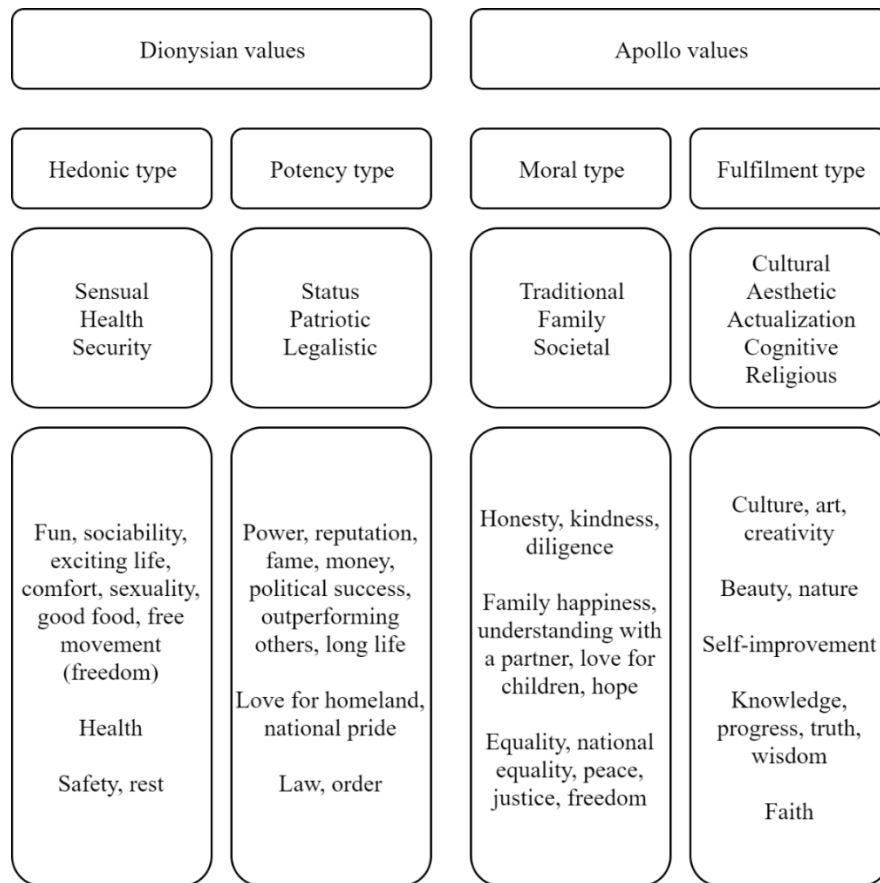
Additionally, recognizing values can help Gen Z communicate better with others. When they are clear about their values, it is easier to communicate them to others and to find a common language with people who share similar values. Recognition of values is crucial for the development of identity, self-confidence and successful interpersonal relationships among Generation Z (Iorgulescu, 2016).

The importance of values is evident in many aspects of our lives. Values play a key role in shaping our identity and self-confidence. When we live in accordance with our values, we feel authentic and fulfilled. When our decisions are in line with our values, we feel confident in our actions and are motivated to achieve our goals (Clegg, Kornberger & Rhodes, 2007).

Understanding one's own values and integrating them into everyday life can be key to mental well-being, self-confidence and success in various areas of life. In a social context, values play an important role in shaping norms, customs and institutions. The values of a community or society can influence behaviour and attitudes, and can have a wider impact on social development and change (Ormiston & Seymour, 2011).

Values differ at the interstate or intercultural level, the national level, the social level as well as the individual level (Musek, 2011). With desire to understand current and future work, it is very important that the values of individuals, whether they are employees or just individuals in society, be thoroughly explored and understood (Zander, Jonsen & Mockaitis, 2016). As mentioned earlier, values vary from individual to individual, and the most important values of each individual form complex categories of values – value orientations, dictated by propriety and live decisions.

There are several different models and scales of values. For the purposes of our research, we used Musek Values Scale (Musek, 2015), which covers four levels of hierarchical structure. The model or scale is constructed so that at the top of the hierarchy are two groups of the largest scale, namely Dionysian and Apollonian values. Each is then further subdivided into two larger value categories. The Dionysian values are divided into two value types, the hedonic and potency types. The Apollonian values are divided into moral and fulfilment type. In the following, each type mentioned above is divided into individual values, which are the starting point of the mentioned model.



**Figure 1:** Musek values scale (Musek, 2015)

For easier understanding, we will, according to Musek (2015), define the values mentioned above and describe each value type individually, which is also shown in Figure 1. The first type is the hedonic type of values, which encompasses more sensory, health and safety values, such as: fun, sociability, comfort, sexuality, good food, free movement (freedom), health, safety and rest. The next group of values is potency type, characterized by more status, patriotic and legalistic values, such as: power, reputation, fame, money, political success, outperforming others, long life, love for homeland, national pride, law and order. The third type of values is the moral type, which encompasses traditional, family and societal values, such as: honesty, kindness, diligence, family happiness, understanding with a partner, love for children, hope, equality, national equality, peace, justice, freedom. The last type of Apollo values mentioned is the fulfilment type, which encompasses cultural, aesthetic, actualization, cognitive and religious values, such as: culture, art, creativity, beauty, nature, self-improvement, knowledge, progress, truth, wisdom and faith.

### 3. METHODOLOGY

Values often shape our decision making processes (Marinčič & Marič, 2022). Therefore, by understanding one's values, we can adequately and more effectively manage them in the future. Therefore, we ask ourselves the research question: What values does the Gen-Z have? The survey was conducted using an anonymous questionnaire that included several sets of questions; first was demographics, second were Apollonian values and third were Dionysian values.

For the purposes of our research, we used Musek Values Scale (Musek, 2015). The questionnaire lists values, with a five point Likert scale, which should be scored as follows: 1- It's not important at all, 2 - It's partially irrelevant; 3 - It is partly important and partly irrelevant; 4 - It's partially important; 5 - It is absolutely important. By calculating average values, we can determine the importance of a value.

Our sample encompasses 51 students from Slovenia. All respondents, of which are 25 (49.02%) men and 26 (50.98%) women, are affiliated with the University of Maribor's Faculty of Organizational Sciences as undergraduate students from all over Slovenia. The respondents were born from 1999 to 2003, with the average year of birth being 2001.75, which means that they are representatives of Gen-Z. Data collection took

place in October 2022, which means that the average age of the respondents was 21 years. Various quantitative statistical methods will be used to analyse the gathered data.

#### 4. RESULTS

In the following tables, we will present the average value of the respondents' answers on their values. Table 1 shows the average value of the respondents' agreement with statements regarding their Dionysian values - Hedonic type and Table 2 shows the average value of the respondents' agreement with statements regarding their Dionysian values – Potential type.

**Table 1:** Average values of respondents' Dionysian values - Hedonic type for Gen-Z students (n = 51).

Value	Mean	Std. Deviation
Joy	4.45	0.83
Entertainment	3.80	0.83
Sociability	4.29	0.83
Exciting life	3.37	0.94
Comfort	3.59	1.10
Sexuality	3.47	1.14
Good food	3.88	1.11
Free movement - freedom	4.67	0.55
Health	4.86	0.40
Security	4.39	0.87
Rest	4.27	0.87

Table 1 presents the calculation of average values for the set of hedonic type of values, which is the set of Dionysian values. The highest rated value in this group is "health", whereas the lowest rated value is "exciting life". From Table 2, we can see the calculation of the average values of the potential type of values, which belongs to the set of Dionysian values. The highest rated value in this group is "order", whereas the lowest rated value is "political success".

**Table 2:** Average values of respondents' Dionysian values - Potential type for Gen-Z students (n = 51).

Value	Mean	Std. Deviation
Power	3.55	0.81
Reputation	3.82	0.79
Fame	2.20	0.89
Money	3.82	0.87
Political success	2.02	1.01
Outdoing others	2.84	1.07
A long life	3.39	1.00
Love for the motherland	3.27	1.20
National pride	3.33	1.28
Order	4.08	0.77
Laws	3.96	0.92

Table 3 shows the average value of the respondents' agreement with statements regarding their Apollonian values - Moral type and Table 4 shows the average value of the respondents' agreement with statements regarding their Apollonian Values - Fulfilment type.

**Table 3:** Average values of respondents' Apollonian values - Moral type for Gen-Z students (n = 51).

Value	Mean	Std. Deviation
Honesty	4.59	0.61
Goodness	4.41	0.67
Industriousness	4.27	0.78
Family happiness	4.29	1.03
Understanding with your partner	4.69	0.55
Love for children	4.59	0.75
Hope	4.45	0.78
Equality	4.45	0.76
National equality	4.59	0.67
Peace	4.71	0.64
Style	4.24	0.74
Justice	4.73	0.53

Table 3 presents the calculation of average values for the set of moral type values, which is a subset of Apollonian values. The highest rated value in this group is “justice”, whereas the lowest rated value is “style”. From Table 4, we can see the calculation of the average values of the fulfilment-type values that belong to the set of Apollonian values. The highest rated value in this group are “nature” and “knowledge”, whereas the lowest rated value is “faith”.

**Table 4:** Average values of respondents’ Apollonian Values - Fulfilment type for Gen-Z students (n = 51).

Value	Mean	Std. Deviation
Culture	3.96	0.75
Art	3.94	0.86
Creativity	3.96	0.89
Beauty	3.67	0.86
Nature	4.61	0.63
Self-improvement	4.29	0.86
Knowledge	4.61	0.60
Progress	4.49	0.78
Truth	4.53	0.73
Wisdom	4.22	0.81
Faith	2.63	1.36

Through the analysis of the collected data based on the students' self-assessments of their values, we have determined their values and the importance they attribute to each of the values.

## 5. DISCUSSION AND CONCLUSION

We conclude the paper by giving our opinion based on the findings of the research. Through our research, we have analysed the values of Gen-Z, paying special attention to their division into Apollonian and Dionysian values. Dionysian values are further classified into hedonistic and potential, while Apollonian values are divided into moral and fulfilling. This division enabled a deeper understanding of the priorities and values of this generation. Based on our findings, we prepare the implications of understanding their values for human resource management.

The highest rated value among Dionysian and hedonistic values is "health", with an average score of 4.86. This value is the most important for members of Generation Z, which indicates a high level of awareness of the importance of health in this population. On the other hand, "exciting life" is the least rated value, which suggests that the respondents put so much emphasis on excitement and adventure. When it comes to potential values, the results show that the ratings are significantly lower compared to hedonic values. The lowest average score (2.02) refers to "political success", while the highest average score (4.08) is assigned to the value "order". This suggests that students value order and organization in their lives more than political success.

Apollonian values, especially moral values, were rated extremely high. "Justice" is the most highly rated value, while "style" is the least rated. The results indicate that generation Z students attach great importance to moral principles and ethical values. "Fulfilling" Apollo values, on the other hand, have more variable ratings. "Knowledge" is the highest rated value, while "faith" is the lowest rated. This may indicate that students consider knowledge to be crucial for their personal and professional development, while faith is not so important in their lives.

The obtained results indicate the high importance of values related to personal well-being and social justice among students of Generation Z. Values such as health, freedom of movement, security, justice, equality, national equality, peace, knowledge, truth and progress are highly rated, which indicates the strong aspiration of this generation towards stability, harmony and personal growth.

On the other hand, values traditionally associated with material success or competition, such as political success, outdoing others, fame and faith, were rated low. This may indicate a change in priorities and values among young people, focusing on inner satisfaction and personal development instead of external symbols of success. Also, it is interesting to note that values such as joy, sociability, comfort, good food, power and culture are rated medium high. This may indicate that these values are important but not central to the lives of this generation. Overall, the results suggest that understanding and adapting ways of working and business practices to respond to these values is key to attracting, motivating and retaining young Gen Z talent in organizations.

The obtained results provide valuable insight into the values and priorities of Generation Z, which can be of great use for adapting educational programs, marketing strategies and employment policies to better respond to their needs and expectations. Also, the results have important implications for human resource management, pointing to the need to adapt policies and practices to respond to the values and priorities of this generation.

Our findings point to the need to distinguish between different types of values, such as hedonic, potential, fulfilling and moral. This can help organizations tailor their approaches to the specific needs and values of their employees. And based on the used division of values, it is simpler to break them down and analyse them in more detail on that basis in order to determine the needs of generation Z.

Research on the values of Generation Z students has great importance from several perspectives. First, it provides insight into the values and priorities of young people who are currently in the education phase, but will soon become part of the workforce. Understanding their values is key to adapting educational programs and employment strategies. For example, adapting flexible working conditions, opportunities for professional development and rewards that are in line with the values of Generation Z can help organizations attract and retain the best talent from this generation (Racolța-Paina & Irini, 2021).

Understanding the values of Generation Z is important for the generation itself, because it helps them better understand themselves, their priorities and desires. This knowledge can help them make informed decisions about their education, career and life in general. Also, understanding their own values can help them communicate better with others, in order to achieve better interpersonal relationships (Iorgulescu, 2016). Understanding their values is also important for the environment, because it helps to build a better understanding of intergenerational differences and conflicts. Knowing the values can help older generations to adapt their approaches and communication in order to be more effective in working with them, whether as teachers, employers or parents (Janssen & Carradini, 2021).

The results of this research have significant implications for human resource management. With values such as health, freedom and safety ranking high, organizations should consider how they can adapt their policies and practices to address these priorities. For example, it is possible that organizations that provide flexible working conditions or promote the health and well-being of employees will be more attractive to this generation. Finally, this research can serve as a basis for further research in the area of values and priorities of young people. Understanding the evolution of these values over time can help predict future trends and adjust organizational strategies.

Knowing the values of Generation Z can help HRM identify potential problems or challenges this generation may face in the workplace. For example, if Gen Z values work-life balance, HR teams can develop policies that support flexible working hours or working from home to accommodate this. Essentially, understanding the values of Generation Z allows HRM to create strategies and programs that match their needs and preferences, which can result in better engagement, satisfaction and retention of a talented workforce (Popaitoon, 2022).

The research paper provided a deep insight into the values of Generation Z students, using Musek's value scale. The results showed that health, freedom, security, justice and knowledge are among the most valued values of this generation, while material values such as political success or an exciting life are less important.

The implications of this research for human resource management are significant. Understanding the values of Generation Z enables HR teams to adapt their policies, programs and practices to attract, retain and motivate young talent (Popaitoon, 2022). For example, adapting processes, creating flexible working conditions and creating training programs that suit their needs can be critical to the success of organizations in attracting and retaining this generation of workforce.

Also, understanding the values of Generation Z helps in predicting future trends in the labor market and adapting organizational strategies. HR teams that are aware of the evolution of values and priorities of this generation can improve their practices and policies in order to remain competitive and efficient in their operations.

Understanding the values of Generation Z is essential for HRM. Adapting HRM policies, programs and practices in line with the values of this generation can be key to the success of organizations in today's dynamic environment (Maloney, Hiatt & Campbell, 2019). Generation Z represents the future of the workforce and society as a whole, and it is crucial to adapt strategies and practices to meet their needs and expectations.

Understanding and appreciating the values of generation Z not only contributes to better management of human resources in organizations, but also to the creation of a more harmonious and productive work

environment for all employees. This research provides a basis for further research and adaptation of HRM practices to ensure that organizations remain relevant and successful in the future.

The main limitation of this study is, that the discussed findings and implications were obtained from a single study; generalizing the results should be done with caution, since the whole research was focused mostly on expectations among Gen-Z students from one country and from one faculty. Further research should include differences in gender, nationality, location, university, field of study, financial status and parents' social status. We also suggest differentiating rural versus urban (Keller & Owens, 2020) students in regards to their values. Also, when discussing Gen-Z, we cannot forget, that internet also has an important effect on values (Hameed, 2011). Additionally, it would be interesting to see how the results change as respondents grow older and gain at least a decade of work experience.

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# CAREER AND WAGE EXPECTATIONS AMONG GEN Z STUDENTS: COMPARISON OF SLOVENIA AND SERBIA

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**Abstract:** *As Generation Z has been entering the global workforce, it has become important for companies to understand not only their characteristics but also their career and wage expectations to meet the evolving needs and aspirations of this generation. This paper explores career expectations and how they relate to wage expectations among Gen Z students, and 119 students enrolled in undergraduate or master's programs at two universities, in the same field of study, but situated in distinct Central and Eastern European countries, the Republic of Slovenia and the Republic of Serbia, were included in the study. Data collection took place in April-May 2024. The results show that Life Balance, Freedom, and Expertise are the most important career expectations in Slovenia and Serbia, but not in the same order. At the same time, Organization Membership and Entrepreneurship are the lowest-ranked values in Slovenia and Entrepreneurship and Management in Serbia. Furthermore, regarding wage expectations, in both countries there is a positive and statistically significant relation between wage expectations after completing the studies and starting to work and the wage expectations when they have 10 years of work experience. In Serbia starting wage expectation is twice lower, but the expectation for a relative increase in the 10 years is almost 60% higher compared to Slovenia.*

**Keywords:** *career expectations, wage, student*

## 1. INTRODUCTION

Generation Z (Gen Z), born between the mid-1990s and early 2010s, exhibits distinct expectations regarding the business environment (Barhate & Dirani, 2022). As Gen Zers enter higher education and the workforce, understanding their career aspirations and wage expectations is an important issue for employers. The investigation of students' career preferences and the underlying determinants is consistently of interest to research within the realm of human resources (Milinković et al., 2017). This paper aims to explore career and wage expectations among Gen Z students in two countries, highlighting key elements influencing their perceptions and attitudes. Even though there is research on this topic, still there is room for further explanation and understanding of cross-national Gen Z students' expectations, particularly focused on career and wage.

Grounding on the Expectancy theory (Vroom, 1964), which has developed into one of the frameworks for examining attitudes and behaviors within work and organizational contexts, this paper examines career and wage expectations among Gen Z students. The Expectancy Theory suggests that an individual's motivation to engage in a particular behavior is determined by their belief that the behavior will lead to a desired outcome. It provides valuable insights into how individuals form and act upon their expectations in various contexts, including the business environment. By exploring Gen Z's expectations regarding careers, the results of the research presented in the paper could give valuable insights for businesses to shape their strategies to meet the evolving needs and aspirations of this generation, ensuring pathways to meaningful and sustainable careers.

The main research questions in this paper are: what are the important elements for Gen Z students regarding their career expectations, and how do career expectations relate to wage expectations among them? The data required for the analysis will be gathered through an online survey among students enrolled in undergraduate or master's programs at two universities, in the same field of study, but situated in distinct Central and Eastern European countries, the Republic of Slovenia and the Republic of Serbia. By understanding the career and wage expectations of Gen Z students, employers can tailor job opportunities to align with their interests and goals.

## 2. LITERATURE REVIEW

Members of Generation Z, or as they are also called, iGeneration, Gen Tech, Online Generation, Post Millennials, "always clicking", "digital natives" or "mobile natives" (Dolot, 2018), were born between the mid-1990s and early 2010s when the greatest changes in the world began to unfold with the web, the internet, smartphones, laptops, freely accessible networks, and digital media (Singh & Dangmei, 2016). As among the most notable characteristics of Gen Z are autonomy, individuality, technology addiction, and a need for speed, it is anticipated that they will exhibit qualities such as multitasking, efficient technology utilization, a preference for individualism, rather than teamwork, creativity, a global perspective, and a preference for unconventional and personalized tasks (Berkup, 2014).

Gen Zers has been entering the workforce, so it is relevant to explore their expectations regarding the business environment, particularly factors shaping their career and wage expectations. These expectations are reshaping the business landscape, prompting businesses to meet the evolving demands of this generation. Understanding the career expectations of Gen Z students requires consideration of various factors and work values, which present what is important for them in their working lives. As working values are regarded as one of the central constructs in career decision-making, Kuron et al. (2015) grouped them into four categories. The first group refers to psychological satisfaction with work - intrinsic work values (such as interesting work, intellectual stimulation, and others); the second group is related to the material aspect of work - extrinsic work values (such as salary, job security, and others); the third group comprises social work values (such as relations with coworkers, contribution to society and other); and the fourth group refers to status values, influence, and power. Our paper focuses on the exploration of career expectations related to one of the extrinsic work values, salary, and related expectations among Gen Z students.

Gen Zers, having grown up in the digital age, are well-informed and interconnected, valuing transparency and accountability from businesses (Seemiller & Grace, 2018), and consequently, they have work values typically different for their generation. The ubiquity of technology has shaped Gen Z's career expectations, with a preference for tech-oriented fields (Twenge, 2017). As digital natives, they value jobs that offer opportunities for creativity, innovation, and remote work flexibility (Alferjany & Alias, 2020; Janin, 2022). Even though, Gen Zers value job security and stability (Gabrielova & Buchko, 2021), they often consider as relevant other factors, such as flexibility, continuous learning, purpose, and adaptability in their career decisions.

They are reshaping the traditional notions of job security and are more focused on building dynamic and fulfilling careers that align with their values and aspirations. In addition, some researchers find that they easily change jobs, seeking a job that will provide them with a sense of purpose (Seemiller & Grace, 2018; Fratričová & Kirchmayer, 2018). Gen Zers are motivated by a desire to make a positive impact on society, influencing their career decisions (Tkalac Verčič & Verčič, 2024; Gaidhani et al., 2019). They seek opportunities for meaningful work aligned with their values, such as sustainability, diversity, and social justice, and they prioritize authenticity, ethical practices, and social responsibility in the business environment (Nguyen Ngoc et al., 2022; Deloitte, 2020, Jankins, 2019).

When it comes to extrinsic work values, particularly salary, they have diverse expectations influenced by various factors such as technological advancements, economic conditions, individual characteristics, social values, and others (Fernandes et al., 2021; Silva & Carvalho, 2021). They may have higher salary expectations, and many prioritize earning potential and financial security (Handshake, 2020), but face the reality of entry-level wages and competitive job markets (Twenge, 2017). On the other side, Gen Z considers self-employment as a way of professional action, especially because they consider it better paid and gives a sense of independence (Pauli et al., 2019; Maurer, 2016).

These expectations are reshaping the business landscape, and it has become pivotal for organizations to comprehend this emerging generation's characteristics and aspirations to fulfill their needs as employees (Barhate & Dirani, 2022). Our paper focuses on the career and wage expectations of Gen Z students, which are important for attracting and retaining talents and understanding generational differences in the workplace.

## 3. METHODOLOGY

This paper comprises the analysis of relevant theoretical frameworks and the results of an ongoing survey. The survey has been conducted in April-May 2024 (still ongoing), using an anonymous questionnaire that included three sets of questions. The first one was aimed at collecting data on the demographic features of the respondents, the second and third sets were aimed at collecting data on career expectations and wage expectations, respectively.

The Career Expectations Questionnaire (career-expectations.pdf, 2024) is compiled from 24 statements, which were measured at a four-point Likert-type scale. The statements relate to eight themes (competition, freedom, management, life balance, organization membership, expertise, learning, and entrepreneurship) that refer to the elements and values of work important for choosing an appropriate career. The total score for each theme was obtained by summing up all three scores related to the theme, with the highest ratings indicating what is most important to one's career and, therefore, should guide their career-making decisions. The questionnaire also included questions on expected wages after students complete their studies and their wage expectations ten years after the completion of studies. We will compare their answers with official average and median wage statistics for each country to see if there are any overly high expectations.

As the research has still been conducting, a sample that we analyzed for this paper encompasses 119 students enrolled in undergraduate or master's programs at two universities, in the same field of study, but situated in distinct Central and Eastern European countries. Of those students, 37 (31.1 %) were from Slovenia and 82 (62.9 %) were from Serbia. All respondents are affiliated with faculties of organizational sciences, focusing on informatics and management. The sample included 109 undergraduate (91.6%) and 10 master (8.4%) students. Totally, 43 male (36.1%) and 76 female (63.9%) students participated in the survey. Of that, 22 male respondents come from Slovenia and 21 from Serbia, while 15 female students are from Slovenia and 61 from Serbia. The average age of the respondents was 23 years (22.6 Slovenia, 23.2 Serbia), which means that they are representatives of Gen Z – their years of birth ranged from 1997 to 2004. The work experience of the students who participated in the survey is presented in Table 1.

**Table 1:** Work experience of participants (n = 109).

	Country		Slovenia		Serbia		Total sample	
	Work experience:		N	%	N	%	N	%
	part-time		4	10,80%	26	31,70%	30	25,21%
	full-time		1	2,70%	10	12,20%	11	9,24%
	freelance		2	5,40%	5	6,10%	7	5,88%
	work through student services		29	78,40%	27	32,90%	56	47,06%
	never worked or are volunteering		1	2,70%	14	17,10%	15	12,61%

To explore the career and wage expectations by analyzing the gathered data, we used statistical methods such as average value (mean), standard deviations, and correlation analysis. The results are shown in the following section.

## 4. RESULTS

In the following tables, we will present the results of the average value of the respondents' agreement with the statements regarding career expectations and the average value of the respondents' wage expectations. Table 2 and 3 show the average value of the respondents' agreement with statements regarding their career expectations by country - Slovenia and Serbia.

**Table 2:** Average values of respondents' career expectations for Slovenia (n1 = 37).

Career expectation	Valid	Mean	Std. Deviation
1. Promotion	37	3,1081	0,87508
2. Control over how and when I work	37	3,2432	0,83017
3. Being able to get a job done well through managing the efforts of others	36	2,9444	0,71492
4. Enough leisure time to travel, relax and be myself	36	3,3611	0,83333
5. Being able to contribute new ideas, which will help me build the future	37	3,2432	0,72286
6. A balance between work and other areas of my life	36	3,5833	0,76997
7. Leading a team on key organizational projects	37	3,1892	0,81096
8. Opening up new business directions through initiating new ideas	37	3,0000	0,91287
9. Being part of an organization	37	2,7027	0,93882
10. Being given challenges, which stretch me intellectually	37	3,1622	0,79977
11. Being able to show, that I have more to offer than my colleagues	37	2,9189	0,82927

12. Being able to identify closely with an organization	36	2,5278	0,87786
13. To be recognized for my expertise	37	3,1622	0,76425
14. Being able to get the most out of people in order to achieve the set goal	37	2,8378	0,89795
15. Taking the risk of getting a new business venture off the ground	37	2,7297	0,93240
16. Being able to put work in its place as an important, but not the only part of my life	37	3,1351	0,82199
17. To have the status, that comes with being part of a successful company	37	2,7568	0,86299
18. To be involved in assignments, which will take the organization forward	36	3,0833	0,76997
19. To be able to see, that I am doing better, than those I am in competition with	36	2,9444	0,95452
20. Knowing, that I am respected for the specialist skills that I bring	36	3,3333	0,75593
21. Being able to work, when and where I want, so long as I can deliver results	36	3,3611	0,89929
22. Knowing every year, that I have further developed my expertise	37	3,4054	0,76229
23. Being able to make decisions without being controlled by organizational bureaucracy	37	3,3243	0,81833
24. The excitement of creating something new, whose success depends on me	37	3,0270	0,86559

**Table 3:** Average values of respondents' career expectations for Serbia (n2 = 82).

Career expectation	Valid	Mean	Std. Deviation
1. Promotion	81	3,3951	0,70141
2. Control over how and when I work	81	3,3704	0,67905
3. Being able to get a job done well through managing the efforts of others	81	2,9506	0,68741
4. Enough leisure time to travel, relax and be myself	81	3,7037	0,53489
5. Being able to contribute new ideas, which will help me build the future	82	3,4756	0,68899
6. A balance between work and other areas of my life	81	3,7778	0,47434
7. Leading a team on key organizational projects	81	2,8148	0,92346
8. Opening up new business directions through initiating new ideas	82	2,8902	0,75369
9. Being part of an organization	82	3,2073	0,89908
10. Being given challenges, which stretch me intellectually	81	3,3210	0,72158
11. Being able to show, that I have more to offer than my colleagues	82	2,7805	0,84655
12. Being able to identify closely with an organization	81	2,8519	0,90982
13. To be recognized for my expertise	81	3,4815	0,69121
14. Being able to get the most out of people in order to achieve the set goal	81	3,0247	0,77420
15. Taking the risk of getting a new business venture off the ground	82	2,3659	0,82420
16. Being able to put work in its place as an important, but not the only part of my life	81	3,4444	0,67082
17. To have the status, that comes with being part of a successful company	82	2,9756	0,90234
18. To be involved in assignments, which will take the organization forward	82	3,1463	0,77175
19. To be able to see, that I am doing better, than those I am in competition with	82	2,9390	0,93423
20. Knowing, that I am respected for the specialist skills that I bring	82	3,6098	0,69843
21. Being able to work, when and where I want, so long as I can deliver results	81	3,4321	0,72350

22. Knowing every year, that I have further developed my expertise	82	3,4878	0,68932
23. Being able to make decisions without being controlled by organizational bureaucracy	82	3,2561	0,76676
24. The excitement of creating something new, whose success depends on me	82	3,0610	0,72602

Table 4 and 5 present eight different themes, where the highest ratings indicate elements and values most important to one's career and should therefore guide their career-making decisions by country. Themes were calculated by summing up statements included in each theme from Tables 2 and 3 as noted in the brackets by each theme in Tables 4 and 5. We can see that the themes with the highest ratings in Slovenia are Life Balance, followed by Freedom and Expertise, whereas the lowest rated themes were Organization Membership and Entrepreneurship. On the other hand, in Serbia, the students value the same items but in different order, Life Balance is the top-ranked, but Expertise is before Freedom, while Entrepreneurship is with lowest ranking, and the next one is Management.

**Table 4:** Average values by career expectation themes for Gen-Z students - Slovenia (n1 = 37).

Themes (statements included in each theme)	Valid	Mean	Std. Deviation
Competition (1+11+19)	36	8,9444	1,73937
Freedom (2+21+23)	36	9,8889	2,14846
Management (3+7+14)	36	8,9722	1,85913
Life Balance (4+6+16)	36	10,1389	1,79129
Organization Membership (9+12+17)	36	8,0278	2,26130
Expertise (13+20+22)	36	9,8611	1,79129
Learning (5+10+18)	36	9,4722	1,79660
Entrepreneurship (8+15+24)	37	8,7568	2,20360

**Table 5:** Average values by career expectation themes for Gen-Z students - Serbia (n2 = 82).

Themes (statements included in each theme)	Valid	Mean	Std. Deviation
Competition (1+11+19)	81	9,1358	1,87585
Freedom (2+21+23)	80	10,0500	1,51699
Management (3+7+14)	80	8,8125	1,74366
Life Balance (4+6+16)	81	10,9259	1,20185
Organization Membership (9+12+17)	81	9,0123	2,08862
Expertise (13+20+22)	81	10,5926	1,53930
Learning (5+10+18)	81	9,9506	1,70221
Entrepreneurship (8+15+24)	82	8,3171	1,75596

Tables 6 and 7 present the wage expectations after completing the studies and starting to work and the wage expectations (by country), when 10 years after they complete their studies. Based on our survey, the expected wage after completing the studies and starting to work among Slovenian students is around 1,800 EUR and the expected wage, when they will have 10 years of work experience is around 4,000 EUR. Serbian students expect a significantly lower starting wage, less than 1,000 EUR, but after 10 years they expect it to grow 3.5 times to around 3400 EUR, which is a much larger gap than in Slovenia where this ratio is around 2.2 times regarding salary increase in 10 years.

**Table 6:** Wage expectations - Slovenia (n1 = 37).

Themes	Valid	Expected wages	
		Mean	Std. Deviation
My wage expectation after I complete my studies and start working is (in EUR)	36	1811,1111	460,29666
My wage expectation, when I will be with 10 years of work experience - or 10 years after I complete my studies is (in EUR)	36	4079,0833	2482,69066

**Table 7:** Wage expectations - Serbia (n2 = 82).

Themes	Valid	Expected wages	
		Mean	Std. Deviation
My wage expectation after I complete my studies and start working is (in EUR)	82	970,6098	303,21873

My wage expectation, when I will be with 10 years of work experience - or 10 years after I complete my studies is (in EUR)	82	3395,1220	1647,21257
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We have already combined all the statements representing each theme in Tables 4 and 5 and then performed a correlation analysis between career expectations and expected wages as presented in Tables 8 and 9. We can notice that in both countries there is a positive and statistically significant relation between wage expectations after completing studies and starting to work and the wage expectations when they have 10 years of work experience. We can also notice from the correlation analysis which of the themes have a positive and which have a negative relation to the expected wages.

**Table 8:** Pearson correlation between career expectation themes and expected wages - Slovenia (n1 = 37).

		My wage expectation after I complete my studies and start working is (in EUR)	My wage expectation, when I will be with 10 years of work experience - or 10 years after I complete my studies is (in EUR)
My wage expectation, when I will be with 10 years of work experience - or 10 years after I complete my studies is (in EUR)	Pearson Correlation	,471**	1
	Sig. (2-tailed)	0,004	
Competition	Pearson Correlation	0,184	,342*
	Sig. (2-tailed)	0,290	0,044
Freedom	Pearson Correlation	0,053	0,018
	Sig. (2-tailed)	0,761	0,917
Management	Pearson Correlation	0,242	0,301
	Sig. (2-tailed)	0,161	0,079
Life Balance	Pearson Correlation	-0,078	-0,281
	Sig. (2-tailed)	0,656	0,102
Organization Membership	Pearson Correlation	0,197	0,028
	Sig. (2-tailed)	0,257	0,873
Expertise	Pearson Correlation	0,034	0,273
	Sig. (2-tailed)	0,847	0,112
Learning	Pearson Correlation	0,019	0,189
	Sig. (2-tailed)	0,913	0,276
Entrepreneurship	Pearson Correlation	0,173	,420*
	Sig. (2-tailed)	0,314	0,011

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

**Table 9:** Pearson correlation between career expectation themes and expected wages - Serbia (n2 = 82).

		My wage expectation after I complete my studies and start working is (in EUR)	My wage expectation, when I will be with 10 years of work experience - or 10 years after I complete my studies is (in EUR)
My wage expectation, when I will be with 10 years of work experience - or 10 years after I complete my studies is (in EUR)	Pearson Correlation	,367**	1
	Sig. (2-tailed)	0,001	
Competition	Pearson Correlation	0,163	0,114
	Sig. (2-tailed)	0,145	0,310
Freedom	Pearson Correlation	-0,007	-0,008
	Sig. (2-tailed)	0,950	0,945
Management	Pearson Correlation	0,091	0,108
	Sig. (2-tailed)	0,425	0,341
Life Balance	Pearson Correlation	-0,033	0,103
	Sig. (2-tailed)	0,771	0,359
Organization Membership	Pearson Correlation	0,080	,248*
	Sig. (2-tailed)	0,476	0,025
Expertise	Pearson Correlation	-0,012	0,092
	Sig. (2-tailed)	0,918	0,416
Learning	Pearson Correlation	0,074	0,117
	Sig. (2-tailed)	0,511	0,299
Entrepreneurship	Pearson Correlation	,237*	0,140
	Sig. (2-tailed)	0,032	0,211

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

Through the analysis of the collected data based on students' expectations, we have determined their career expectations and their wage expectations. We have also compared their wage expectations to the average and median wages in each county. The results show, that in Slovenia there are positive and statistically significant relations between expectation themes Competition and Entrepreneurship and wage expectation

after 10 years of work, and in Serbia between Entrepreneurship and initial wage expectations and Organization Membership and wage expectation after 10 years of work.

## 5. DISCUSSION AND CONCLUSION

Through our research, we have found that the career and wage expectations among Gen Zers are connected. We can see that the themes with the highest ratings are Life Balance, followed by Expertise and Freedom in Slovenia, and Freedom and Expertise in Serbia, whereas the lowest rated themes were Organization Membership and Entrepreneurship in Slovenia and Entrepreneurship and Management in Serbia, and thus we provided the answer to the first research question. The distinctions can be explained through cultural diversities and the different levels of economic development between the two countries. Each theme has a positive or negative effect on the expected wage in both countries, which answers the second research question. However, not all relations are statistically significant. The variety in expected wage increase after 10 years of work can be explained by the continuous, steady, and considerable annual increase in average salary in Serbia in recent years compared to the more stable macroeconomic situation in Slovenia.

Whereas the themes per se are not expected to have a huge influence in terms of wage expectations right after the completion of studies or starting to work, we can notice, that in Slovenia after 10 years of work experience such themes as Competition and Entrepreneurship have a statistically significant relation with wage expectations, while in Serbia this is the case with Organization Membership. However, in Serbia Entrepreneurship has a statistically significant relation with starting wage expectations.

When comparing their wage expectations, we include the official statistical data for the average wages in each country, which were for February 2024 1,449 EUR for Slovenia (Statistical Office of the Republic of Slovenia, 2024) and 803 EUR for Serbia (Statistical Office of the Republic of Serbia, 2024). The difference in the expected wages found through our research and the actual average wages in each country can be explained by not being familiar with the current average wage in each country, by an optimistic viewpoint of the students participating in our survey, and by a potential "delulu effect" (What does Delulu mean? | Later Social Media Glossary, 2024), which is eminent to individuals lacking real-world experience.

This study has several limitations that simultaneously expose several opportunities for further research. First, the discussed findings and implications were obtained from a single study; generalizing the results should be done cautiously. Second, the research focused mostly on expectations among Gen Z students. To have more valid results in separate analysis per country we tend to widen the sample, as this research is still ongoing. Furthermore, the research can also include other countries.

Further research should include an examination of the differences in career and wage expectations depending on different factors, such as gender, nationality, field of study, financial status, and others. Additionally, it would be interesting to see how the results change as respondents become more mature, for example when they graduate and start working, or after gaining several years of working experience.

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# PROBLEMS OF GENDER (IN)EQUALITY IN HEALTHCARE INSTITUTIONS IN SLOVENIA

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**Abstract:** *The issue of gender equality is a complex and multifaceted phenomenon that extends across various social and professional spheres, including healthcare institutions. Although the healthcare sector is often perceived as an area of high professional standards and equal opportunities, practice shows that significant inequalities still exist among employees based on gender. These inequalities not only affect the work environment and employee satisfaction but can also impact the quality of care received by patients. In this article, we focus on analyzing the nature, scope, and consequences of inequality among employees in selected healthcare institutions. Through a thorough review of existing studies and empirical data, we aim to understand the underlying causes of such inequality and identify strategies to reduce it. We will examine various aspects, such as balancing professional and personal life, career advancement, access to leadership positions, as well as sexual harassment and workplace discrimination. By addressing these challenges, we aim to contribute to the development of a more equitable work environment in healthcare institutions that promotes diversity, inclusivity, and professional growth for all employees, regardless of gender.*

**Keywords:** *gender equality, employees, labour market, health organization*

## 1. INTRODUCTION

Gender inequality is a complex and multifaceted phenomenon that extends across various social and professional spheres, including healthcare institutions. Although the healthcare sector is often perceived as a realm of high professional standards and equal opportunities, the practice shows that significant gender-based inequalities still exist among employees. These inequalities not only affect the work environment and employee satisfaction but can also impact the quality of care received by patients.

In this contribution, we focus on analyzing the nature, extent, and consequences of gender inequality among employees in selected healthcare institution. Through a thorough review of existing studies and empirical data, we aim to understand the underlying causes of such inequality and identify strategies to reduce it. We will examine various aspects, such as wage disparity, career advancement, access to leadership positions, as well as sexual harassment and discrimination in the workplace.

By addressing these challenges, we endeavor to contribute to the development of a more equitable work environment within healthcare institutions, one that promotes diversity, inclusion, and professional growth for all employees, regardless of gender. Through analysis and discussion, we aim to provide insights into this complex issue and stimulate further research and measures to improve the situation in practice.

## 2. THEORETICAL REVIEW

### 2.1. GENDER EQUALITY

Gender equality is one of the fundamental human rights and a principle of democratic societies aimed at achieving gender parity. It entails the equal participation of women and men in society, including equal rights and responsibilities, equal opportunities, and equal power to influence planning and decision-making in all areas of public and private life, as well as equal opportunities to enjoy all rights and develop personal potentials (Government Office for Development and European Cohesion Policy, 2016). Gender equality is crucial for a fair and sustainable society.

Gender equality thus refers to efforts to treat people equally regardless of their gender. This includes eliminating discrimination based on gender and ensuring equal opportunities, rights, and access to resources

for all regardless of gender identity. This may involve equal pay for equal work, equal access to education, healthcare services, and political participation, as well as combating gender-based violence and stereotypes.

When we talk about gender equality, the terms gender equality and equal opportunities are often interchangeably used. Gender equality refers to equal recognition, power, and participation of both genders in all areas of public and private life. Gender equality stands in contrast to inequality and not to gender differences, with the aim of promoting full participation of women and men in society (Kozmik, 1998). Equal opportunities mean that women and men have equal chances to participate as they wish in economic, political, social, and cultural life (Kozmik and Salecl, 1999). All actions and processes that unjustifiably place an individual in a less favorable legal, political, economic, or social position based on their gender constitute discrimination" (Flander, 2004).

The beginnings of legal legislation on gender equality in the European Union date back to 2000 when the EU adopted the Employment Equality Directive (2000/78/EC). The directive prohibits discrimination based on gender and promotes equality in employment between men and women. The Employment Equality Directive provides a basis for further adoption of legal acts in the field of gender equality in the workplace, as it defines rules and requirements for equal treatment of men and women in access to employment, employment conditions, promotion, equal pay for equal work or work of equal value, legal protection, measures in case of sexual harassment or harassment, and similar matters.

A few years later, specifically on March 5, 2006, the European Union adopted the Directive on Equal Treatment - Directive of the European Parliament and of the Council of 5 July 2006 on the implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation (2006/54/EC). The content of the Equal Treatment Directive represents an enhancement of the legal framework for ensuring equality between men and women in employment. In addition to the main provisions outlined in the Employment Equality Directive, the Equal Treatment Directive also establishes a legal framework regarding maternity and parental leave. Specifically, the Equal Treatment Directive sets minimum standards for maternity leave and parental leave and protection against dismissal during these periods.

Based on the Equal Treatment Directive, the European Commission defined the Gender Equality Strategy 2020-2025 (COM/2020/152 final) in March 2020. The Gender Equality Strategy 2020-2025 is the European Union's long-term plan to promote gender equality and address issues related to inequality between men and women in the workplace. This strategy provides a framework for actions and policies that the EU will implement over a five-year period (2020-2025) to achieve a more equal social and economic position between genders. Some key objectives and areas of action within this strategy include:

- Equality in the labor market: Promoting equal opportunities and treatment between genders in employment, salary payment, career advancement, and balancing work and family life.
- Equality in economic and public life: Increasing the representation of women in leadership and decision-making positions and promoting gender equality in the economic and public sectors.
- Equality in families and society: Supporting the reconciliation of work and family life, preventing violence against women, and promoting gender equality in social roles and relationships.
- Equality in healthcare and social care: Ensuring gender equality in access to healthcare and social services and addressing specific healthcare issues of women.
- Equality in the international context: Promoting gender equality in international cooperation, including foreign policy and development assistance.

The strategy includes concrete measures, objectives, and indicators to monitor progress in gender equality. It is important to emphasize that the goal of the strategy is to achieve a more equitable society where men and women have equal opportunities, equal treatment, and equal access to resources and rights.

## **2.2. GENDER EQUALITY IN THE LABOR FORCE**

Gender equality in the labor market refers to the concept of ensuring equal opportunities, treatment, and access to employment and job opportunities regardless of gender. This includes eliminating gender-based discrimination in hiring, pay, promotion, and other aspects of work. Gender equality in the labor market is essential for the realization of fundamental human rights, promoting economic growth, and ensuring fairness in society. This can be achieved by adopting appropriate legislation, policies, and practices, as well as promoting awareness and education about the importance of gender equality.

Gender equality in the labor market encompasses several different aspects: employment, pay, promotion, work-life balance, and prevention of sexual harassment. Ensuring equal employment opportunities for all regardless of gender means that all candidates should be considered based on their qualifications, experience, and abilities, rather than their gender. Reducing gender pay gaps involves ensuring equal pay for equal work

and eliminating gender-based pay discrimination. Providing equal opportunities for career advancement regardless of gender means that individuals should be assessed and promoted based on their achievements, abilities, and dedication to work, rather than their gender. Promoting policies and practices that enable work-life balance for all employees, regardless of gender, including policies regarding parental leave, flexible working hours, and remote work options. Preventing sexual harassment involves providing a safe and respectful work environment and preventing sexual harassment in the workplace (Coron, 2019).

Gender equality in the labor market also includes the prohibition of gender-based discrimination. Discrimination can be direct or indirect. As defined by the Directive of the European Parliament and of the Council on the implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation, direct discrimination occurs when a person is treated less favorably on the grounds of gender than another person in a comparable situation, while indirect discrimination occurs when seemingly neutral provisions, criteria, or practices put persons of one gender at a particular disadvantage compared to persons of another gender, unless these provisions, criteria, or practices are objectively justified by a legitimate aim and the means of achieving that aim are appropriate and necessary (2006/54/EC).

The field of gender equality in the labor market is also addressed in the Gender Equality Strategy 2020-2025. Together with legal obligations, the strategy brings numerous benefits to organizations, impacting their performance, culture, and sustainability. The Gender Equality Strategy 2020-2025 is important for organizations for several reasons:

- **Legal framework and compliance:** The strategy is based on legislative directives and guidelines from the European Union concerning gender equality. Organizations must comply with legal requirements and equality standards to avoid legal consequences such as fines or reputational damage.
- **Social responsibility:** Organizations are increasingly aware of their social responsibility to promote gender equality. Participating in and implementing the strategy can contribute to improving the status of women in society and increasing inclusivity and diversity.
- **Employee benefits:** Creating an equitable and inclusive work environment can contribute to higher employee satisfaction, increased productivity, and retention of talented individuals. Organizations that promote gender equality attract and retain a diverse workforce.
- **Innovation and creativity:** A diverse work environment based on equality fosters different perspectives, experiences, and ideas. This can lead to greater innovation and better problem-solving.
- **Reputation enhancement:** Organizations actively implementing gender equality strategies can build a positive reputation in society. This can attract more customers, partners, and investors.
- **Growth opportunities:** Achieving gender equality can lead to more balanced decision-making structures, which can contribute to better utilization of talents and skills within the organization. This can lead to improved performance and organizational growth.
- **Prevention of discrimination and conflicts:** Active work for gender equality can reduce discrimination and inequality and prevent potential conflicts within the organization.
- **Promotion of equal opportunities for development:** Providing equal opportunities for education, training, and advancement can help create a professional and competent workforce and reduce gender gaps at various levels of the organization.

### **2.3. REVIEW OF GENDER EQUALITY IN THE SELECTED HEALTHCARE ORGANIZATION**

Before conducting the survey in the selected healthcare organization, we analyzed the gender balance in selected positions and individual job roles based on existing statistical data. The statistics in this report serve to illustrate the current gender composition and identify any potential gender imbalances. All data refers to December 31, 2022.

In the healthcare institution, there are a total of 532 employees, of which 441 are women (82.9%) and 91 are men (17.1%). Regarding the type of contracts, 15 out of 91 male employees are employed on a fixed-term basis, including 1 trainee, while 76 are employed on an indefinite basis. Out of a total of 468 women, 49 are employed on a fixed-term basis, including 7 trainees, and 392 are employed on an indefinite basis.

There are 27 people employed in leadership positions in the hospital, including 7 men and 20 women. Currently, a woman is employed as the hospital director, and two male individuals hold positions as assistant directors. There are 12 individuals employed as department heads, including 3 men and 9 women. Men occupy the positions of Head I (2 males) and Head V, while women occupy the remaining positions of heads. There are 3 individuals employed as Head of the Medical Laboratory, including 1 male and 2 females. The majority of women, 8 out of 9, are employed as Professional Heads.

In the healthcare positions at the selected healthcare organization, a total of 390 people are employed. The gender representation of employees heavily favors women, as there are only 59 men (15.1%) and 331 women

(84.9%) employed in healthcare positions. The smallest deviations in gender representation are among physicians, with 24 men (35.3%) and 42 women (64.7%) in this role. Conversely, among nurses, the majority are women. Out of a total of 190 employed nurses, 164 are women (86.3%) and only 26 are men (13.7%). The same trend is observed among other healthcare workers, where women also dominate. Among various healthcare associates, with the exception of physicians and nurses, the majority are women, with 125 out of 134 employees (93.3%) being women, while only 9 are men (6.7%). In addition to healthcare workers, the selected healthcare organization employs 94 non-healthcare workers. Of these, 25 are men (26.6%) and 69 are women (73.4%). As of December 31, 2022, there were 57 active students, with 48 women and only 9 men. The proportion of women among active trainees and students is as high as 84%.

In the past three years, out of a total of 532 employees, 140 have been promoted, including 18 men (out of 91) and 122 women (out of 441), which means that 19.8% of men and 27.6% of women have been promoted in the past three years. Out of the 18 men who were promoted, 1 man was promoted by one pay grade, and 17 were promoted by two pay grades. Out of the total of 122 women who were promoted, 93 (84.4%) were promoted by 2 pay grades, 7 were proposed for promotion by 2 pay grades but were only promoted by 1 pay grade, and 22 were promoted by 1 pay grade.

Considering the nature of work and professions, it is understandable that there is a predominance of women at the selected healthcare organization. It is worth noting that women hold positions at all leadership levels as well as in all professions.

### 3. RESEARCH

#### 3.1. Research setting and participants

Among the employees at the selected healthcare institution in Slovenia, a survey on gender equality and other areas of gender equality among employees was conducted in October 2023.

The full set of questionnaires was completed by a total of 74 participants, which represent our sample, of whom 12 (16.2%) were men and 62 (83.8%) were women. The majority of respondents, specifically 29 (39.2%), were aged 30 to 39. They were followed by respondents in the age group of 40 to 49 years, numbering 23 (31%). 14 respondents were aged 50 or older, and 8 respondents were aged 20 to 29.

10 respondents completed secondary school, while 43 had higher education, college, or university degrees. 18 of the surveyed employees at the clinic completed a master's degree, and three have a doctoral degree. Out of 74 respondents, 36 were employed in non-healthcare positions, specifically 5 in management, 1 as a researcher, 21 as professional, and 9 as administrative staff. The remaining respondents were employed in healthcare positions, including 10 physicians, 14 nurses, and 14 healthcare workers or associates.

#### 3.2. Results

"The first set of questions in the survey questionnaire addressed the area of work-life balance. We assessed whether employees at the selected healthcare organization experience difficulties in balancing their professional and personal lives. The average score of statements related to the alignment of work and private life was 3.36, with a standard deviation of 1.24 (Table 1). The results indicated that employees do not perceive significant difficulties and perceive their professional and personal lives as balanced.

**Table 1:** Average alignment of work-life balance

	NUMBER	MIN	MAX	AVERAGE	STD
<b>Work-life balance</b>	74	1	5	3,63	1,243
<b>All</b>	74				

Crucial for the field of gender equality is the comparison of responses regarding the alignment of professional and private life by gender. The research results have shown that women even sometimes assess the alignment of their professional and private lives better than men.

**Table 2:** Alignment of work-life balance by gender

<b>WORK-LIFE BALANCE</b>	<b>MEN</b>	<b>%</b>	<b>WOMEN</b>	<b>%</b>	<b>ALL</b>
I don't agree at all	1	8,3	3	4,8	4
I partially disagree	3	25	10	16,1	13
I neither agree nor disagree	2	16,7	8	12,9	10
I partially agree	0	0	21	33,9	21
I totally agree	6	50	20	32,2	26
<b>TOGETHER</b>	<b>12</b>	<b>100</b>	<b>62</b>	<b>100</b>	<b>74</b>

The next section of the survey examined respondents' opinions on equal opportunities for men and women in hiring, promotion, and employment in leadership positions. A desire for a leadership position was expressed by a good third of the respondents (37.8%), of which 66.7% were men and 33.3% were women. The results indicate that men have twice the desire for a leadership position compared to women (Table 3 and 4)

**Table 3:** Desire for a leadership position

	<b>NUMBER</b>	<b>%</b>
<b>YES</b>	28	37,8
<b>NO</b>	46	62,2
<b>TOGETHER</b>	<b>74</b>	<b>100</b>

**Table 4:** Desire for a leadership position by gender

	<b>YES</b>	<b>%</b>	<b>NO</b>	<b>%</b>	<b>TOGETHER</b>
<b>MEN</b>	8	66,7	4	33,3	12
<b>WOMEN</b>	21	33,3	41	66,7	62
<b>TOGETHER</b>	<b>28</b>	<b>100</b>	<b>45</b>	<b>100</b>	<b>74</b>

Respondents largely (75.6%) believed that both genders have equal opportunities in occupying leadership positions. 20.3% of them thought that men have more opportunities, while only 4.1% believed that women have more opportunities for occupying leadership positions (Table 5).

**Table 5:** Opinion on advantage in occupying leadership positions

	<b>NUMBER</b>	<b>%</b>
<b>MEN</b>	15	20,3
<b>WOMEN</b>	3	4,1
<b>BOTH THE SAME</b>	56	75,7
<b>TOGETHER</b>	<b>74</b>	<b>100</b>

Male respondents were 83% convinced that both genders have equal opportunities for occupying leadership positions, with one respondent (8.3%) believing that men have more opportunities, and another respondent (8.3%) suggesting that women have more opportunities. On the other hand, 22.6% of female respondents believed that men have an advantage in occupying leadership positions, 74% agreed that both genders have equal opportunities, and only 3% believed that women have advantages in occupying leadership positions (Table 6).

**Table 6:** Opinion on advantage in occupying leadership positions by gender

	<b>MEN</b>	<b>%</b>	<b>WOMEN</b>	<b>%</b>	<b>BOTH THE SAME</b>	<b>%</b>	<b>TOGETHER</b>
<b>MEN</b>	1	8,3	1	8,3	10	83,4	12
<b>WOMEN</b>	14	22,6	2	3,3	46	74,2	62
<b>TOGETHER</b>	15		3		56		74

The majority of respondents (86.5%) believed that both genders are equally qualified for a leadership position, with only 6.8% believing that one gender is more qualified. The results did not significantly differ between men and women (Table 7 and Table 8).

**Table 7:** Qualification for a leadership position

	<b>NUMBER</b>	<b>%</b>
<b>MEN</b>	5	6,8
<b>WOMEN</b>	5	6,8
<b>BOTH THE SAME</b>	64	86,5
<b>TOGETHER</b>	74	100

**Table 8:** Qualification for a leadership position by gender

	<b>MEN</b>	<b>%</b>	<b>WOMEN</b>	<b>%</b>	<b>BOTH THE SAME</b>	<b>%</b>	<b>TOGETHER</b>
<b>MEN</b>	1	8,3	1	8,3	10	83,4	12
<b>WOMEN</b>	4	6,5	4	6,5	54	87%	62
<b>TOGETHER</b>	5		5		64		74

Continuing, respondents were asked who has an advantage in advancement within the organization. 77% of respondents believed that everyone in the organization has equal opportunities for advancement regardless of gender, 21.6% of them believed that men have an advantage in advancement, and only a small percentage (1 respondent) believed that women have an advantage (Table 9).

**Table 9:** Advantage in advancement

	<b>NUMBER</b>	<b>%</b>
<b>MEN</b>	16	21,6
<b>WOMEN</b>	1	1,4
<b>BOTH THE SAME</b>	57	77
<b>TOGETHER</b>	74	100

Male respondents overwhelmingly believed (91%) that both men and women have equal opportunities for advancement within the organization, while 17% fewer women, specifically 74%, shared this view. 24% of women perceived men to have more advantages in advancement, whereas only 8% of men held this belief. None of the male respondents indicated that women have more advantages in advancement (Table 10).

**Table 10:** Advantage in advancement by gender

	<b>MEN</b>	<b>%</b>	<b>WOMEN</b>	<b>%</b>	<b>BOTH THE SAME</b>	<b>%</b>	<b>TOGETHER</b>
<b>MEN</b>	1	8,3	0	0	11	91,7	12
<b>WOMEN</b>	15	24,2	1	1,6	46	74,4	62
<b>TOGETHER</b>	16		1		57		74

As part of the survey, the awareness of advancement opportunities among employees was assessed. 28.4% of respondents were familiar with the opportunities, 39% partially, and 32.4% were unaware of advancement possibilities (Table 11). Responses did not significantly differ by gender, although among women, the proportion of those unfamiliar with advancement opportunities was slightly higher than among men (Table 12). The results indicate that employees are relatively poorly informed about advancement opportunities within the organization, suggesting a need for increased attention to informing employees about advancement opportunities.

**Table 11:** Awareness of advancement opportunities

	<b>NUMBER</b>	<b>%</b>
<b>YES</b>	21	28,4
<b>NO</b>	24	32,4
<b>PARTIALLY</b>	29	39,2
<b>TOGETHER</b>	74	100

**Table 12:** Awareness of advancement opportunities by gender

	<b>YES</b>	<b>%</b>	<b>NO</b>	<b>%</b>	<b>PARTIALLY</b>	<b>%</b>	<b>TOGETHER</b>
<b>MEN</b>	4	33,3	4	33,3	4	33,4	12
<b>WOMEN</b>	17	27,4	20	32,3	25	40,3	62
<b>TOGETHER</b>	21		24		29		74

Half of the respondents believed that the organization partially enables them to achieve their career goals. 30% of respondents believed that the organization enables them to achieve their career goals, and 20% believed that the organization does not enable them to achieve their career goals. Responses did not significantly differ based on the gender of the respondents (Table 13 and Table 14).

**Table 13:** Enabling career goal attainment

	<b>NUMBER</b>	<b>%</b>
<b>YES</b>	22	29,7
<b>NO</b>	15	20,3
<b>PARTIALLY</b>	37	50
<b>TOGETHER</b>	74	100

**Table 14:** Enabling career goal attainment by gender

	<b>YES</b>	<b>%</b>	<b>NO</b>	<b>%</b>	<b>PARTIALLY</b>	<b>%</b>	<b>TOGETHER</b>
<b>MEN</b>	4	33,3	2	16,7	6	50	12
<b>WOMEN</b>	18	29	13	20	31	50	62
<b>TOGETHER</b>	22		24		29		74

Respondents were also asked about their opinion on who has advantages in employment. The majority of respondents (82.4%) believed that neither gender has an advantage in employment, 13.5% believed that men have an advantage in employment, and only 4% of respondents believed that women have an advantage in employment (Table 15).

**Table 15:** Preference in employment

	NUMBER	%
<b>MEN</b>	10	13,5
<b>WOMEN</b>	3	4,1
<b>BOTH THE SAME</b>	61	82,4
<b>TOGETHER</b>	74	100

The results of comparing responses by gender showed that all male respondents believe that both genders have equal opportunities in employment. Among female respondents, however, the answers were more diverse. 16% of women believed that men have an advantage in employment at the clinic, 5% believed that women have an advantage, and 79% of female respondents believed that both genders have equal opportunities.

**Table 16:** Preference in employment by gender

	MEN	%	WOMEN	%	BOTH THE SAME	%	TOGETHER
<b>MEN</b>	0	0	0	0	12	100	12
<b>WOMEN</b>	10	16,1	3	4,8	49	79,1	62
<b>TOGETHER</b>	10		3		61		74

The last section of the questionnaire covered questions regarding sexual discrimination and violence. The results showed that 80% of respondents know what sexual discrimination and violence mean, 4% do not know, and 16% are partially aware of the meaning (Table 17). The results did not significantly differ between male and female respondents (Table 18).

**Table 17:** Understanding the meaning of sexual discrimination and violence

	NUMBER	%
<b>YES</b>	59	79,7
<b>NO</b>	3	4,1
<b>PARTIALLY</b>	12	16,2
<b>TOGETHER</b>	74	100

**Table 18:** Understanding the meaning of sexual discrimination and violence by gender

	YES	%	NO	%	PARTIALLY	%	TOGETHER
<b>MEN</b>	10	83,3	0	0	2	16,7	12
<b>WOMEN</b>	49	79	3	4,8	10	16,2	62
<b>TOGETHER</b>	59		3		12		74

Subsequently, knowledge of protocols for handling sexual violence or harassment was examined. Only 36.5% of respondents are fully familiar with the protocol, an equal percentage are partially aware of it, and 27% of respondents stated that they are not familiar with the protocol for dealing with sexual violence and harassment (Table 19).



**Table 19:** Knowledge of protocols for dealing with sexual violence and harassment

	NUMBER	%
<b>YES</b>	27	36,5
<b>NO</b>	20	27
<b>PARTIALLY</b>	27	36,5
<b>TOGETHER</b>	74	100

The research results surprisingly showed that men are more familiar with protocols for handling sexual violence and harassment than women. Only 8.3% of men responded that they are not familiar with the protocols, while this was the case for over 30% of women. The rest either fully or partially know the protocol (Table 20). The results indicate the need for awareness-raising, particularly among female employees in the clinic, about protocols for handling sexual violence and harassment.

**Table 20:** Knowledge of protocols for dealing with sexual violence and harassment by gender

	YES	%	NO	%	PARTIALLY	%	TOGETHER
<b>MEN</b>	4	33,3	1	8,3	7	58,4	12
<b>WOMEN</b>	23	37,1	19	30,6	20	33,3	62
<b>TOGETHER</b>	27		20		27		74

Similar results to those regarding knowledge of protocols for handling sexual violence and harassment were also found regarding awareness of sanctions in cases of sexual violence. Only a small third of respondents (28.4%) are fully aware of the sanctions, while 39.2% are partially aware, and 32.4% of employees do not know the sanctions at all in cases of reported sexual violence (Table 21).

**Table 21:** Knowledge of sanctions in cases of sexual violence

	NUMBER	%
<b>YES</b>	21	28,4
<b>NO</b>	29	39,2
<b>PARTIALLY</b>	24	32,4
<b>TOGETHER</b>	74	100

In analyzing the results based on the gender of the respondents, it was also evident in this question that women are less familiar with sanctions in cases of sexual violence. Forty-two percent of women responded that they are unfamiliar with the sanctions, while only a quarter (25%) of men answered similarly. A third of men and a third of women are partially familiar with the sanctions, while the rest are familiar with sanctions in cases of sexual violence (Table 22). The results indicate the need for awareness-raising, particularly among female employees at the clinic, regarding sanctions in cases of sexual violence

**Table 22:** Knowledge of sanctions in cases of sexual violence by gender

	YES	%	NO	%	PARTIALLY	%	TOGETHER
<b>MEN</b>	5	41,7	3	25	4	33,3	12
<b>WOMEN</b>	16	22,6	26	42	20	32,4	62
<b>TOGETHER</b>	21		29				74

## 4. CONCLUSION

Equal inclusion of both genders in healthcare is understood as wealth and an advantage, both contributing to faster and higher-quality development of healthcare. A review of data on the current state at the selected clinic in Slovenia shows a predominance of the female population, particularly evident in healthcare nursing. Nevertheless, there is still more we can do in terms of gender equality and eliminating discrimination based on sexual orientation to further improve patient healthcare.

The research results indicate differences in opinions between men and women on certain issues. It has been particularly evident that women face more challenges in balancing their professional and personal lives than men, and they are less familiar with protocols and sanctions in cases of sexual violence and harassment. Women also, to a slightly lesser extent than men, believed that everyone has equal opportunities for advancement and employment and for occupying leadership positions, or a higher percentage than men believed that men have more opportunities. However, women were less aware of promotion opportunities than men and expressed less desire for leadership positions than men. The research results suggest a relatively positive opinion of surveyed employees about gender equality at the clinic, but improvements in this area are still needed.

Gender equality in the labor market is crucial for a just and sustainable society. When we ensure equal opportunities for employment, equal pay for equal work, and support for work-life balance regardless of gender, we create a more productive, innovative, and inclusive work environment. Although some progress has been made in this area, challenges persist, making continuous efforts in awareness, legislation, and practices crucial. Advocating for gender equality in the labor market is not only a moral obligation but also a strategic decision benefiting individuals, businesses, and society as a whole. Therefore, it is time to commit together to creating a more equitable future, where the contributions of all are respected and valued, regardless of gender.

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# THE INFLUENCE OF ATTITUDES TOWARDS GENDER EQUALITY ON THE PERCEPTION OF FEMALE ENTREPRENEURSHIP BARRIERS

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**Abstract:** *Purpose of this study is to determine the relationship between attitudes towards gender equality and the perception of women's entrepreneurship barriers.*

*Conducted through an online survey, the research included 166 respondents from the territory of the Republic of Serbia. SPSS software was used for the analysis, and different groups were compared based on attitudes towards gender equality.*

*It was observed that group affiliation regarding attitudes towards gender equality affects different perceptions of following barriers: financial barriers, lack of self-confidence and lack of social capital (networks, contacts). Groups that are more inclined to a gender equal society (second, third) perceive these barriers as more significant.*

*Another valuable finding was achieved by the test of independence which revealed that gender conditions group affiliation, through specific attitudes towards gender equality.*

*This paper enables policy makers to formulate adequate strategies aimed at greater participation of women in entrepreneurial activities, but also contributes to the further study of barriers.*

**Keywords:** *women entrepreneurship, barriers, gender equality, Republic of Serbia*

## 1. INTRODUCTION

With the development of society and human rights, the issue of gender equality is expanding. The traditional role of women as primarily mothers and housewives in modern society is changing (Radović & Marković, 2017), and they are increasingly involved in business processes on the market. Nevertheless, their confrontation of family and business life, and personal decisions and choices in the direction of one of the two, open up space for public condemnations, subjective interpretations and irreconcilable public attitudes regarding what a modern woman should and may do. These problems are characteristic exclusively for less developed countries like the Republic of Serbia, where patriarchal attitudes are still deeply rooted among part of the population. They are not necessarily bad, but unfortunately they have their own negative product - stereotypes, prejudices, various forms of discrimination and violence (Dokmanović, 2018). Therefore, gender equality is a priority of prosperous societies in which the two sexes are not conflicting parties, but equally important factors of a society whose interest is economic growth and general well-being (Čopić, 2016).

The United Nations (UN) recognized this by setting it as one of the Sustainable Development Goals (the fifth) and a significant element of achieving the others (Kim, 2017), for example 1. poverty reduction, 3. health, 8. decent work and economic growth, etc. (Manandhar et al., 2018). Despite the indisputable importance of gender equality for economic and social development, which is recognized by leading international institutions and is therefore officially "on paper" in various state acts of the Republic of Serbia, it has not been achieved in practice (Torlak, 2016). Although women make up about fifty percent of the working-age population, they exhibit higher rates of unemployment and inactivity (RZS, 2020). There is a wage gap between women and men, women are less likely to occupy managerial positions, there is gender segregation, i.e. the concentration of women or men in certain sectors (Babović & Petrović, 2021), and only every third entrepreneur is a woman (GEM, 2022).

The literature recognizes the untapped potential and importance of female entrepreneurship as a potential lever for achieving gender equality and thus the development of society as a whole. Female entrepreneurship is also a generator of economic development because it creates jobs (Todorovic et al.,

2016), encourages competitiveness (Pinkovetskaia et al, 2020) and improves the quality of life of the community. In many countries, however, women start businesses at a lower rate than men because they face more barriers than male entrepreneurs. According to the Agency for Business Registers (2023), out of a total of 300,250 active entrepreneurs, 33.7% are women entrepreneurs, while in 2011 this percentage was only 25.8% (Babović, 2012), and only 24.4% of women are directors or legal representatives (APR, 2023). Although entrepreneurs of both sexes face different barriers, female entrepreneurs have additional ones - barriers of a personal nature - lack of confidence (Pines et al, 2010) and inclination to risk (Shmailan, 2016), difficult access to financing sources (Lečić-Cvetković, Čurović & Rajković, 2022), inadequate education (Todorovic et al, 2016), lack of knowledge of regulations (UN Women), the double burden of family and professional life, and in developing countries like the Republic of Serbia, female entrepreneurs also face socio-cultural restrictions. Women in the Republic of Serbia in the business world are undeniably not treated equally and are discriminated against in various ways - individuals and institutions underestimate their knowledge and abilities, they receive lower salaries for the same position, the possibility of advancement to the highest management positions is hindered, the so-called "glass ceiling" (Babic & Hansez, 2021) etc. As much as women are limited in starting businesses, their societies do not benefit from the ambition, creativity and expertise of half the population.

The available literature recognizes the importance of all three components of this paper:

- 1) That the full participation of women in public and private life, i.e. the achievement of full gender equality, is of immense importance for the development of the economy and a prerequisite for the inclusion of a greater number of women in entrepreneurial activities
- 2) That the discrimination of women and their treatment as a subordinate gender due to patriarchal attitudes, i.e. socio-cultural barriers are a limiting factor of women's entrepreneurial activity
- 3) That knowing the barriers faced by female entrepreneurs is a condition for overcoming them and thus the development of female entrepreneurship

All of these elements are individually comprehensively processed theoretically - the importance of a gender-equal society, ways of achieving gender equality, socio-cultural barriers in entrepreneurship, the importance of overcoming barriers to encourage the development of female entrepreneurship, while primary research is focused either on the perception of barriers by female entrepreneurs (Babović, 2023) or on perceptions of attitudes about gender equality (Ćopić, 2020). The only attempt to combine these elements into one whole was realized by the Spanish study (Ilie et al., 2021). It shows that perceptions of inequality increase the gender gap even though specific and effective policy measures have been implemented in society, which ultimately affects women's entrepreneurial intentions, due to the fact that perceptions create psychological barriers. If perceptions do not change, the entrepreneurial intentions and initiatives of women will not increase either. However, its only focus is the impact of perceptions on socio-cultural barriers, and it is not clearly established whether attitudes towards gender equality influence the perception of other barriers, to what extent and in what way. Also, there are no studies on public perceptions of barriers and their (negative) impact on women's entrepreneurial activity. Having this in mind, research was launched to understand how attitudes towards gender equality affect the perception of barriers faced by female entrepreneurs when starting an entrepreneurial activity.

The goal of the research is to determine the relationship between attitudes towards gender equality and the perception of women's entrepreneurship barriers, that is, how specific barriers are perceived by those who favour a gender-equal society, as opposed to those who are in favor of male dominance.

Knowledge of these perceptions and their correlation with attitudes towards gender equality enables policy makers to formulate adequate strategies aimed at greater participation of women in entrepreneurial activities, but also to contribute to the further study of barriers, and thus a two-sided incentive for the development of female entrepreneurship.

## **2. MATERIALS AND METHODS**

With aim to conduct research that examines the influence of gender, age, education level and attitudes towards gender equality, a survey was designed and data was collected. The sample included 166 adult respondents from the territory of the Republic of Serbia.

The survey was conducted online from January 25 to February 24 using the Google Forms service. The sampling methods used were the convenience method, the "snowball" and the quota sample in order to achieve a sufficient number of respondents of both sexes, all age categories, levels of education, etc. to

ensure "quasi-representativeness" (Bešić, 2019). Although the sampling methods used belong to methods that are not based on probability, which is considered a non-representative sample, our sample covered different categories of respondents (a sufficient number), which provides the condition to apply analyses and tests dealing with group comparisons and thus reveal differences between different groups.

The research was preceded by an analysis of the available literature and the results of empirical research (of women entrepreneurs), on the basis of which a questionnaire was created. Participation in the research was voluntary, and the questionnaire was anonymous. The questionnaire distribution process was completed by sending the questionnaire to potential respondents via email, Facebook Messenger and Instagram using the author's private profile.

The questionnaire consisted of three parts.

The first part of the survey contained questions related to the characteristics of the sample. These questions were related to the gender, age and level of education of the respondents.

The second part of the survey referred to a set of eight attitudes (statements) about gender equality, where the respondents answered on a Likert scale how much they agreed with each of them.

The third part of the survey included questions about barriers that are considered to have the greatest negative impact on starting an entrepreneurial activity. These barriers have previously been studied in the available literature (Carranza et al., 2018; Poggesi et al., 2016; Schwab, 2018; Ministry of Economy of Republic of Serbia, 2018; Bobić, 2017; Vossenberg, 2013; Shmailan, 2016). Their perceived impact was measured on a Likert scale (1-strongly disagree, 5-strongly agree).

After the data were collected and encrypted, statistical analysis was performed using SPSS 25 statistical software. Descriptive statistics was performed to describe the sample, and then the studied groups were compared using Mann-Whitney and Kruskal-Wallis non-parametric tests to examine the impact of differences between groups on perceptions of barriers and proposed policy measures. Additionally, Chi-square test for independence was applied to explore the influence of different factors on a particular group affiliation regarding their attitudes towards gender equality. These tests were chosen as a suitable analytical tool offering reliability and robustness for non-normally distributed data. The Mann-Whitney test is used to examine differences between two independent groups on a continuous scale (Pallant, 2009), making it suitable for examining differences in attitudes towards gender equality between genders, as well as for post-hoc tests. The Kruskal-Wallis test is an upgrade of the Mann-Whitney, enabling the comparison of the results of three or more groups (Cleophas et al., 2016), that is, in our case, how perceptions vary in relation to a particular group affiliation regarding their attitudes towards gender equality. On the other hand, Chi-square test for independence is a non-parametric technique for investigating correlation between two categorical variables (Franke et al., 2012), which enables to explore if gender, age and education level have impact on a particular group affiliation regarding their attitudes towards gender equality.

Together, these three tests enable a clear and detailed understanding of the influence of various factors on attitudes towards gender equality, perception of barriers and the observation of differences between them, which contributes to scientific and practical conclusions.

The research set up in this way starts from three hypotheses:

H1 Overall attitudes towards gender equality influence the perception/preference of certain barriers.

H2 Respondents more inclined to a more equal society perceive socio-cultural barriers as particularly influential.

H3 Knowing the specific impact of attitudes towards gender equality on the perception of female entrepreneurship barriers is of particular importance when creating measures to overcome them.

A description of the sample is presented in Table 1.

**Table 1.** Characteristics of the sample of respondents (n=166)

		<b>N</b>	<b>%</b>
Gender	Men	66	39.8
	Women	100	60.2
Age	18-26	52	31.3
	27-35	57	34.3
	36-44	26	15.7
	> 45	31	18.7
	High school	30	18.1
Education	Three-year college	22	13.3
	University	67	40.4
	Master or PhD	47	28.3

As mentioned before, 166 respondents participated in the research, of which 60.2% were women. When we look at the age structure of respondents, the majority of respondents fall into the category of 27-35 years old (34.3%), but the participation rate of respondents aged 18-26 is also high (31.3%). When it comes to the level of education of the respondents, the largest number of respondents have completed university (40.4%), while as many as 28.3% of respondents have completed a master's or PhD. The smallest number of respondents has completed a three-year college (13.3%).

### 3. THE RESULTS OF THE RESEARCH

The second part of the survey consisted of 8 statements/attitudes towards gender equality. The results of each individual statement (1-5) are added to the total score. Scores from 17 to 40 were obtained which were then divided into three groups by equal percentiles based on scanned cases (Table 2).

**Table 2.** Binned total results of attitudes towards gender equality

	Group	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 (17-30)	60	36.1	37.7	37.7
	2 (30-34)	47	28.3	29.6	67.3
	3 (>34)	52	31.3	32.7	100.0
	Total	159	95.8	<b>100.0</b>	
Missing	System	7	4.2		

After dividing the respondents into three groups, the condition for applying the Kruskal-Wallis test has been met. A statistically significant difference was observed (table 3) in the perception of three barriers: the first (Chi-Square: 6.191,  $p=0.045$ ), the second (Chi-Square: 6.145,  $p=0.046$ ) and the seventh (Chi-Square: 9.774,  $p=0.008$ ). The highest average mean rank was exhibited by the third group for the first barrier (88.98 vs. 78.03 of second group vs 68.67 of first) and the seventh barrier (87.20 vs. 86.63 of second vs 64.64 of first), and by the second group for the second barrier (89.74 vs. 77.49 of third vs 69.31 of first). The third group, the most inclined towards gender equality, recognizes the importance of financial barriers and the lack of social capital (networks, contacts), while the second group, which exhibits moderate attitudes towards gender equality, perceives a lack of self-confidence as a crucial barrier.

**Table 3.** Kruskal-Wallis test comparing groups regarding attitudes towards gender equality

	bar1	bar2	bar3	bar4	bar5	bar6	bar7	bar8	bar9
Chi-Square	6.191	6.145	1.379	.794	.328	3.391	9.774	.823	.111
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.045	.046	.502	.672	.849	.184	.008	.663	.946

The subsequent (post-hoc) Mann-Whitney tests (tables 4 and 5) comparing the first and third group revealed a statistically significant difference for the first (Mann-Whitney U: 1086,  $p=0.012$ ) and the seventh barrier (Mann-Whitney U: 1069.50,  $p=0.007$ ). The third group exhibited a higher mean rank for these two barriers. However, the size of the impact ( $d<0.3$ ) is small according to Cohen (Pallant, 2009). The comparison of the second and third groups did not give any statistically significant result, while the comparison of the first and second groups (table 5) revealed a difference in the perception of the second ( $U=992$ ,  $p=0.011$ ) and the seventh barrier ( $U=974.50$ ,  $p=0.010$ ). The second group exhibited a higher mean rank compared to the first group for these two barriers, while the effect size is small.

**Table 4.** Post-hoc Mann-Whitney test comparing 1st and 3rd group

	bar1	bar2	bar3	bar4	bar5	bar6	bar7	bar8	bar9
Mann-Whitney U	1086.000	1327.500	1166.500	1405.500	1385.500	1424.500	1069.500	1457.500	1484.000
Wilcoxon W	2856.000	3097.500	2762.500	3235.500	2610.500	2649.500	2839.500	2783.500	3254.000
Z	-2.499	-.948	-1.042	-.598	-.232	-.135	-2.718	-.137	-.307
Asymp. Sig. (2-tailed)	.012	.343	.298	.550	.817	.892	.007	.891	.759

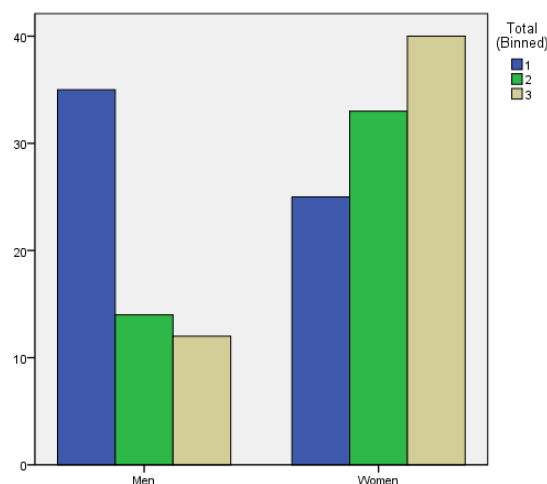
**Table 5.** Post-hoc Mann-Whitney test comparing 1st and 2nd group

	bar1	bar2	bar3	bar4	bar5	bar6	bar7	bar8	bar9
Mann-Whitney U	1195.500	992.000	1211.000	1350.000	1278.000	1118.500	974.500	1225.500	1353.500
Wilcoxon W	2965.500	2762.000	2201.000	2478.000	2989.000	2888.500	2744.500	2936.500	3123.000
Z	-1.099	-2.532	-.153	-.393	-.385	-1.803	-2.587	-.742	-.222
Asymp. Sig. (2-tailed)	.272	.011	.878	.695	.700	.071	.010	.458	.824

The Kruskal-Wallis and Mann-Whitney tests enabled us to compare the perceptions of female entrepreneurship barriers of different groups regarding their attitudes towards gender equality. However, it is unknown what factors determine particular group affiliation. For this purpose, we use the Chi-square test for independence to explore if gender, age and education level have an impact on a particular group affiliation regarding their attitudes towards gender equality. Examining of correlation between gender and group affiliation (table 6) discovered an unequivocal correlation (Chi-Square=16.72,  $p=0.000$ , Cramer's  $V=0.32$ ). It can be concluded that gender affects group affiliation, which can be clearly observed from chart 1. Men mostly belong to group 1, while women belong to group 3.

**Table 6.** Chi-square independence test between gender and group affiliation

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	16.720 <sup>a</sup>	2	.000
Likelihood Ratio	16.796	2	.000
Liner-by-Linear Association	14.959	2	.000
N of Valid Cases	159		

**Figure 1.** Bar chart of gender comparison regarding group affiliation

Crossing age (table 7) and level of education (table 8) with group affiliation did not give statistically significant results. Since  $p>0.05$ , we conclude that age and level of education do not affect certain group affiliation.

**Table 7.** Chi-square independence test between age and group

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.530 <sup>a</sup>	6	.202
Likelihood Ratio	8.524	6	.202
Liner-by-Linear Association	3.779	1	.052
N of Valid Cases	159		

**Table 8.** Chi-square independence test between level of education and group

	Value	df	Asymptotic Significance (2-sided)
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Paerson Chi-Square	12.038 <sup>a</sup>	6	.061
Likelihood Ratio	12.862	6	.045
Liner-by-Linear Association	9.047	1	.003
N of Valid Cases	159		

## 4. CONCLUSION

The research problem of this paper was to understand how attitudes towards gender equality influence the perception of barriers faced by female entrepreneurs when starting an entrepreneurial activity. In this regard, primary research was conducted with the aim of determining the correlation between attitudes towards gender equality and perceptions of female entrepreneurship barriers, that is, how concrete barriers are perceived by those more inclined to a gender-equal society, as opposed to those who are in favour of male dominance.

Valuable findings were obtained through this primary research. It was observed that group affiliation regarding attitudes towards gender equality affects different perceptions of barriers. The analysis revealed differences between the groups in the perceptions of three barriers: financial barriers, lack of self-confidence and lack of social capital (networks, contacts). As the first hypothesis H1 states: "General attitudes towards gender equality influence the perception/preference of certain barriers", it can be considered proven.

Groups that are more inclined to a gender equal society (second, third) exhibited higher mean ranks in the perception of certain barriers. The third group, which consist of respondents who have the most inclined attitudes towards gender equality, places distinct importance on financial barriers and the lack of social capital, while the second group emphasizes the lack of self-confidence. However, neither group perceives socio-cultural barriers as particularly influential. Consequently, the second hypothesis H2, which states: "Respondents more inclined to an equal society perceive socio-cultural barriers as particularly influential", must be rejected. Still, the test of independence between gender and group affiliation displayed a significant correlation between them. Gender conditions group affiliation, through specific attitudes towards gender equality. Perceptions of specific gender equality attitudes are not the subject of this paper, but it is obvious that this gender gap in perceptions of gender equality re-establish and encourages socio-cultural barriers in indirect way. What is particularly worrisome is that the sample consists primarily of university-educated young individuals, aged up to 36, from the territory of Belgrade. What kind of results would we get if we examined respondents with lower levels of education and from the provinces? As the attitudes of younger men are directed towards gender inequality, this implies that the reduction of the gender gap will not be achieved for decades.

Certainly, a deeper analysis is needed with a larger number of respondents, of different levels of education and background, who would answer more questions regarding gender equality and barriers in order to draw more radical conclusions, which also represents a limitation of this study. Another limitation is that a large number of respondents answered with "undecided" on the Likert scale, which reduces the value of study findings, so the use of a four-point Likert scale must be considered for further research.

This interwoven relationship between gender, attitudes towards gender equality and perceptions of female entrepreneurship barriers is of exceptional importance for policy makers. Knowing the differences in the perceptions of different groups regarding attitudes towards gender equality facilitates the conception of superior strategies and provides an incentive for the development of female entrepreneurship by overcoming barriers. This proves the third hypothesis H3, which states: "H3 Knowing the specific impact of attitudes towards gender equality on the perception of female entrepreneurship barriers is of particular importance when creating measures to overcome them.

Improving the conditions and perspectives of female entrepreneurship is a prerequisite for the participation of a larger number of women in entrepreneurial activities, and it can only be achieved by continuous monitoring of women's entrepreneurship state, researching its various aspects and solving perceived problems with incentive policy measures that affect the reduction of the gender gap in entrepreneurship.

Future research directions go in four directions. The first is to conduct a research on a larger sample in the Republic of Serbia, by adjusting the characteristics of the sample and the Likert scale based on the stated limitations of the study in order to strengthen or modify the findings. The second is that the research focuses on the socio-cultural framework in which women's entrepreneurial activity takes place, especially on the



perception of gender equality attitudes in order to analyse the indirect (limiting) impact on barriers and female entrepreneurship in general. The third is to conduct the same or similar research in neighbouring countries, and based on that, a cross-nation study of differences in perceptions of barriers. The last direction would summarize all the findings and focus on a concrete policy measures needed for complete participation of women in entrepreneurship, change of the socio-cultural context, empowering women and encouraging gender equality.

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# ASPIRING STUDENT ENTREPRENEURS AND STARTUP FOUNDERS IN SERBIA: COMPARISON OF PROFILES

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**Abstract:** *Entrepreneurial education plays a pivotal role in shaping the mindset of future leaders and innovators, especially in economies striving for innovation and growth like Serbia. This study investigates the entrepreneurial mindsets (EM) of students at the Faculty of Organizational Sciences in Serbia, and compares the sociodemographic characteristics of those with above-average EM with the typical profile of startup founders in the Serbian startup ecosystem. Findings reveal that while male students dominate, there's a significant proportion of females with strong EM. Additionally, students from business management backgrounds show higher involvement in entrepreneurial activities compared to their counterparts in information technology. The study underscores the impact of educational initiatives on fostering entrepreneurial engagement among youth, suggesting pathways for future research and educational interventions. However, generalizability is constrained by the sample's focus on the Faculty of Organizational Sciences, urging broader inclusion in future studies.*

**Keywords:** *entrepreneurial mindset, startup, founder, students, profile*

## 1. INTRODUCTION

Entrepreneurial education is a prominent and highly researched topic within the field of entrepreneurship (Bauman & Lucy, 2021; Jardim et al., 2021; Hassan et al., 2021; Cui & Bell, 2022; Motta & Galina, 2023; Alakaleek et al., 2023). Many authors try to identify in which way the educational process improves the affinity toward entrepreneurship and motivates students to start their businesses. In today's fast-changing global economy, nurturing an entrepreneurial mindset is crucial for societies. The increasing need for creative solutions to complex problems has highlighted the importance of entrepreneurial education in molding the thinking of tomorrow's leaders and innovators. Serbia is currently in the stage when it is essential to increase the number of startups to generate a foundation capable of producing successful and innovative companies, not only at the national or regional level but also at the global. The promotion of entrepreneurship is among the strategic goals of the Republic of Serbia (Jaško et al., 2023). Fostering the entrepreneurial mindset from a young age is one of the leading directions for generating more startups in future years.

In this research, we tend to measure the entrepreneurial mindsets of students of the Faculty of Organizational Sciences (in Serbian Fakultet organizacionih nauka – FON) in Serbia, identify those with a higher orientation towards entrepreneurship, and compare their profiles with the personal profiles of startup founders from Serbia. The first part of this paper provides a theoretical background and literature overview of the entrepreneurial mindset (EM) and general factors that determine the EM of students. After that, we describe the tool used for measuring the entrepreneurial mindsets of students and the statistical analysis applied for making comparisons. This is followed by the descriptive statistics of our sample and main research results. Afterward, we discuss the findings, provide concluding remarks, identify research limitations, and suggest directions for further research.

## 2. THEORETICAL BACKGROUND AND STAGE SETTING FOR THE RESEARCH

### 2.1. Entrepreneurial mindset and personal profile characteristics as its antecedents

Despite a growing interest in understanding the entrepreneurial mindset, there is no universally agreed definition of EM. One of the first definitions was offered by McGrath and MacMillan (2000, p. 15) who explain EM as the "ability to sense, act, and mobilize under uncertain conditions". Generally, scholars acknowledge

EM's distinct perspectives: cognitive - mental models, behavioral - actions for opportunities, and emotional - entrepreneurial feelings (Naumann, 2017; Kaplan & McGourty, 2020; Kuratko et al., 2021). Mathisen and Arnulf (2014) elaborate on mindsets as automated cognitive processes aiding task performance, molded by experience. These mental sets, influenced by experience, shape individuals' automatic and unconscious responses to stimuli, contributing to goal achievement without conscious awareness. To measure EM, these authors devised a scale assessing elaborating, implementing, and compulsiveness mindsets (Mathisen & Arnulf, 2014), which quantitatively measures mindset intensity across entrepreneurial activities' stages. The authors explain that the journey towards entrepreneurial actions begins with developing an elaborating mindset, transitioning to implementing a mindset focusing on practical engagement, and culminating in compulsiveness reflecting dedicated behaviors.

Drawing from Krueger and Brazeal's (1994) Entrepreneurial Potential Model, which assesses individual characteristics and environmental factors influencing entrepreneurial potential, research on antecedents of EM among students commonly investigates various sociodemographic variables. While specific findings vary, frequently explored antecedents include gender (João & Silva, 2018; Franceško et al., 2022), educational background, both curricular and extracurricular activities (Arranz et al., 2017; Rodriguez & Lieber, 2020; Motta & Galina, 2023), and students' prior experiences (Fayolle & Gailly, 2015; Chafloque-Céspedes et al., 2021).

On the other side, both practitioners and scholars in the field of entrepreneurship explore the profile of entrepreneurs/startup founders in terms of their sociodemographic characteristics, as its understanding is seen as pivotal for providing tailored support, predicting success, optimizing educational programs, and developing effective policies to foster entrepreneurship. Even though specific characteristics may differ, commonly investigated encompass: age and gender (Daspit et al., 2023; Vitaz et al., 2024), background, level, and field of education (Mihajlović et al., 2023; Cui & Bell, 2022; GSER, 2023; Vitaz et al., 2024); as well as previous entrepreneurial experience (Mihajlović et al., 2023; Kerr et al., 2018; GSER, 2023; Vitaz et al., 2024).

Based on both academic and practitioner sources, we identified the profile characteristics, as EM antecedents that will be analyzed in our research, and used for comparison between the students with high attitudes towards entrepreneurship and startup founders in the Republic of Serbia.

## **2.2. Setting the stage for the research**

The Faculty of Organizational Sciences, a part of the University of Belgrade, is one of the most modernly organized faculties in the region. During intense changes, FON has become a leading and referential educational and scientific institution in the fields of information systems and technologies, as well as management and organization. FON has always been following global trends and consequently was among the pioneers in the Serbian education ecosystem that has recognized the importance of innovation and entrepreneurship. The Research and Development Center at FON was launched in 2017, driven by the enthusiasm of faculty members united by a recognized need to create a stimulating and developmental environment for collaborative work at the faculty. This is a meeting place for students, teachers, mentors, partner organizations, businesses, and entrepreneurs, with the mission of gathering talents through unique cooperation programs, encouraging curiosity, arousing interests, and initiating first professional and entrepreneurial experiences. In this way, it strives to contribute to the quality of student life so that during their studies they follow professional trends and opportunities and are more ready to undertake future business ventures. The Development Strategy of the Faculty of Organizational Sciences 2023-2033 ([https://en.fon.bg.ac.rs/wp-content/uploads/2023/12/Strategija\\_FON\\_ENG.pdf](https://en.fon.bg.ac.rs/wp-content/uploads/2023/12/Strategija_FON_ENG.pdf)) identifies the promotion of entrepreneurship as one of the strategic goals. Accordingly, FON has founded a startup incubator that is partly financed by The Ministry of Science, Technological Development and Innovation of the Republic of Serbia. It was designed to develop and execute the programs that support startup foundation and growth. Since FON is recognized as a strong partner for supporting startups in the areas of business and product development, market analysis, and setting go-to-market strategy, it was offered a partnership by the Faculty of Agriculture, University of Belgrade to enhance technology transfer in the area of agriculture and agrotech. As a result, a joint startup incubator was established in 2023.

The entrepreneurial initiatives at FON can be divided into two general categories. The first one is directed towards academic staff. Through carefully designed programs FON teachers are being introduced into the startup world. They are given the perspective of the importance of this topic and basic knowledge that helps them introducing the entrepreneurial topics into their courses, but also to work with student startup teams. The second group of activities includes programs for student startups in the early development stages, where they are given the support of academic mentors and representatives of numerous stakeholders from the Serbian startup ecosystem and international entities.

Startup Scanner is an annual research and comprehensive report on the state of the startup ecosystem in the Republic of Serbia, carried out by the Digital Serbia Initiative within the "Venture an Idea" project, in cooperation with USAID and partners. FON is one of the key partners in this project. This research has started in 2020 and since then provided an annual report on various aspects that help in better understanding of the characteristics and opportunities in the Serbian startup ecosystem and provide useful information to anyone interested in startup companies and those who can contribute to their development. The report points out the key problems and shortcomings of the ecosystem, whose identification can facilitate and encourage the creation of activities and projects for improving and solving the identified problems.

One of the main topics covered by the report focuses on the profile of startup founders in Serbia. Various sociodemographic characteristics are being analyzed, such as their age, gender, level of education, field of education, and previous entrepreneurial experience. As stated above, different research recognizes those variables, among others, as the most relevant factors that determine the entrepreneurial mindset.

Therefore, our research explores those students' profile characteristics and compares them to profiles of founders from the local startup ecosystem to identify potential intersections, disparities, and underlying factors influencing entrepreneurial engagement among student populations.

### **3. METHODOLOGY**

For comparing the profiles of aspiring student entrepreneurs and startup founders in Serbia we use two datasets. The first one, related to the students, is generated from our original research. The second one, that provides the insights into the profiles of entrepreneurs and startup founders, is publicly available from Startup Scanner.

Our research was conducted on a sample of 201 students from the Faculty of Organizational Sciences. The study aimed to determine the sociodemographic characteristics of student profiles that have been found to exhibit a more developed entrepreneurial mindset compared to the average values of the observed population. To assess the level of entrepreneurial mindset, a scale developed by Mathisen and Arnulf (2014) was used. This scale measures the level of EM through three components (elaboration, implementation, and compulsiveness) using 25 statements measured on a Likert five-point scale. To reduce the dimensions of the questionnaire, exploratory factor analysis was conducted on the collected data using the Principal Component Method, resulting in a Kaiser-Meyer-Olkin value of 0.941, exceeding the recommended threshold of 0.6 (Kaiser, 1970), and a factorable correlation matrix with a significant Bartlett test of sphericity (Sig. < .000). The analysis revealed three factors with eigenvalues above 1, which accounted for 48.4% of the factor solution. This implies that 48.4% of the information is contained in the 25 items distributed across three factors (elaboration, implementation, and compulsiveness). Nominal values, i.e., arithmetic means of all corresponding items, were calculated for all generated factors. To determine the baseline that divides the observed sample into parts with below-average and above-average EM, the arithmetic mean for each of the examined components was used (Elaboration 3.5, Implementation 2.8, and Compulsiveness 2.6). Accordingly, 62 students had an above-average entrepreneurial mindset, whose profiles were further analyzed in subsequent steps.

The analysis of the results at the level of the observed subsample was conducted through an examination of basic sociodemographic characteristics used within the framework of the Startup Scanner across the entire startup ecosystem in Serbia: age, gender, level of education, field of education, and previous entrepreneurial experience. Additionally, a comparative analysis of the characteristics of FON students with above-average EM and respondents within the Startup Scanner was presented. This comparative analysis aims to demonstrate the extent of overlap or deviation between the observed groups of respondents.

### **4. RESULTS**

In the observed group of respondents, a larger proportion (58%) were male, compared to 42% female respondents. Considering that the respondents were undergraduate and master's students, it can be inferred that in most cases, the age range was between 19 and 24 years. The observed subsample was equally divided between master's and undergraduate students. Unlike the gender composition of the selected subsample, a significantly larger difference between the observed groups was found in the variable field of education. Specifically, 77.4% of respondents with a more pronounced EM were from the fields of Business management, while the minority, 22.6%, were from the field of Information Systems and Technologies. Within the Business management specialization subsample, a larger number of male respondents were present, while in the Information Systems and Technologies specialization, the female population was more represented. Analyzing

the extent to which respondents were exposed to entrepreneurship-related topics, it can be concluded that more than 80% of respondents had exposure to entrepreneurial topics in the selected subsample. This somewhat describes the higher values of the measured EM factors. Considering students' field of education, the results reveal that students in the Business Management specialization had more experience with entrepreneurship-related topics through the completion of entire courses in this area (41%), compared to students in the IT field of study, of whom only 14% had such experiences.

Taking into account the age of the respondents, their professional engagement was analyzed from two perspectives: their professional engagement during their studies and their initiation or participation in the development of a specific entrepreneurial venture. One-third of the respondents (30%) had not been professionally engaged up to the time of this research, while an almost equal number were occasionally engaged, temporarily engaged, or full-time employed (24.2%, 22.6%, and 22.6%, respectively). No significant differences were identified when these data were observed by gender or field of study. On the other hand, considering involvement in the development of an entrepreneurial venture, 58% of the subgroup respondents had not participated in entrepreneurial activities, while the rest were either part of an entrepreneurial venture (25.8%) or had independently initiated their own venture (16%). Looking at it from a gender perspective, a higher proportion of the female population had participated in entrepreneurial activities (40%) compared to the male portion of the observed subsample (36.1%). Additionally, it was concluded that respondents in the Business Management specialization were significantly more involved in entrepreneurial activities (45.8%) compared to those in the IT specialization (28.5%). When examining the relationship between work experience and entrepreneurial behavior, it is concluded that respondents from the observed subgroup who engage in part-time and full-time employment during their studies participate in entrepreneurial ventures, either independently or as part of a team, in two-thirds of cases.

## **5. DISCUSSIONS AND CONCLUSIONS: COMPARISON WITH THE LOCAL ECOSYSTEM**

An ambitious, innovative, and experienced team of founders can be pivotal for the success of a startup, often surpassing the importance of the initial idea itself (Vitaz et al., 2024). The Startup Scanner 2024 (Vitaz et al., 2024) reaffirmed previous findings, indicating that startup founders in Serbia are predominantly male, aged between 30 and 39, possess higher education degrees, and are presently located in Serbia. The acquisition of pertinent knowledge for startup establishment and management primarily stems from prior work experience. According to the 2024 Startup Scanner, 82.8% of startup founders are male, while female founders constitute 17.2% of startups in Serbia.

Conversely, an analysis of the entrepreneurial attitude among a subsample of observed students suggests that while male students comprise the majority, their proportion slightly exceeds half of the observed subset. This prompts inquiry into why fewer women engage in entrepreneurial pursuits post-graduation, despite certain entrepreneurial mindset components being more pronounced among female students compared to their male counterparts. This discrepancy could potentially be attributed to recent initiatives targeting the student population to foster entrepreneurial thinking and behavior, with the ecosystem effects expected to manifest in the future. Considering the European average of female founders (15.5%) and the presence of 18% female founders in top European ecosystems (Vitaz et al., 2024), it is evident that global efforts are required to encourage and support women in becoming startup founders, a recognition reflected in various EU support programs tailored to this demographic.

The analysis by the Startup Scanner reveals that the largest cohort of startup founders in Serbia falls within the age bracket of 30 to 39 years, comprising 41% of respondents. Founders aged between 40 and 49 constitute 25.5% of the total, whereas individuals aged 15 to 29 represent founders in 28.2% of startups, marking a significant increase compared to 2022 and 2023 (19.5% and 19.2%, respectively). Only 5.3% of founders are aged over 50, indicating a growing trend of youth involvement in entrepreneurial endeavors. Over the past three years, the Faculty of Organizational Science has implemented several programs aimed at promoting and supporting entrepreneurial initiatives among young individuals in this age group. Best practice examples from FON have been extended to other higher education institutions in Serbia through collaborative efforts focused on fostering entrepreneurial orientation among academic staff and instilling an entrepreneurial mindset and behavior within the student population. The rise in the number of young founders underscores the success of programs aimed at cultivating entrepreneurial thinking and providing early-stage support within the startup ecosystem.

Analysis of the educational background of startup founders in Serbia conducted by the Startup Scanner reveals that the majority hold higher education qualifications, with a significant proportion possessing master's degrees (35.1%). Additionally, 29.9% hold bachelor's degrees, 8.0% have doctorates, 10.6% have high school

diplomas, and 10.1% are currently pursuing bachelor's degrees. With 85% of startup founders in Serbia possessing or pursuing higher education, comparisons with the surveyed sample remain relevant for analysis and discussion, indicating that conclusions drawn from the observed sample can be interpreted within the context of assessing the impact of higher education contributions to startup ecosystem development. Furthermore, the Startup Scanner indicates a slight increase in the number of student founders, with 10.6% enrolled in bachelor's programs and 1.6% in master's programs, compared to the previous report, suggesting an increasing attraction of younger entrepreneurs to the startup ecosystem.

Regarding the field of study of startup founders, the Startup Scanner analysis highlights that nearly two-thirds have technical backgrounds, while slightly over 20% come from business backgrounds. However, proportions in the observed subset are inversely proportional. Nevertheless, given the disparity within the overall surveyed sample, a deeper analysis was conducted, revealing that around 35% of students with technical backgrounds exhibit above-average EM, compared to approximately 30% of students with business backgrounds. Thus, while attitudes toward entrepreneurship are more pronounced among those with technical backgrounds within the observed student population, they do not align to the extent suggested by the Startup Scanner at the national level in Serbia. This underscores the need for initiatives to further encourage business-oriented students to engage in startup founding or be recognized as essential components of future founding teams.

According to the Startup Scanner, the majority of startup founders (72.9%) attribute their key knowledge for founding and managing startups to previous work experience. Within the observed subset, even 70% of students with above-average EM were occasionally, temporarily, or fully employed, aligning with the average profile of startup founders in Serbia. Analyzing the previous startup experience of founders, the Startup Scanner indicates that 33.5% of founders in Serbia were previously engaged in another startup. In our subset, however, 42% of students with above-average entrepreneurial mindsets had prior entrepreneurial experience as founders or co-founders. This further confirms that current initiatives within academia and the ecosystem as a whole have contributed to a higher engagement of younger populations in entrepreneurial ventures. This represents a key mechanism for the continued advancement of the startup ecosystem in Serbia, transitioning from an activation phase to a globalization phase.

Although the generation gap between the two analyzed groups is evident, it does not represent a limitation of this research since sociodemographic characteristics of the respondents are compared, rather than their career and professional experience. The results can be useful for students with entrepreneurial aspirations to direct their careers during their studies, in terms of choosing a focus and engaging in additional activities, in a direction that can increase their chances of entrepreneurial success. They can also be beneficial to participants in the entrepreneurial and innovation ecosystem who support startups in the early stages of development, by better assessing the chances of success when evaluating teams, and by providing teams with appropriate mentorship and educational support through the activities they implement.

The main limitation of this study lies in the sample, which, although it encompassed students with technical and business backgrounds within the leading institution for these fields in Serbia, thus reducing the potential influence of other variables such as location, teaching methods, or available programs and initiatives, could still be expanded to include other faculties and universities in Serbia. In addition to this direction, future research could also focus on the identified gaps between the profiles of startup founders and students with above-average EM, primarily concerning gender distribution and educational fields.

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# DETERMINING THE IMPORTANCE OF EXTERNAL CRITERIA FOR THE ENROLLMENT IN THE FACULTY OF ORGANIZATIONAL SCIENCES

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**Abstract:** *The paper provides an answer to the question of which external criteria are important for the decision to enroll in the Faculty of Organizational Sciences (FOS). The answer was obtained through a literature review and surveying of freshmen. The most significant criteria identified are as follows: Accreditation/recognition of the university, Type of degree awarded, Language of instruction, Quality of education, Quality of teaching, Companies where graduates are employed and, Employment opportunities after graduation. The conclusion offers guidelines on how the research findings can be utilized in practice, primarily for branding the faculty, and also provides recommendations for further research.*

**Keywords:** *learning analytics, academic analytics, university branding, faculty branding*

## 1. INTRODUCTION

In the corporate world, data accompanying business processes have long been recognized as a valuable resource and subject to detailed analysis. With increased investments in the education sector, there has been a growing need to monitor the outputs of the educational process (Illeris, 2003), leading faculties to explore the opportunities offered by data-driven approaches. An example of such an approach in educational institutions is Academic Analytics (AA), a process of analyzing data collected at universities aimed at supporting decision-making processes and reporting to stakeholders, as well as Learning Analytics (LA), which focuses on the learning process rather than educational processes.

Initially, AA and LA approaches posed unfamiliar challenges for educational institutions, but today, with critical evaluation of their possibilities and limitations, they are increasingly being utilized. Analytics, once considered a new and unfamiliar tool potentially leading to oversimplification (Campbell, DeBlois & Oblinger, 2007), has quickly become part of the natural environment. However, attention is drawn to the potential dangers of decision-making on such a significant social issue as education, based on data processing results using machine algorithms. Faculty orientation towards analytics may imply an excessive focus on quantitative indicators of success, such as the institution's position on rankings. The dominant focus of faculties on their public reputation may potentially lead to conformity, strengthening mechanisms of control and discipline, and consequently causing stress among staff and students (Morrish, 2020).

Although conformity is not in line with the social function of educational-scientific institutions, it cannot be ignored that the reputation and image of a faculty are important factors for students when deciding which faculty to choose (Cabrera, La Nasa, 2000). Another reason prompting faculties to proactively manage their public image is the longstanding dedication of business schools to brand building. Some faculties acknowledge the necessity of branding efforts, while others hold an ambivalent or even cynical attitude towards it (Frandsen, Gotsi, Johnston, Whittle, Frenkel & Spicer, 2018). On the other hand, research results involving 20,045 American high school students using a specific internet platform for choosing colleges show that future students are dissatisfied with how faculties contact them. Respondents report that the electronic messages

sent by faculties are perceived as spam, and 27% of them believe that faculties communicate too similarly in such communications (Patch, 2022).

The application of analytics in educational institutions should create a basis for developing new practices that contribute to achieving the organization's goals and strategies (Norris, Baer, Leonard, Pugliese & Lefrere, 2008). One such goal for a faculty could be enrolling the highest-ranked candidates. On the other hand, candidates aim to enroll in their desired faculty, so in reality, even if they are well-ranked after the entrance exam at one faculty, they may enroll in another. The aim of this paper is to determine the importance of external criteria that prospective students consider when making decisions about choosing a faculty. A preliminary list of criteria has been determined through a literature review, and the importance of these criteria for candidates has been established by freshmen's opinions on each criterion. The practical implications of this paper are directed towards providing a basis for informed decision-making at the faculty and university levels regarding ways to attract candidates through potential adjustments to enrollment policies and practices.

## 2. CHOOSING A FACULTY

Choosing a faculty is a highly complex process, especially when considering the constraints on candidates' freedom of choice. For example, the decision to choose a faculty for some students is largely defined by their life circumstances or innate characteristics. Numerous studies examine the selection of faculties and issues related to race, class, ethnicity, gender, etc. (Freeman, 1999; Cho, Hudley, Lee, Barry & Kelly, 2008; Chapman, Contreras & Martinez, 2018). Although understanding the complexity of this choice is important, this paper focuses on factors that the faculty can directly influence through various actions, namely external criteria. Generally, we can speak of three phases of faculty decision-making, where the first phase involves the development of a tendency to enroll in a faculty, the second involves gathering information about faculties, and finally, the choice of faculty is made (Hossler & Gallagher, 1987). In all phases, which interweave, numerous factors influence decision-making, and the following chapter provides a brief overview of the literature on this topic.

Factors influencing the choice of faculty can generally be divided into two groups: student characteristics and external influences. It is necessary to emphasize that in such general divisions, socio-economic status (Chapman, 1981), along with family income, parental education, etc. (Han, 2014), are considered under student characteristics, which do not necessarily represent individual characteristics but primarily the social group to which they belong. Further division of external influences includes: the influence of significant individuals in the environment, faculty characteristics, and faculty efforts to communicate with prospective students (Chapman, 1981), each of which is discussed in the following chapter.

When students were asked to choose one person from their environment who helped them the most in choosing a faculty, 43% mentioned their parents (Chapman, 1981). Numerous studies focused on the role of parents in choosing a faculty indicate that even in later years, not much has changed in this regard (Bers & Galowich, 2002; Workman, 2015; Flaster, 2018). Cabrera & La Nasa (2000) believe that parental characteristics, parental experience of studying, and parental involvement in the decision-making process significantly influence the final decision. Additionally, parents influence decision-making through the financial and emotional support they provide to prospective students.

Factors grouped under faculty characteristics include aspects such as location, infrastructure, available study programs, available financial aid, i.e., all relatively permanent characteristics of educational institutions (Chapman, 1981). This group can also include the faculty's ranking on international lists as it represents a relatively permanent characteristic (even when there are fluctuations in an institution's position on rankings, they are usually minor changes). Only 11% of students consider faculty ranking to be influential, with candidates from families with college education and higher incomes being concerned. In contrast, 60% of respondents claim that faculty ranking is not important at all (Clarke, 2007).

Future students report that, of all the ways faculties communicate with them, the most influential on the final decision are campus visits, open house events, followed by the official faculty website and brochures issued by the faculty (Constantinides & Zinck Stagno, 2011). According to the same study, the influence of social media is at the bottom of the list, but there are findings that students, through questionnaires, expressed little or no influence of social media on their choice of faculty, only to reveal through in-depth interviews that they gathered significant information about the faculty and studying precisely "online" (Shields & Peruta, 2019). A novelty in this influence group, especially for Serbia, is specialized platforms for choosing faculties. Research on users of such platforms (Patch, 2022) shows that high school graduates deciding on their choice of faculty

are mostly influenced by advice received at school or from faculty advisors, recommendations from family or friends, but also information from specialized web platforms.

A study conducted among prospective students in Turkey focused on obtaining information and considered as many as 13 criteria and sub-criteria (Ürer Erdil, Tümer, Nadiri & Aghaei, 2021), but did not consider so-called "internal criteria," making it comparable to our research. The AHP method was applied in the study. Since a total of 13 criteria and 48 sub-criteria were ranked in the research, they will not be commented on in the text but are presented in Table 1 according to rank.

Table 1: Overview of the Importance of Criteria and Subcriteria for Choosing a Faculty Obtained by Applying the AHP Method (Ürer Erdil, Tümer, Nadiri & Aghaei, 2021)

<b>Criteria</b>	<b>Determined Importance Criterion</b>	<b>Subcriteria</b>	<b>Determined Importance Subcriteria</b>
Employment Opportunities During Studies and Scholarships	0.123	Availability of Financial Aid and Scholarships in the Institution	0.614
		Opportunities for Part-time Jobs	0.209
		Opportunities for Summer Jobs	0.178
Local Living Conditions	0.109	Cost of Living in the Region	0.511
		Culture and People's Lifestyle	0.313
		Interaction of Locals with Students	0.118
		Climate	0.058
College Admission Requirements	0.104	College Admission Requirements	0.615
		Results from Previous Entrance Exams	0.385
Accommodation, Accessibility, and Sales Facilities	0.102	Campus Appearance	0.272

		Accommodation	0.187
		Sales Facilities	0.168
		Private Rooms or Apartments	0.138
		Campus Student Life	0.128
		Public Transportation	0.106
Academic Programs	0.098	Curriculum	0.29
		Specific Academic Courses Offered	0.219
		Representation of Academic Content in the Program	0.194
		Course Content	0.149
		Representation of Practical Content in the Program	0.148
Campus Facilities	0.096	Computer Labs	0.257
		Cultural Activities	0.252
		Availability of University Medical/Healthcare	0.207
		Campus Security	0.155
		Library	0.066

		Sports Facilities	0.064
Social Life	0.075	Social Activities	0.565
		Extracurricular Activities	0.435
Recognition of the Institution in an International Context	0.065	Interaction between Domestic and International Students	0.511
		Academic Reputation of the Institution	0.286
		University Rankings	0.203
Medium of Instruction and Educational Issues	0.062	Availability of Specific Academic Programs (Field of Study)	0.327
		Accreditation/Recognition of the University	0.249
		Type of Degree Awarded	0.237
		Language of Instruction	0.187
Quality	0.054	Faculty (University Teaching Staff)	0.439
		Quality of Education	0.219
		Quality of Teaching	0.176
		Teaching Method	0.166

Interaction between Staff and Students	0.049	Small Lecture Groups	0.457
		Staff-to-Student Ratio	0.294
		Program Quota	0.249
Employment Opportunities After Graduation	0.032	Companies Where Graduates are Employed	0.395
		Employment Opportunities After Graduation	0.359
		Institution's Ability to Employ Graduates	0.246
Reputation of the Institution	0.032	Number of Students at the University	0.236
		Presence of Students from the Interviewee's Country at the University	0.192
		Alumni Association	0.173
		Presence of International Students at the University	0.142
		Years of Experience in Higher Education	0.14
		Opinions of University Alumni or Current Students	0.117

### 3. METHODOLOGY

#### 3.1. Sample

The sample consists of 111 students who enrolled at the Faculty of Organizational Sciences in 2023. At the time of participating in the study, all respondents were first-year students at the mentioned faculty. Males comprised 54.1% of the sample, while females comprised 45.9%. A total of 46.4% of the respondents were born in Belgrade, 20% in central Serbia, and 15.5% in western Serbia. A significantly smaller number of respondents came from other regions of Serbia, while a total of 4.5% of respondents were born outside of Serbia.

### 3.2. Considered External Criteria

Based on the review of the field of decision-making in choosing a faculty prepared in the second chapter of the paper and in consultation with experts from the Faculty of Organizational Sciences, we defined a list of 73 relevant external criteria for our study, as presented in Table 2.

Tabel 2: Considered External Criteria for Choosing a Faculty

Criteria	Labels
Availability of financial aid and scholarships at the institution	V1
Opportunities for part-time jobs	V2
Opportunities for summer jobs	V3
Cost of living in the city	V4
Culture and lifestyle of people in the city	V5
Interaction of locals with students	V6
Climate	V7
Admission requirements for the college (average grade, number of subjects in the entrance exam...)	V8
Results from previous entrance exams	V9
Appearance of the college	V10
Quality of accommodation in student dormitories	V11
Stores nearby	V12
Private rooms or apartments (price, quality, availability)	V13
Social life at the college	V14
Public transportation	V15
Curriculum and program	V16
Subjects/exams at the college	V17
Representation of academic content in the program	V18
Content of subjects (topics covered)	V19
Representation of practical content in the program	V20
Computer labs	V21
Cultural activities	V22
Availability of university medical/healthcare	V23
Campus safety	V24

Library/Reading room	V25
Sports facilities	V26
Extracurricular activities	V27
Interaction between local and foreign students	V28
Academic reputation of the institution	V29
University and college rankings	V30
Availability of specific academic program (study area)	V31
Accreditation/recognition of the university	V32
Type of degree awarded	V33
Language of instruction	V34
University teaching staff	V35
Quality of education	V36
Quality of teaching	V37
Teaching methods	V38
Class size	V39
Staff-to-student ratio	V40
Program quota (how many students are enrolled)	V41
Companies where graduates are employed	V42
Employment opportunities after graduation	V43
Institution's ability to employ graduates	V44
Alumni association	V45
Presence of international students at the university	V46
Years of operation of the college	V47
Alumni or current student opinions	V48
Exchange programs	V49
Collaboration/agreements with industry	V50
Practical work in teaching	V51
Elective courses	V52
Academic qualifications of staff	V53
Communication skills of staff	V54
Staff connections with industry	V55
Friendly behavior of staff	V56
Research activity of staff	V57
Textbooks	V58
Easy access to materials	V59



Parents' opinion of the college	V60
Teachers' opinion of the college	V61
Siblings' opinion of the college	V62
Friends' opinion of the college	V63
Family's opinion of the college	V64
Availability of master's programs	V65
Distance learning options	V66
College appearance in television and newspapers	V67
College presence on social media	V68
College website	V69
Visit of college representatives to high school	V70
Prospective student visit to college	V71
Public perception of the college	V72
Student organizations	V73

### 3.3. Data Collection and Processing

All data were collected using Google Forms, where respondents evaluated the influence of each of the 73 variables on their choice of faculty. The assessment was expressed on a five-point Likert scale. The data were processed using R Studio. The analyses applied included calculating measures of central tendency, ANOVA, and T-test. ANOVA was used to test whether there is a statistically significant difference in average ratings for each external criterion based on the region the respondents come from, while the T-test was used to test based on the gender of the respondents.

## 4. RESULTS

Below are the results for all variables with an average rating greater than 4 (Table 3). The variables rated as most important are: Employment opportunities after graduation (V43), Accreditation/recognition of the university (V32), Quality of education (V36), Companies where graduates are employed (V42), Subjects/exams at the college (V17), Quality of teaching (V37), Institution's ability to employ graduates (V44), Easy access to materials (V59), Type of degree awarded (V33), Practical work in teaching (V51), Curriculum and program (V16), Representation of practical content in the program (V20), University and college rankings (V30), Teaching methods (V38), Academic reputation of the institution (V29), Friendly behavior of staff (V56), Content of subjects (topics covered) (V19), Computer labs (V21), Language of instruction (V34), Social life at the college (V14), Communication skills of staff (V54), and Admission requirements for the college (V8).

Table 3: Variables Rated as Most Important

	Mean	SD
V43	4.784	0.594
V32	4.658	0.694
V36	4.631	0.687
V42	4.559	0.709
V17	4.550	0.795

V37	4.505	0.808
V44	4.505	0.785
V59	4.423	0.949
V33	4.364	0.974
V51	4.342	0.939
V16	4.315	0.934
V20	4.270	0.884
V30	4.261	0.871
V38	4.261	0.902
V29	4.252	0.939
V56	4.180	1.029
V19	4.171	1.035
V21	4.108	1.065
V34	4.082	1.220
V14	4.055	1.132
V54	4.054	1.119
V8	4.036	1.026

Below are all the variables where the median rating was 5 (Table 4), namely: Curriculum and program (V16), Subjects/exams at the college (V17), Representation of practical content in the program (V20), Accreditation/recognition of the university (V32), Type of degree awarded (V33), Language of instruction (V34), Quality of education (V36), Quality of teaching (V37), Companies where graduates are employed (V42), Employment opportunities after graduation (V43), Institution's ability to employ graduates (V44), Practical work in teaching (V51), and Easy access to materials (V59).

Table 4: Variables with the Highest Median Values

	Median
V16	5
V17	5
V20	5
V32	5
V33	5
V34	5
V36	5
V37	5
V42	5
V43	5
V44	5

V51	5
V59	5

Variables that meet both criteria (mean and median rating above 4) are:

- V32: Accreditation/recognition of the university
- V33: Type of degree awarded
- V34: Language of instruction
- V36: Quality of education
- V37: Quality of teaching
- V42: Companies where graduates are employed
- V43: Employment opportunities after graduation.

For the obtained mean values, appropriate analyses were conducted to examine whether the demographic characteristics of the respondents are related to the answers they provided. It was found that gender and the region from which the respondents come are indeed related to the answers they provided, but only for certain criteria.

By applying the T-test, statistically significant differences were found in relation to gender for the following variables: V49 (p-value= 0.003921), V26 (p-value= 0.004622), V59 (p-value=0.03029), and V30 (p-value= 0.03085). Specifically, for Exchange programs, Sports facilities, Easy access to materials, and University and college rankings. By applying ANOVA, statistically significant differences were found in relation to the region from which the respondents come for the following variables: V13 (p-value= 0.0000258), V11 (p-value= 0.001116), and V48 (p-value= 0.00344). Specifically, for Private rooms or apartments (price, quality, availability), Quality of accommodation in student dormitories, and Alumni or current student opinions.

#### 4. CONCLUSION

The research results indicate that students who choose to enroll at the Faculty of Organizational Sciences are guided by the idea of employability, quality learning experiences (quality of education and teaching, inclusion of practical content in teaching, friendly attitudes of staff, communication skills of staff, etc.), and the institution's recognition in the academic context (accreditation and recognition of the faculty, type of degree awarded, university and college rankings, etc.). Additionally, it was noted that the criterion "Sports facilities" is more important to male students, while "Exchange programs", "University and college rankings", and "Easy access to materials" are more important to female students. Furthermore, criteria such as "Private rooms or apartments (price, quality, availability)", "Quality of accommodation in student dormitories", and "Alumni or current student opinions" are more important to students coming from outside Belgrade.

Such findings should be compared with the decisive criteria for candidates applying to other technical faculties, and then generally to faculties at the University of Belgrade, University of Niš, and University of Novi Sad. Conducting similar research at other educational institutions would provide a clearer insight into the specificity of the criteria order observed among candidates at FOS. It is possible that the order of criteria depends not on the faculty for which students are applying but on other factors, such as the instability of the socio-economic situation, which consequently encourages high school students to emphasize the role of employability.

Regardless of whether the observed criteria order is specific to candidates at a given faculty, the results can be used for informed decision-making regarding attracting candidates through adaptation of enrollment policies and practices. Activities accompanying the announcement of calls for enrollment in undergraduate studies involve presenting the faculty to high school seniors. Such activities can be adapted to the results of our research so that candidates receive information that matches their priorities. For example, potential candidates can be provided with statistics on the employment of graduated students or career stories of individuals who

have completed the given faculty. Similarly, candidates can be informed about the opportunity to gain professional experience through involvement in student organizations or within internal faculty projects.

The examples mentioned should be taken with caution as they represent one of the potential courses of action. The key is that information about the most important enrollment criteria for faculty can be used to adapt enrollment policies and practices and monitor the effects of such adaptations. A potential direction for further research, apart from a larger sample and the application of more advanced methods, involves considering different outcomes against which the effects of the implemented adaptations can be tracked.

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# STUDENTS' APPROACHES TO E-LEARNING AND QUALITY OF E-LEARNING

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**Abstract:** *The efficiency of an e-learning system cannot be achieved without a high level of system quality, which attracts students and increases their usage of the e-learning system. This is particularly important when students are studying from home. The results of the study offer new insights and suggestions for decision-makers to ensure the successful usage and adoption of e-learning systems. The questionnaire was distributed among the students of the Faculty of Organizational Science at the University of Maribor. It included students of all genders and all levels of study—bachelor's, master's, and doctoral students. We measured students' approaches to e-learning against various factors that hinder or improve their studies, thereby assessing the quality of e-learning. Our study examines how the factors of e-learning influenced the perceived quality of e-learning.*

**Keywords:** *students, e-learning, quality, approaches*

## 1. INTRODUCTION

Educational institutions have a fundamental responsibility to prioritize the education of successive generations of students. The effectiveness of education hinges on the outcomes produced by the system. It's crucial to assess the quality of education from the perspective of students, who are the ultimate beneficiaries of the service. Maintaining high quality is essential to foster the growth of knowledge and skills. Governments should guarantee the quality of education to equip students for a globally competitive environment. Moreover, educational institutions should not solely concentrate on imparting knowledge but also engage students in research and innovation endeavors (Elumalai et al., 2020).

Many universities traditionally conduct their educational activities in physical lecture halls (Ebner et al., 2020). Nonetheless, the emergence of the Internet and associated technologies has revolutionized conventional teaching approaches, ushering in modern methods of instruction. Technological advancements have transcended the confines of traditional classrooms, facilitating continuous learning opportunities. Internet technologies enable distance learning and facilitate communication between students and educators at any time of the day (Elumalai et al., 2020).

In response to these developments, numerous universities and colleges have embraced online education and established virtual classrooms. These platforms allow students to pursue their education even without being physically present in traditional classrooms (Elumalai et al., 2020).

E-education, distance learning, and online learning are distinct terms that all refer to the broader concept of e-learning (Alqahtani & Rajkhan, 2020). This form of learning isn't a new phenomenon; it was already present in educational institutions prior to the pandemic. E-learning encompasses various technological learning methods, including websites, learning portals, and video conferencing (Abdullah & Ward, 2016; Haghshenas, 2019; Mohr Satar et al., 2020).

Alqahtani and Rajkhan (2020) define e-learning as a collection of applications and processes that utilize electronic media and tools to deliver education and training. Mustafa et al. (2021) describe online learning as the utilization of network technologies to create, adopt, and seamlessly implement learning processes globally, at any time and location. According to this definition, online learning incorporates a blend of different technologies, with computers playing a central role. Computers possess the capability to tailor learning processes to individual needs and existing knowledge, while also documenting progress and providing feedback on misconceptions. Therefore, the accessibility of computer systems is crucial in online education.

E-learning is experiencing steady growth year after year, driven by numerous advantages such as flexibility, accessibility, and cost-effectiveness (Almaiah et al., 2020). These systems have become integral components of modern university curricula (Abdullah & Ward, 2016). Embracing a holistic approach to learning, e-learning empowers educators to select diverse teaching methods, fostering both individual and social knowledge development (Mustafa et al., 2021). E-learning platforms aid teachers in effectively managing, planning, implementing, and monitoring the learning and teaching processes. Many of these platforms are freely available, ensuring uninterrupted learning even during pandemics (Almaiah et al., 2020). E-learning systems introduce innovative learning methods, enabling educators to deliver instructional content through various mediums such as video, audio, images, animations, and text. They also offer online learning environments and timely feedback mechanisms (Abdullah & Ward, 2016). There are two primary types of e-learning: asynchronous and synchronous. The categorization depends on the level of interaction between students and professors. Synchronous e-learning necessitates real-time interaction between students and professors through tools like Zoom. Asynchronous e-learning, on the other hand, allows students to access and use the system independently, as seen in platforms like Moodle (Mustafa Suliman Oun Alla, 2013).

The aim of our study was to answer the following research question:

RQ: How do the factors of trust, digital culture, self-efficacy, and quality of e-learning system influence the perceived quality of e-learning?

## 2. THEORETICAL REVIEW

The successful utilization of e-learning systems is influenced by several key factors, including trust, digital culture, self-efficacy, and the quality of the e-learning system itself (Almaiah et al., 2020). These factors play crucial roles in either enhancing or impeding distance learning experiences. In our research, we aim to explore how these factors specifically impact the overall quality of e-learning.

### 1. Trust factors

Trust, as per Salloum et al. (2019), refers to an individual's willingness to embrace vulnerability based on positive expectations regarding another person's intentions or behavior, within the context of risk and interdependence. It's a pivotal factor in enhancing the adoption of e-learning systems. This trust element encompasses aspects like information privacy, system security, and reliability. Moreover, universities should regularly update their security measures to safeguard against viruses, enhancing users' trust in the system. Trust on the Internet itself is a critical element in fostering trust among users. By providing efficient and thoroughly vetted e-learning systems that prioritize safety and accessibility, universities can instill trust and encourage greater adoption of these systems among students (Almaiah et al., 2020). Thus, the following hypothesis is proposed:

*H1: There is a positive relationship between trust and the perceived quality of e-learning.*

### 2. Digital culture factors

Digital culture is a concept that describes how technology and the internet are shaping human interaction. It encompasses our behavior, thinking, and communication within society. Digital culture includes aspects such as the internet, artificial intelligence, security, privacy, and policy, and often involves using social media as our primary mode of interaction (Fotopoulou & Thornham, 2020). It plays a crucial role in increasing the acceptance rate of e-learning systems among students. The first factor contributing to this is the enhancement of ICT literacy and skills among e-learning users, which can lead to increased usage of the system. The second factor is the transformation of society into an e-society. The third factor is connecting students through social media, which is the most effective way to reach them and encourage the adoption of e-learning systems (Almaiah et al., 2020). Therefore, the following hypothesis is proposed:

*H2: There is a positive relationship between digital culture and the perceived quality of e-learning.*

### 3. E-learning system quality factors

The quality of the e-learning system is a critical determinant of user satisfaction and influences their perceptions and acceptance of technological innovations. Conversely, a major factor leading to distrust and subsequent reduced usage of e-learning systems is often attributed to their poor quality (Salloum et al., 2019). These systems may encounter barriers related to accessibility, availability, and usability, particularly among individuals with lower proficiency in Internet usage. Hence, it's imperative to assess at the university

level, whether all students have equal opportunities to utilize the e-learning system (Almaiah et al., 2020). Thus, the following hypothesis is proposed:

*H3: There is a positive relationship between E-learning system quality and the perceived quality of e-learning.*

#### 4. Self-efficacy factors

Self-efficacy, defined by Abdullah & Ward (2016) as an individual's belief in their capability to perform a specific task, is a crucial factor in determining the adoption of e-learning systems in educational settings. Training programs play a significant role in ensuring high performance for both students and professors. Therefore, universities should offer training initiatives to enhance participants' IT skills. Additionally, raising awareness is a key element that motivates students to engage with e-learning systems, ultimately enhancing their self-efficacy (Almaiah et al., 2020). Thus, the following hypothesis is proposed:

*H4: There is a positive relationship between self-efficacy and the perceived quality of e-learning.*

#### 5. Quality of e-learning

E-learning significantly enhances accessibility for students and is often enjoyable. It enables professors to enhance the presentation of content and activities in online environments while also providing the ability to record content for students to revisit. Both students and professors find e-learning user-friendly and convenient, fostering stronger connections between them. Additionally, e-learning facilitates two-way communication and collaboration among students, further enriching the learning experience (Elumalai et al., 2020).

### 3. METHODOLOGY AND RESEARCH RESULTS

The study focused on students from the Faculty of Organizational Sciences who participated in online classes, including undergraduates (1st, 2nd, and 3rd year), master's students (1st and 2nd year), and doctoral students (1st, 2nd, and 3rd year). A self-made questionnaire with three parts was used for data collection, with the third part, evaluating the quality of e-learning, adapted from Elumalai et al. (2020).

The questionnaire employed a 5-point Likert scale (5-strongly agree, 4-agree, 3-neutral, 2-disagree, 1-strongly disagree). The first part gathered demographic information such as gender and level of study. The second part included four variables (trust, digital culture, self-efficacy, and e-learning system quality) with various statements. The third part focused on the quality of e-learning, featuring six statements for direct effect.

Data collection was conducted using the 1ka online survey platform, ensuring no missing data as all questions were mandatory. Statistical analysis was performed using SPSS at a significance level of 0.05. Before analyzing the results, the reliability of the questionnaire was assessed. Questionnaire reliability refers to its consistency in yielding the same results when measuring the same properties repeatedly. In other words, if an individual were to complete the questionnaire multiple times under identical conditions, consistent results should be obtained (Field, 2005).

Cronbach's alpha is most used as a measure of reliability. Cronbach's alpha values range from 0 to 1, generally higher values mean better construct reliability (Tavakol & Dennick, 2011).

**Table 1:** Calculation of the reliability coefficient

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of items
0,914	0,921	21

The value of the Cronbach's coefficient is 0.914. Since its value is greater than 0.8, we can conclude that the scale is reliable enough.

**Table 2:** Sample characteristics - Gender

Gender	Respondents	Percent
Men	56	44,1
Women	71	55,9
Total	127	100,0



The questionnaire was completed by students of the Faculty of Organizational Science who were engaged in distance learning. Out of 127 responses, 56 were from male students and 71 from female students, as detailed in Table 2. The largest proportion of responses (37%) came from students in their 2nd year of undergraduate studies. Following them were master's students, with 23% from the 1st year and 25% from the 2nd year. 9% of responses were from students in their 3rd year of undergraduate studies, while only 2% were from first-year students. As anticipated, doctoral students accounted for the smallest share of responses.

The average values of the answers (and standard deviations) in the sample, referring to the key factors influencing the successful use of the e-learning system, are shown in Table 3.

**Table 3:** Average values and standard deviations of the answer

	Mean	Std. Deviation
The e-learning system is trustworthy.	4,11	0,88
The e-learning security system is regularly updated to protect the system from viruses.	3,96	0,91
E-learning resources are effective and transparent.	4,07	0,94
Using the e-learning system is safe and free.	4,19	0,94
All learning activities through the e-learning system are carried out legally based of the Privacy Act.	4,30	0,79
<b>Trust</b>	4,13	0,69
I am offered the opportunity to increase ICT (information and communication technology) literacy and skills to use e-learning.	3,94	1,00
The faculty society is changing into an e-society.	3,81	1,01
I am regularly informed about what is happening at the faculty through various social media.	4,07	0,91
<b>Digital culture</b>	3,94	0,72
With the help of an e-learning system, I can achieve better learning outcomes.	3,75	1,07
In the e-learning system, I see the point of using it only for distance learning.	3,12	1,24
The e-learning system is friendly and easy to use.	4,13	0,90
The e-learning system meets my expectations and I do not see any risk in it.	3,93	1,01
<b>E-learning system quality</b>	3,73	0,72
I can participate in various training programs in the field of IT skills.	3,70	1,03
When I use an e-learning system I feel confident and motivated.	3,87	1,02
I feel capable of fulfilling all the obligations in an e-learning system.	4,28	1,10
<b>Self-efficacy</b>	3,95	0,79
E-learning raises the level of students' attainment and makes it enjoyable.	4,15	0,97
E-learning improves the professor's presentation of contents and activities.	3,21	1,01
E-learning enhances the bonding between students and professors.	2,41	1,22
E-learning is student-friendly and easy to use.	4,13	0,93
E-learning enables the professor to record the lecture and listened again by students.	3,62	1,44

E-learning provides two-way communication and cooperation among students.	3,20	1,31
<b>Quality of e-learning</b>	<b>3,45</b>	<b>0,84</b>

The first factor we predicted to influence the use of e-learning is trust. We checked this with five statements. For the most part, student agree with the statements, so the average of the trust related responses is 4.13. We predicted that digital culture also influences e-learning. We tasted this assumption with tree statements and found that students agree with them. The average response to digital culture is 3.94. The third factor that is supposed to affect e-learning is the e-learning system quality. We found that the students agree with three statements. With the statement: In the e-learning system, I see the point of using it only for distance learning, they neither agree nor disagree. The average response for this factor is 3.73. Self-efficacy is the four factor that is expected to affect e-learning. We checked it with the help of three statements. We found that students agree with them. The average response to self-efficacy is 3.95. The dependent variable quality of e-learning was checked with the help of six statements. With statements: E-learning raises the level of students' attainment and makes it enjoyable; E-learning is student-friendly and easy to use; E-learning enables the professor to record the lecture and listened again by students, students agree. Students are neutral on two statements: E-learning improves the professor's presentation of contents and activities; E-learning provides two-way communication and cooperation among students. Students disagree that E-learning enhances the bonding between students and professors. The average of answers related to the quality of e-learning is 3.45.

**Tabel 4:** Pearson Correlation and hypothesis Testing

		Perceived quality of e-learning	Hypothesis Testing
Trust	Pearson Correlation	0,681**	r=0.681
	Sig. (1-tailed)	0,000	p<0.05
	N	127	H1 accepted
Digital culture	Pearson Correlation	0,577**	r=0.577
	Sig. (1-tailed)	0,000	p<0.05
	N	127	H2 accepted
E-learning system quality	Pearson Correlation	0,616**	r=0.616
	Sig. (1-tailed)	0,000	p<0.05
	N	127	H3 accepted
Self-efficacy	Pearson Correlation	0,676**	r=0.676
	Sig. (1-tailed)	0,000	p<0.05
	N	127	H4 accepted

\*\*. Correlation is significant at the 0.01 level (1-tailed).

The results indicate that trust has a positive relationship with the quality of e-learning ( $r=0.681$ ,  $p<0.05$ ); therefore, H1 is accepted. The findings revealed that digital culture has a positive relationship with the quality of e-learning ( $r=0.577$ ,  $p<0.05$ ); therefore, H2 is accepted. The results expressed that the e-learning system quality has a positive relationship with the quality of e-learning ( $r=0.616$ ,  $p<0.05$ ); therefore, H3 is accepted. The values indicate that the self-efficacy has a positive relationship with the quality of e-learning ( $r=0.676$ ,  $p<0.05$ ); therefore, H4 is accepted. The results indicate that all variables have a positive relationship with the perceived quality of e-learning; therefore, all hypotheses are accepted.

#### 4. CONCLUSION

The research findings indicate that factors such as trust, digital culture, self-efficacy, and e-learning system quality have a positive correlation with the overall quality of e-learning. When students trust in e-learning and believe in their ability to excel in this environment, the quality of e-learning improves. Moreover, maintaining a conducive culture and high-quality e-learning systems is crucial for elevating the overall quality of e-

learning within the faculty. Achieving a high level of system quality is particularly essential for enhancing the efficiency of e-learning systems, thereby increasing student usage, especially in times when students are studying remotely from home. These insights from the study provide valuable guidance for decision-makers aiming to ensure successful usage and adoption of e-learning systems. However, it's important to note that this study is limited to students of the Faculty of Organizational Science at the University of Maribor. Further research is necessary to refine and expand upon these findings. Nonetheless, this study offers an initial glimpse into students' acceptance of e-learning, laying the groundwork for future investigations and improvements in this area.

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# IMPACT OF RECENT AMENDMENTS TO THE LAW ON EMPLOYMENT OF FOREIGN NATIONALS ON THE SERBIAN LABOUR MARKET

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**Abstract:** *This paper examines the impact of recent legislative changes concerning the employment of foreign nationals on Serbia's labor market. The amendments, implemented in early 2024, aim to streamline administrative procedures, extend the duration of temporary residence permits, introduce biometric permits, and reduce the time required to obtain permanent residency. By facilitating the entry and integration of foreign workers, these reforms are designed to enhance Serbia's attractiveness as a destination for global talent and investment. The analysis explores the potential economic and cultural benefits, such as increased foreign investment and a more diverse workforce, while also addressing the challenges of implementation, including the need for efficient administrative processes and potential social integration issues. The findings suggest that these legislative changes could significantly boost Serbia's economic development by creating a more dynamic and inclusive labor market.*

**Key words:** *Employment law, Foreign nationals, Serbia labor market*

## 1. INTRODUCTION

Prior to February 2024, the labor market in Serbia was designed to protect natives at the detriment of foreigners in terms of employment by companies both local and international. With regulation laws such as to employ a foreigner, a company needed to submit a request at the national employment service to conduct a market search to see if there is not a Serbian with the same competency who is currently unemployed at the time of the job opening.

For every foreigner employment, the company had to hire two more Serbians regardless if they had the necessary qualification or not for the position. Investigation as proven that the social-demographic background, and other attributes such as host language, duration of the stay was able to some extent to explain the low participation of migrant as a labor force and the income differences.

In recent years, Serbia has taken significant steps to modernize its legislation regarding the employment of foreign nationals, aiming to become a more attractive destination for global talents and investors. The latest amendments to the law on the employment of foreign nationals, which came into effect at the beginning of 2024, represent an important milestone in this direction. These reforms include the simplification of administrative procedures, the extension of temporary residence permits, the introduction of biometric permits, and the shortening of the period required to obtain permanent residency. This paper aims to analyze the impact of these legislative changes on the labor market in Serbia, examining how the new regulatory framework facilitates the entry and integration of foreign workers into the Serbian economy. Special attention will be given to the potential economic and cultural benefits these reforms bring, as well as the challenges that may arise during their implementation.

## 2. CURRENT STATE OF THE LABOR MARKET IN SERBIA

The labor market in Serbia has been experiencing several significant changes, influenced by both domestic economic conditions and global trends. As of 2024, Serbia faces a dual challenge of relatively high

unemployment rates, particularly among the youth, and a shortage of skilled labor in certain high-demand sectors such as IT, engineering, and healthcare. According to the Statistical Office of the Republic of Serbia, the unemployment rate has shown a gradual decline in recent years, reaching around 10.3% in 2023. However, youth unemployment remains substantially higher, indicating a mismatch between the skills possessed by the young workforce and the demands of the labor market.

Economic growth has been steady, with a GDP growth rate of approximately 3.5% annually, driven by sectors such as manufacturing, services, and IT. Foreign direct investment (FDI) has played a crucial role in this growth, with Serbia becoming an attractive destination for investors due to its strategic location, favorable tax policies, and skilled labor force. The labor market still struggles with issues such as low wages compared to EU standards, a high informal economy, and brain drain, where skilled professionals seek better opportunities abroad.

### **3. ANALYSIS OF POLICIES BEHIND LEGISLATIVE CHANGES**

Recent amendments to the law on the employment of foreign nationals in Serbia are part of a strategic policy change aimed at solving several key issues:

Attracting foreign talent:

- The aim of this policy is to increase the attractiveness of Serbia as a destination for qualified foreign workers. There is a growing need to fill skills gaps in critical sectors such as technology, engineering and healthcare. By simplifying the administrative process and extending the duration of the residence permit, Serbia aims to attract and retain global talent.

Increasing economic competitiveness:

- Improving Serbia's competitive position on the global market.
- Simplified procedures and longer residence permits reduce the administrative burden on companies, making it easier for them to hire and retain foreign workers. This, in turn, improves the business environment and attracts more foreign investment.

Promoting social integration:

- Facilitate the social and economic integration of foreign nationals.
- By providing a clearer path to permanent residence and enabling more categories of foreign nationals (such as students and volunteers) to work, the policies aim to more fully integrate foreign nationals into Serbian society and economy (Fragomen).

### **4. PROPOSAL FOR MEASURING THE IMPACT OF LEGISLATIVE CHANGES**

To effectively measure the impact of the recent legislative changes on the labor market in Serbia, a comprehensive and multi-faceted approach is required:

- **Employment Rates** - track changes in the employment rates of foreign nationals before and after the implementation of the new laws.
- **Skill Gap Analysis** - measure the extent to which the skill gaps in key sectors are being filled by foreign workers.
- **Economic Indicators** - monitor FDI inflows, GDP growth, and the overall productivity of sectors that heavily employ foreign nationals.
- **Employer Satisfaction Surveys** - conduct surveys among businesses to gauge their satisfaction with the new administrative processes and the availability of skilled labor.
- **Employee Satisfaction Surveys** - survey foreign workers to understand their experiences with the new regulations and their overall satisfaction with living and working in Serbia.
- **Social Cohesion Index** - develop an index to measure the level of social integration of foreign nationals, including their participation in community activities, language proficiency, and social connections.
- **Permanent Residency Applications** - track the number of foreign nationals applying for and obtaining permanent residency under the new rules.
- **Processing Times** - measure the average time taken to process work and residence permits before and after the reforms.

- Cost Analysis - assess the cost savings for both the government and applicants resulting from the streamlined processes.

The Law on Amendments to the Law on the Employment of Foreigners ("Official Gazette of the RS", No. 62/2023) prescribe a new procedure for issuing a single permit for temporary stay and work of foreigners in the Republic of Serbia, which starts to be applied from February 1, 2024.

Based on the aforementioned laws, the following were published in the "Official Gazette of RS", number 6/2024:

- Rulebook on the approval of temporary residence.
- Rulebook on submission of applications for permanent residence electronically.
- Rulebook on issuing a single permit for temporary residence and work of a foreigner.

We have the following data from the National Employment Service of the Republic of Serbia:

- In 2022, a total of 35,180 work permits were issued to foreign nationals, of which 5,919 permits were issued to women.
- In 2023, 52,184 work permits were issued, of which 9,877 were issued to women.
- The largest number of foreign workers in 2022 came from China, Turkey, Russia, India, Cuba, Macedonia and Ukraine.
- In 2023, the most work permits were issued to citizens of China, Turkey, Russia, India, Cuba, Nepal and Sri Lanka.

#### 4.1. Current employment situation in Serbia

As of the end of 2023, the employment rate in Serbia saw notable shifts due to legislative changes. Prior to these changes, the employment rate was steadily increasing, reaching approximately 49.1% in Q4 2022. After the implementation of the new law on the employment of foreign nationals in early 2024, the rate continued to improve slightly, indicating positive reception and potential job market expansion. By Q2 2024, the employment rate had risen to around 50.3%, reflecting increased job opportunities and the facilitation of foreign employment procedures (Statistical office of the Republic of Serbia).

#### 4.2. Analysis of policies that lead to changes in the law

Recent amendments to the Law on the Employment of Foreign Citizens in Serbia were driven by several key policy objectives, such as compliance with European Union standards: Serbia aims to harmonize its legislative framework with EU norms, so that foreign citizens, especially those from the EU, made it easier to work and stay in Serbia.

Economic digitization - The government has advocated digitization in various sectors. This includes the introduction of online applications for work and residence permits, reducing red tape and speeding up processing times.

Attracting foreign talent is reflected in the fact that the amendments also focus on attracting highly qualified experts, investors and digital nomads. This is in line with global trends of using foreign talent to stimulate economic growth and innovation (National employment service of Serbia).

**Table 1:** Amendments to the Law (

Amendments	
The primary modification implies the full digitization of the process. Applications for a combined work and residence permit will now be processed through a single portal called "e-Administration". This implies electronic submission of the entire application, together with all the necessary documents.	
1.	Once approved, the unique work residence permit will be issued as a biometric document. It is important to note that the regulations regarding the single portal, electronic visa and single work permit entered into force on February 1, 2024. However, most of the other provisions listed in the Law on Employment of Foreigners entered into force in August. 4, 2023.

- A unified permit, which was previously issued for up to one year, is now issued for a period of up to 3 years. Additionally, it can be extended for the same duration, contingent upon the reasons for which temporary residence is granted. The deadline for renewing existing temporary residence permits has been extended as well. Foreigners residing in Serbia can now apply for renewal until the expiration date of their previously valid permit, as opposed to the previous requirement of applying 30 days before expiration. Furthermore, the competent authority is now mandated to decide on the request for issuing a unified permit within 15 days of the submission of the proper request, which is a significant reduction from the previous processing time of up to 60 days.
- 2.
  3. Under the updated law, individuals can now apply for permanent residence after three continuous years of approved temporary residence, a reduction from the previous requirement of five years. The law introduces harsher penalties for legal entities, ranging from 500,000 to 2 million dinars.
  4. Additionally, foreigners who fail to comply with legal obligations will face fines ranging from 50,000 to 150,000 dinars for the offense.

#### 4.3. - Employment Registration

In the first quarter of 2024, the total number of employed individuals reached 2,364,580. Out of this figure, 1,898,894 were employed by legal entities, 414,777 were entrepreneurs and their employees or self-employed individuals, and 50,909 were registered individual agricultural producers (Statistical office of the Republic of Serbia, 2024).

Compared to the first quarter of 2023, the overall employment rate increased by 14,833 individuals, representing a 0.6% rise. Specifically, employment with legal entities increased by 11,079 individuals (0.6%), while entrepreneurs and self-employed individuals rose by 8,239 individuals (2.0%). However, the number of registered individual agricultural producers (farmers) decreased by 4,485 individuals (8.1%).

In contrast, compared to the previous quarter, the total number of employed individuals decreased by 3,124 individuals, representing a 0.1% decline. This decrease primarily stemmed from a reduction in employment among entrepreneurs and self-employed individuals, which decreased by 2,145 individuals (0.5%). Additionally, the number of registered individual agricultural producers (farmers) decreased by 942 individuals (1.8%), while employment with legal entities experienced a minor decrease of 37 individuals.

The number of foreigners employed in Serbia was 37,521. This number includes foreign nationals who are employed by domestic legal entities, entrepreneurs or as individual agricultural producers. Compared to the same period of the previous year, that number increased by 1,257 persons, which represents an increase of 3.5%. These data indicate a continuous growth in the employment of foreigners in Serbia during the first quarter of 2024.

In the same period, the total number of work permits for foreign citizens in Serbia was 8,632. This represents an increase of 1,184 permits compared to the same period last year, which is a growth of 15.9%. These data indicate a continuous demand for foreign workers in Serbia.

**Table 2:** Registered employment

	Number of employed	Changes relative to the previous quarter		Changes relative to the same quarter of the previous year	
		differences	indices	differences	indices
Registered employment - total	2364580	-3124	99.9	14833	100.6
Workers engaged in long-term and temporary/occasional employment within legal entities.	1898894	-37	100.0	11079	100.6
Individuals operating as entrepreneurs, along with their employees, and those independently conducting business activities, encompassing both long-term and temporary/occasional employment arrangements.	414777	-2145	99.5	8239	102.0
Persons registered as independent agricultural producers, commonly referred to as farmers.	50909	-942	98.2	-4485	91.9

Source: Statistical office of the Republic of Serbia, 2024. Retrieved from <https://www.stat.gov.rs/en-us/vesti/statisticalrelease/?p=15105&a=24&s=2402>

Unemployment denotes the proportion of the labor force that is not employed but actively seeking work. (Macrotrends):

- In 2022, Serbia's unemployment rate stood at 8.68%, marking a decrease of 1.38% compared to 2021.
- Conversely, in 2021, the unemployment rate was 10.06%, reflecting a 1.05% increase from 2020.
- In 2020, the unemployment rate was 9.01%, demonstrating a decrease of 1.38% from 2019.
- Lastly, in 2019, the unemployment rate in Serbia was 10.39%, indicating a decrease of 2.34% from 2018.

## 5. MEASURING THE IMPACT OF LEGISLATIVE CHANGES

In order to measure the impact of the new law on the labor market in Serbia, the following steps can be taken:

- Employment rate analysis - monitor changes in employment rates before and after the implementation of the law using quarterly data from the Republic Institute of Statistics.
- Statistics of foreign workers - track the number of foreign nationals who apply for and receive work permits, comparing these figures before and after the legal amendments.
- Employment by Sector - assess which sectors are seeing the most significant increase in foreign workers, identifying trends in industry demand.
- Economic indicators - assess broader economic indicators such as GDP growth, foreign investment inflows and innovation indices to correlate with the inflow of foreign experts and investors.

By systematically analyzing these indicators, the effectiveness of the law in improving the labor market in Serbia and attracting foreign talent can be comprehensively assessed.

## 6. DISCUSSION

The recent legislative changes to Serbia's employment laws for foreign nationals represent a significant development aimed at boosting the country's economic competitiveness and addressing critical labor market needs. These reforms, which include simplifying administrative procedures, extending temporary residence permits, introducing biometric permits, and shortening the period required for permanent residency, are designed to make Serbia a more attractive destination for skilled foreign workers and investors.

By increasing economic competitiveness, the processes of submitting applications for work and residence permits are being streamlined, Serbia is reducing bureaucratic barriers that previously hindered foreign investment and the employment of qualified foreign workers. This is likely to increase foreign direct investment (FDI) and attract multinational companies looking for a more efficient regulatory environment (National Employment Service of Serbia).

The labor market in Serbia faces significant skills shortages in sectors such as IT, engineering and healthcare. The new laws facilitate the entry of qualified professionals into these critical sectors, potentially bridging the skills gap and increasing overall productivity and innovation in the economy. This is key for sectors that have high growth potential and are key to the economic development of Serbia.

The positive trend in employment rates, with an increase from 49.1% in Q4 2022 to 50.3% in Q2 2024, suggests that legislative changes are beginning to bear fruit. The ability to attract and retain foreign talent not only fills current vacancies but also contributes to overall economic growth by increasing the labor force participation rate and reducing unemployment. The move towards digitalization of the work and residence permit application process aligns with global e-government trends and improves the efficiency of administrative procedures. This modernization effort makes Serbia more attractive to technology experts and companies, further integrating the country into the global digital economy (Zunic's Law).

## 7. CONCLUSION

Upon examining the impact of recent amendments to the law on the employment of foreign nationals on the labor market of Serbia, it is evident that these changes have had a significant positive impact. Improved procedures for employing foreign workers have provided greater flexibility to employers while simultaneously enhancing the protection of employees' rights. This has resulted in increased interest from foreign investors in investing in Serbia, contributing to a more dynamic development of the labor market. However, it is crucial to



continue monitoring and evaluating these changes to ensure they contribute to the long-term prosperity and stability of the Serbian economy and labor market.

It is important to highlight that these amendments to the law on the employment of foreign nationals have contributed to creating a more favorable business environment in Serbia, attracting new talents and skills to the country. This is crucial for enhancing the competitiveness of the Serbian economy in the global labor market. Moving forward, continuous monitoring of the implementation of the law and adjusting regulations to align with the needs of the labor market will be essential to sustaining the positive effects of these changes.

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# **ORGANIZATIONAL STRATEGY AND HYBRID PROJECT MANAGEMENT**

# YOUTH PROJECT ENGAGEMENT: THE ROLE OF EDUCATIONAL INSTITUTIONAL SUPPORT

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**Abstract:** *This paper aims to investigate the role of academic institutional support in extracurricular activities among youth (18-24 years old) in the Republic of Serbia. The research has been conducted among 1638 high school and university students. Kruskal-Wallis and Mann-Whitney tests were used to analyze differences between groups. Key research results indicate that extracurricular activities such as student project engagement and participation in student organization plays crucial roles in students' life. Students who participate more in projects perceive higher levels of educational support compared to their counterparts. The research results could be useful to create adequate policy recommendation and programs among higher institutions in Serbia.*

**Keywords:** *youth, project, higher education institution, support*

## 1. INTRODUCTION

Institutions of higher education play an important role in society, because they should provide support programs to young people through continuous youth engagement. Effective student services help young people to focus their energy to the right curricular and extracurricular activities. Proactive systems in higher education should anticipate the future needs of the labor market and the expectations of young people to create educational curricula and programs of extracurricular activities. Such programs should certainly include student projects, participation in student organizations, participation in debates, solving case studies, participation in different types of student competitions. As it was said in the movie *"Field of dreams"* the main idea comes from sentence *"If you build, they will come"*. The key idea in education should support system development that will help students to achieve their full potentials.

Particularly during the transition from secondary schools to universities, dedicated onboarding educational programs should be established to support young individuals effectively. Providing clear communication of requirements towards first-year students contributes to a lower degree of dropout of young people as well as a better transition of young people to higher levels of study and inclusion in academic life (Mah & Ifenthaler, 2019). Penn-Edwards & Donnison (2011) emphasize the first week of their study because that's when they get resources, presentations and the most important instructions and materials, as well as tips for studying. Rubio et al. (2017) in their study analyzed resource disparities among first-generation students in higher education, to assess their experiences and obstacles. The key results show that education costs and lack of information about higher educational institution were important obstacles, while the majority received funding from family.

## 2. STUDENT EXTRACURRICULAR ENGAGEMENT

Extracurricular engagement is important for young adults, to gain their first experiences through involvement in projects, connect with others and have more fulfilling daily obligations. Bundick (2011) analyzed the connection between high school extracurriculars and positive youth development, with a focus on the personal meaningfulness of such engagement. The key research results indicate that participation in student leadership and volunteering was correlated with positive development.

Similar conclusion got the Martinez et al. (2016) in their research, how participation in numerous extracurricular activities (sports, clubs, and arts) and combinations thereof is linked to high school students' perceptions of school climate, finding that involvement in extracurriculars is associated with more positive perceptions, though the effects vary by activity type and combination, suggesting that extracurricular participation may contribute to fostering a positive school environment. Forneirs et al. (2015) emphasize that participants engaged in sports-related activities showed greater developmental effects and higher levels of school engagement. Also,

this research suggests that parents and adult mentors should encourage and endorse students' participation in a variety of extracurricular endeavors, including high school sports, to promote positive youth development.

Social relationships, including those with teachers, peers, and parents, have been consistently associated with students' life satisfaction, problem behaviors, and school bonding, underscoring the importance of interpersonal connections in enhancing overall well-being (Pham & Murray, 2015). Additionally, personal growth initiatives and intentional efforts toward academic success have been linked to higher levels of life satisfaction among university students (Noor et al., 2020). Bjelica & Jovanović (2016) found that extracurricular among students influence their life satisfaction, and higher education institution should promote wellbeing programs for youth.

### 3. INSTITUTIONAL SUPPORT

Paek et al. (2021) suggests enhancing undergraduate Computer Science students' GPA with an Innovation, Competency, and Experience score, utilizing a web-based platform called RadGrad to encourage and reward involvement in extracurricular activities, showcasing the potential value of a holistic assessment for promoting career-relevant experiences alongside traditional coursework. Institutions can effectively support students in their extracurricular activities by providing mentorship programs, implementing evaluation and incentives systems, and offering career advising programs to mitigate potential negative impacts on academic performance (Almasry et al., 2017). Additionally, collaboration with student organizations and stakeholders can simplify and identify student engagement in relevant activities promoting leadership development (Janke et al., 2016).

Enriching the student experience and promoting overall success can be achieved by stimulating transferable skills through extracurricular programs and project engagement (Huffman et al., 2019). Furthermore, other research indicates a positive correlation between extracurricular activities and academic performance, recognized to reduced academic stress and enhanced learning productivity (Utomo et al., 2019). These activities provide avenues for talent cultivation, interest exploration, and unique qualities development, contributing to personal growth and academic success. However, effective management and organization of extracurricular activities by educational institutions is crucial for their successful implementation (Fitri & Setyowati, 2018).

### 4. METHODOLOGY

The research is supported by the Science Fund of the Republic of Serbia, within the project "Engagement in Academic Achievements and Extracurricular Activities as Predictors of Life Satisfaction among High-school and University Students - SHINE". The preparation of this study has been done by three institutions: Institute of Economic Sciences in Belgrade, University of Belgrade, Faculty of Organizational Sciences and Faculty of Law. This study aimed to investigate the influence of institutional support measures on youth in the Republic of Serbia, with a focus on their engagement in student projects. Participants in the research included high school and university students aged 15 to 24 residing in the Republic of Serbia. This study presents a segment of the extensive research findings, specifically focusing on the participation of young individuals in projects (Table 1). The data analysis was conducted using SPSS 29.0 software, utilizing Cross-tabulations to illustrate demographic findings across the levels of institutional support. Furthermore, the Kruskal-Wallis and Mann-Whitney tests were applied to determine any significant differences.

**Table 1:** Sample characteristics of engineering students

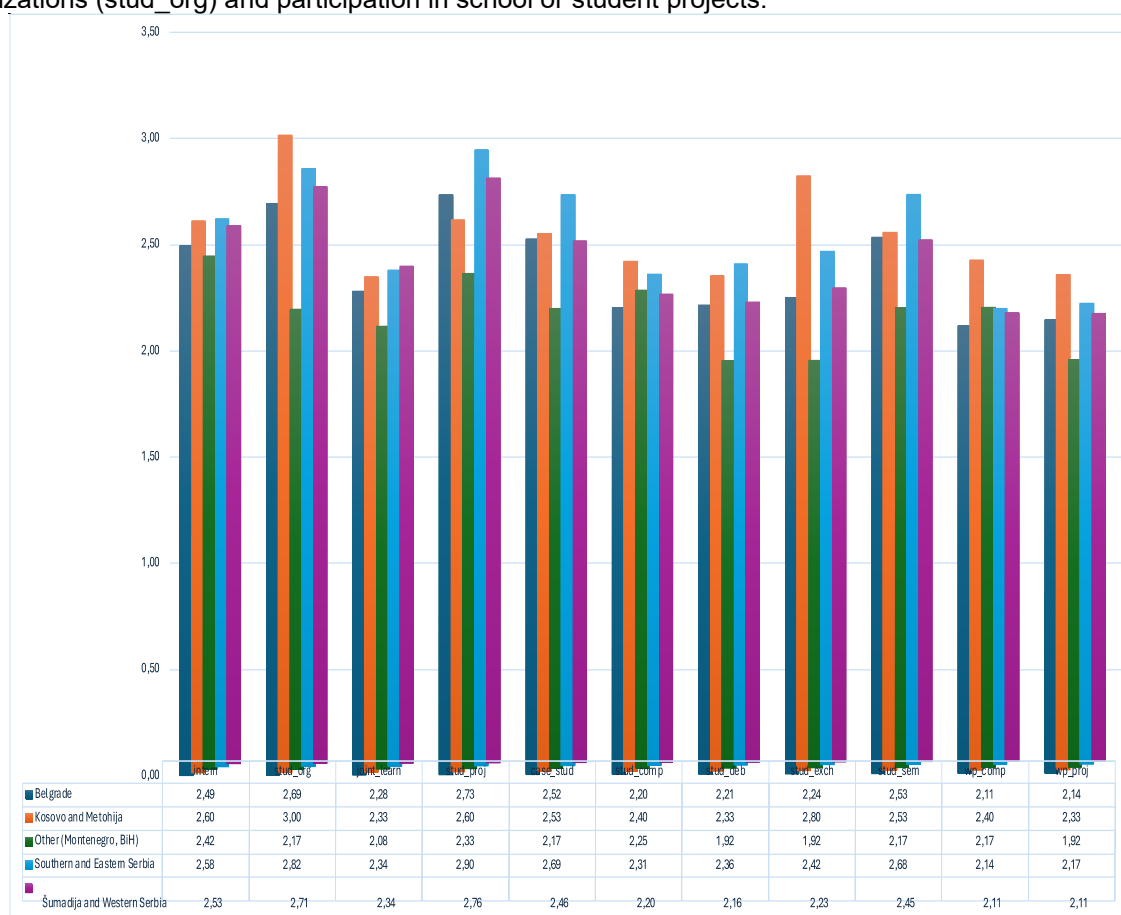
Characteristics	n (%)
<b>Gender</b>	
- Male	489 (29.9)
- Female	1149 (70.1)
<b>Region of origin</b>	
- Belgrade Region	913 (55.7)
- Vojvodina Region	100 (6.1)
- Šumadija and Western Serbia	425 (25.9)
- Southern and Eastern Serbia	173(10.6)
- Kosovo and Metohija	15 (0.9)
- Other (Montenegro, BiH)	12 (0.7)
<b>Member of student organization</b>	
- Yes	417 (25.5)
- No	1221 (74.5)
<b>Student project engagement - stud_proj</b>	

- 1 - I still haven't decided	304 (18.6)
- 2 - I don't plan to do it	241 (14.7)
- 3 - I plan to do it	634 (38.7)
- 4 - I did it or I'm currently doing it	459 (28.0)

## 5. RESEARCH RESULTS

In the research we have conducted analysis on youth engagement in different types of extracurriculars analyzing following factors: 1. Participation in business practice programs in companies - **internal**; 2. Participation in a student organization or group - **stud\_org**; 3. Participation in a joint learning program or other formal program where groups of students attend one or more classes/courses together - **joint\_learn**; 4. Participation in school or student projects - **stud\_proj**; 5. Participation in solving business case studies - **case\_stud**; 6. Participation in school or student academic competitions - **stud\_comp**; 7. Participation in debates and public discussions - **stud\_deb**; 8. Participation in the student exchange program - **stud\_exch**; 9. Participation in specialized seminars, professional gatherings, and events - **stud\_sem**; 10. Colaborative work with a member of the teaching staff on preparation for competitions. **wp\_comp**; 11. Colaborative work with a member of the teaching staff on a research or commercial project - **wp\_proj**. Scale from 1 to 4 has been used to assess the level of students' extracurricular engagement.

These extracurricular activities often show interconnections, while involvement in one may complement or enhance involvement in another. Figure 1 shows a wide-ranging summary of extracurricular activities about the students' regional origins. It is essential to note the diverse backgrounds from which students originate. The research findings suggest that the major engagement among youth lies in involvement in student organizations (**stud\_org**) and participation in school or student projects.



**Figure 1:** Participation of students in academic extracurricular activities based on their region of origin

Considering the significance of students' project engagement as one of the highly rated extracurricular activities, we have conducted an analysis focusing on youth engagement across various institutional support measures. Although project management is something that is taught mainly at university, there are also initiatives that have been implemented in elementary schools, where such initiatives have contributed to a more structured thinking among the younger population (Delle-Vergini et al., 2023). Students were supposed to evaluate to what extent the institution they attend emphasizes the following: a. Allocating a significant amount of time to study and academic work - **inst\_learn**; b. Providing support to students to achieve academic

success - **inst\_accsup**; c. Use of learning support services (reading room, library, laboratory) - **inst\_serv**; d. Promoting interactions among students from diverse socio-economic backgrounds, racial identities, religious affiliations, etc. - **inst\_netw**; e. Provision of resources aimed at enhancing the overall well-being of students, encompassing recreational activities, healthcare provisions, and counseling services - **inst\_welf**; f. Assistance in managing extracurricular commitments and obligations, including work and familial responsibilities - **inst\_extracurr**; g. Participation in forums and gatherings dedicated to contemporary social, economic, and political issues - **inst\_events**. The Likert scale have been used to evaluate the institutional support: 1- not at all, 2 - weak, 3 - solid, 4 - to a great extent, 5 - completely.

Overall, the mean values show that institutional support activities received varying levels of ratings, with **inst\_welf** ( $3.04 \pm 1.274$ ) and **inst\_extracurr** ( $2.97 \pm 1.297$ ) demonstrating the lowest scores among the surveyed activities (Table 2). Conversely, **inst\_serv** obtained the highest rating ( $3.92 \pm 1.132$ ). Using the Kruskal Wallis test, differences were obtained for all parameters of institutional support. However, to determine the difference between the groups, the Mann Whitney test was used. A subsequent comparison of groups utilizing the Mann-Whitney test discovered a statistically significant difference between students who have not yet decided or do not intend to participate in projects, and those who either plan to participate or are currently engaged in such activities. It was observed that students already involved in projects exhibited the highest average assessment of institutional support.

**Table 2:** Analysis of educational institutional support in relation to student project engagement

stud_proj		inst_learn	inst_accsup	inst_serv	inst_netw	inst_welf	inst_extracurr	inst_events
1	Mean	3.29	3.21	3.71	2.96	2.82	2.62	3.08
	N	304	304	304	304	304	304	304
	Std. Deviation	1.149	1.206	1.224	1.312	1.317	1.317	1.294
2	Mean	3.34	3.22	3.60	3.00	2.85	2.70	3.13
	N	241	241	241	241	241	241	241
	Std. Deviation	1.073	1.075	1.228	1.173	1.216	1.101	1.146
3	Mean	3.72	3.65	4.06	3.41	3.17	3.10	3.50
	N	634	634	634	634	634	634	634
	Std. Deviation	.974	1.043	1.026	1.266	1.192	1.253	1.193
4	Mean	3.89	3.87	4.02	3.45	3.10	3.16	3.70
	N	459	459	459	459	459	459	459
	Std. Deviation	.990	1.090	1.105	1.367	1.354	1.370	1.235
Total	Mean	3.63	3.57	3.92	3.28	3.04	2.97	3.42
	N	1638	1638	1638	1638	1638	1638	1638
	Std. Deviation	1.054	1.123	1.132	1.307	1.274	1.297	1.240
Kruskal-Wallis H		77.681	89.785	38.335	45.902	21.989	50.307	64.038
df		3	3	3	3	3	3	3
Asymp. Sig.		<.001	<.001	<.001	<.001	<.001	<.001	<.001

## 6. CONCLUSION

Higher educational institutions in the Republic of Serbia play a significant role in shaping the overall course for the career path development of young people. This study is part of the research financed by the Science Fund of the Republic of Serbia in the field of Social Sciences and Humanities Program, Ideas. To analyze new avenues, this research has the main goal of analyzing differences and needs for young people engaged in extracurricular activities. The main findings suggest that student project engagement and membership are the highest-rated activities among youngsters. Also, there is a notable difference in the perception of institutional support among those who are not engaged in projects and their counterparts. Students engaged in projects and other extracurriculars perceive a higher level of institutional support. The results of the study could be useful for policymakers and leaders of educational institutions.

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# TRANSFORMING MANUFACTURING WITH AI: A PROJECT MANAGEMENT PERSPECTIVE

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**Abstract:** *Project management is crucial in efficiently achieving business objectives in the contemporary manufacturing industry. Introducing artificial intelligence (AI) as support in project management processes opens up opportunities for resource optimization, cost reduction, and project performance improvement. This paper delves into the importance and repercussions of employing artificial intelligence in project management within the manufacturing sector. It scrutinizes particular instances, advantages, and hurdles stemming from this transition, including an examination of the implementation of elements from Industry 4.0, Virtual Reality (VR), and the concept of Industry 5.0.*

**Keywords:** *Artificial intelligence (AI), Industry 4.0, Industry 5.0, Manufacturing industry, Project management*

## 1. INTRODUCTION

In the manufacturing sector, effective project management is a vital function, directly influencing companies' success. Although traditional project management approaches are long-standing industry pillars, they increasingly need to improve to address the ever-more complex market demands and technological innovations. In this context, artificial intelligence is critical in transforming how projects are planned, implemented, and controlled.

Utilizing artificial intelligence in project management yields various advantages, such as enhancing resource allocation efficiency, conducting predictive risk assessments, automating processes, and expediting data-informed decision-making.

Complex projects are susceptible to unexpected events, and early identification of potential risks and their effective prioritization is crucial. Machine learning algorithms can scrutinize extensive datasets to discern patterns and trends, facilitating improved resource allocation and project scheduling.

Conversely, deep learning methods can process unstructured data, such as project narratives and risk reports, facilitating enhanced accuracy in scenario planning and proactive risk management. AI can also analyze vast datasets to identify potential risks early and prioritize them based on their probability and impact. Additionally, artificial intelligence (AI) can propose strategies for mitigating risks by leveraging historical data and established industry norms, promoting a proactive approach to risk management.

Moreover, leveraging advanced analytical tools empowers project managers to anticipate potential issues and implement preemptive measures to mitigate them before they manifest. Introducing new technologies necessitates investment in staff training, integration with current systems, and addressing concerns regarding data security.

This paper's objective is to explore the influence of artificial intelligence on project management within the manufacturing industry. It analyzes specific examples of implementation, identifies benefits and challenges, and provides guidelines for successfully integrating this technology into business processes by examining the application of Industry 4.0 and Industry 5.0 aspects, with the impact of virtual reality (VR).



## **2. Models for decision-making in project management through the application of AI**

Project management is undergoing a significant transformation with the integration of artificial intelligence. Machine learning and deep learning are powerful AI tools contributing significantly to this transformation.

### **2.1. Machine and deep learning algorithms**

According to Raffaele Cioffi in [13, pp. 2-3], Machine learning algorithms introduce a revolutionary change in project management through their ability to analyze large amounts of historical project data, including budgeting, timelines, resource allocation, and past project outcomes. Additionally, machine learning can predict the success of the current project by analyzing data from similar projects, such as cost estimates, feasibility of deadlines, and potential resource constraints.

Decision-making relies on information, and through machine learning, Data from previous projects can undergo analysis to pinpoint potential delays and bottlenecks in analogous endeavors. Predicting these issues allows project managers to adjust schedules and minimize disruptions proactively.

These algorithms can manage more complex and unstructured data sources by drawing insights from the architecture and operations of the human brain. Creating realistic simulations, Deep learning can be applied to create complex simulations of potential project outcomes in different scenarios, where AI enables the simulation of varying project paths. This ability to simulate various future scenarios allows project managers to identify possible disruptions, where deep learning can help identify unexpected events that could impact the project, enabling proactive measures to mitigate their impact.

Integrating machine learning and deep learning algorithms into project management methodologies introduces a novel domain of well-informed decision-making and proactive planning in complex projects facilitated by artificial intelligence. This brings about more efficient resource allocation, reduced project risk, and increased project success.

### **2.2. RISK MANAGEMENT WITH THE HELP OF AI**

Following *Obejide in [10, p.1073 – 1077]*, the success of project management depends on the ability to navigate the sea of potential risks. Traditionally, risk identification and mitigation rely on human expertise and experience. However, artificial intelligence (AI) offers a powerful solution by analyzing vast amounts of data to proactively identify risks, determine priorities, propose mitigation strategies, and even develop dynamic emergency plans. AI generates predictive warning systems for specific risks, with the ability to assess the likelihood of each identified risk. If a new threat arises in the project, AI can quickly propose new mitigation strategies based on current data and historical experiences. This dynamic adaptation ensures that mitigation strategies are always relevant and practical. Integrating AI into risk management enables projects to be adaptable and more resilient, reducing exposure to risk over time.

### **2.3. Improvement of manufacturing industry project management methods**

Information systems support the automation of projects, budgeting tasks, customer and supplier relationships, manufacturing cycle management, routine accounting, monitoring, and performance evaluation. As emphasized in [2] and [10], some of the well-known methods that will be enhanced and automated include Business Performance Management (BPM) and Strategic Enterprise Management (SEM).

In the future, automated information systems will be integrated into organizational frameworks at the enterprise level, aiming to:

- Facilitate the management processes of selected management cycles within the organization.
- Plan finances according to budgeting principles.
- Plan and practically organize the production process in two areas: organizational and technical (specification, warehouse, and production accounting).
- Establish an internal resource exchange system for production.
- Plan and organize staff work and how to best utilize their abilities.
- Ensure interoperability with IoT platforms. In the interaction architecture, integration with maintenance and repair systems (TOiR) and the company's ERP system should be provided.

- Consolidate all accessible data into a Business Analysis (BI) subsystem, presenting it through a suitable interface for a thorough examination and subsequent result evaluation. Furthermore, develop motivational programs for staff.
- Develop a professional education system with an emphasis on project management knowledge.

When considering project management for new products or ventures in unfamiliar markets, it's advisable for the model to be flexible and open to adopting methodologies from either PMBOK or Agile. During the regular production phase, it's recommended to utilize a process iterative approach or Agile methodology. The analytical approach model facilitates a shift from a relatively inflexible budgeting system to a more adaptable project management framework. This shift entails continuous monitoring and guidance of budgets by the project team, resulting in increased realism. Furthermore, the model enhances adaptability to changes in the market, and mechanisms are integrated to ensure comprehensive engagement of project team members, particularly through the utilization of Agile methodology.

### 3. INDUSTRY 4.0 AS A FORM OF OPENING THE DOOR TO INDUSTRY 5.0

Embracing the "Industry 4.0" paradigm has brought about substantial changes in the technologies employed for designing and producing intricate technical products. These changes encompass various aspects of industrial automation, ranging from sensor deployment and process automation to data integration and visualization, as well as providing cognitive assistance to users in decision-making.

As per *Borovik [9, p. 307]*, German business, political, and scientific figures introduced the term "Industry 4.0" to the public in 2011. It was characterized as an initiative to bolster industry competitiveness through heightened integration of "cyber-physical systems" (CPS) in manufacturing.

*Borovik, referring to McKinsey's insights in [9, p. 307]*, summarized their view as follows: "The forthcoming phase in the digitalization of manufacturing encompasses four significant advancements: 1) a remarkable increase in data volume and computing power, particularly propelled by new networks offering low-energy wide-area coverage; 2) the rise of analytics and business intelligence; 3) innovative forms of human-machine interaction such as touch and augmented reality systems; 4) the propagation of digital instructions, including advanced robotics and 3D printing."

Following *Borovik [9, p. 307- 309]* and *Xu in [14]*,

Industry 4.0 encompasses four foundational components: Cyber-Physical Systems (CPS), the Internet of Things (IoT), Internet-based services, and Smart factories. Moreover, six critical technologies have been identified as central to its advancement: Industrial Internet of Things (IIoT) and CPS, additive manufacturing (3D printing), big data, artificial intelligence (AI), collaborative robots (CoBots), and virtual reality (VR). The primary emphasis lies in the technical facets of their implementation, where the presence of human intelligence and labor is minimized, almost to the point of non-existence. This aspect has ignited extensive debates among scientists and researchers worldwide.

The emerging paradigms of Industry 5.0, as outlined by *Evgeniy Bryndin [8, pp. 25-28]* and *Borovik [9, pp. 307 - 309]*, introduce a fresh outlook on the challenges stemming from the integration of Industry 4.0 within the manufacturing sector. Industry 5.0 entails infiltrating artificial intelligence into everyday human activities, fostering a symbiotic "collaboration" between humans and AI to augment human capabilities.

In 2016, the Japan Business Federation Keidanren suggested renaming the notion of Industry 5.0 to "Society 5.0" (Super Smart Society), a proposition that received backing from the Government of Japan's Cabinet Council for Science, Technology, and Innovation, as evidenced by research *[8, pp. 25-27]*. Unlike the notion of Industry 4.0, Society 5.0 transcends the boundaries of the manufacturing domain and addresses broader societal issues by seamlessly merging physical and virtual realms. Society 5.0 embodies a societal paradigm where advanced IT technologies, the Internet of Things (IoT), robotics, artificial intelligence, and augmented reality (AR) are deeply integrated into everyday life, industry, and various other sectors to enrich the welfare and convenience of all individuals.

#### 3.1 The importance of the Internet of Things

According to *Skobelev and Borovik [9, p.308]*, IoT is a rapidly advancing technology that complements the traditional Internet of People and is the foundation for automation in Industry 4.0 and Society 5.0. Referencing the official recommendation ITU-Y.2060 - Overview of the Internet of Things from *[9, p.308]*, "IoT is a global infrastructure for the information society, facilitating advanced services through the interconnection of physical

and virtual entities using existing and evolving interoperable information and communication technologies." Additionally, as noted in [16, p.1], in a general sense, a "thing" refers to an object from either the physical world (physical things) or the informational realm (virtual things) that can be identified and integrated into communication networks.

### 3.2 APPLICATION AND SIGNIFICANCE OF MULTI-AGENT SYSTEMS

The integration of IoT (IIoT) technologies, as described in [5, p.3] and [9, p.308], entails transferring computational processes to the virtual realm, often referred to as the "cloud," where virtual counterparts of real-world objects operate based on predefined algorithms and rules. Intelligent agents serve as intermediaries between the physical and virtual domains, capable of sensing data from the real world, making decisions, and coordinating with other entities or users in real-time. Simultaneously, physical objects can operate autonomously or contribute to more intricate production processes.

A multi-agent system, as elucidated in references [9, 17, 18], constitutes a sophisticated network of diverse entities known as agents, each tasked with resolving distinct "private" dilemmas within a familiar environment. These agents operate in a loosely coupled manner, collaborating and communicating to collectively attain predefined system goals. Interaction within this system can manifest in two primary forms: direct communication through message exchange among agents or indirect interaction, wherein specific agents adapt their behaviors in response to the presence or actions of others. Consequently, they can influence alterations in the external environment with which they engage. This dynamic interplay among agents, whether directly or indirectly, fosters the emergent behavior necessary for achieving overarching system objectives.

The development of digital ecosystems, where services interact collaboratively or competitively within "systems of systems," is facilitated by multi-agent systems and technologies. These systems offer solutions for complex tasks such as resource planning and optimization, as well as knowledge acquisition across Big Data and Small Data domains. This evolution has the potential to elevate basic IoT into the intelligent Internet of People and Things, often termed the Internet of agents.

### 3.3 ONTOLOGICAL APPROACH WITHIN MULTI-AGENT SYSTEMS

An ontology is a comprehensive repository of concepts utilized as fundamental components in information management systems. This ontological approach has been embraced in various multi-agent systems, employing ontologies as knowledge repositories for intelligent agents containing domain-specific data and decision-making methodologies.

When integrating the ontological approach and multi-agent systems, three qualitatively different approaches, following *the [9, p. 308]*, can be classified:

- Each agent maintains an ontology consisting of information and principles exclusively accessible to itself.
- A centralized, unified ontology is stored, typically on a specific agent, to be accessed uniformly by all agents.
- A partially unified and partially distributed ontology.

## 4. INDUSTRY 5.0

Following *Evgeniy in [8, pp. 25 - 26]*, the international advancement in science and technology paved the way for the global community to shift progressively towards establishing and overseeing the fifth industrial generation. This transition is facilitated by cognitive-technological intelligence supported by ensembles of intelligent agents, digital twins, and automated systems driven by artificial intelligence.

In Industry 5.0, sophisticated robots equipped with secure cognitive artificial intelligence will undertake specialized high-tech tasks across various sectors. Humans will impart knowledge to these cognitive robots, fostering professional advancement through iterative self-enhancement towards technological singularity. The control of artificial intelligence, reaching technological singularity, will hinge upon the outcomes of self-improvement activities conducted in simulation mode within virtual environments. This AI can be a valuable ally to humanity in the safe evolution of living environments.

According to *Evgeniy in [8, p.24-25]*, Industry 5.0 represents a progression that builds upon the foundation set by Industry 4.0 and the infrastructure provided by the 5G network. Its objective is to enhance all facets of production by incorporating intelligence and adaptability into manufacturing processes. By utilizing the architecture of 5G and segmenting it into multiple virtual layers, manufacturers can tailor each layer to meet

specific applications within a unified physical network infrastructure. This integration of virtual and physical realms fosters the development of cyber-physical complexes, establishing a unique digital ecosystem. At the heart of this ecosystem lies the cyber-physical system, which serves as both an organizational and technical framework for managing information flow and seamlessly integrating computational resources into physical production workflows.

When undertaking projects to modernize production in the manufacturing sector, seamless interoperability between automated equipment and software must be ensured. Adherence to strict standards for organizing and managing Industry 5.0 is paramount.

In the management of Industry 5.0, artificial intelligence holds a distinct position, offering sophisticated organizational methodologies for overseeing its economic landscape. From a logical standpoint, it's evident that the primary catalysts for economic advancement encompass the presence of demand for specific benefits, the accessibility of resources to fulfill those benefits (including technologies facilitating their efficient utilization), and the driving force capable of orchestrating the transformation of those resources into finalized products.

This pivotal catalyst encompasses various entrepreneurial attributes, leadership qualities, unwavering determination, a profound sense of personal accountability, and a spectrum of other traits. The primary objective of managing Industry 5.0 is to establish a distinctive ecological milieu for human endeavor within a broader framework, encompassing facets of project management, technological oversight, and the human dimension of economic engagement.

#### **4.1 CREATIVE COOPERATION BETWEEN MAN AND ROBOT**

The trend of incorporating human involvement in manufacturing processes is growing. This engagement goes beyond mere setup and assistance, also aiming to enhance production line efficiency. Many companies are now employing robotic arms, known as CoBots, like the Universal Robots UR10. These CoBots improve the accuracy of human work and the overall quality of the end product and increase productivity, effectiveness, and efficiency in production lines.

Findings from [8,9] propose that Industry 5.0 will reshape the roles of mechanical elements and human workers within manufacturing. Robots will be delegated repetitive and monotonous tasks, freeing up space for human creativity.

This new standard fosters a more collaborative relationship between humans and machines and aims to make the industry smarter. Manufacturers have developed specialized machines that can work alongside humans safely. Implementing this new standard will undoubtedly benefit all companies within the manufacturing industry as part of the ongoing industrial revolution.

#### **4.2 BIG DATA 5G, ARTIFICIAL INTELLIGENCE AND VIRTUAL REALITY IN INDUSTRY 5.0**

At the core of digital Industry 5.0 are fifth-generation communication networks (5G), complemented by the analysis of BIG Data and the Internet of Things (IoT), with artificial intelligence as the primary driving force.

Virtual Reality (VR) allows humans to enter another world, affecting their sensory organs, primarily vision. Augmented Reality (AR) seamlessly merges the real-world environment with virtual world, enriching the user's experience. The application of VR, AR, and AI can contribute to all spheres of life, both in human beings' everyday activities and in the manufacturing processes of the production industry.

Following the research of *Trakadas in [6] and Evgeniy in [8, p.27,28]*, the synergy between the 5G network and Internet of Things (IoT) technology, augmented by Industrial IoT sensors (IIoT) and supported by artificial intelligence (AI), holds the potential to elevate production automation levels significantly. This advancement could entail the substantial integration of industrial robots, effectively reducing reliance on human labor.

#### **4.4 The impacts of Virtual Reality (VR) and Augmented Reality (AR)**

As noted by *Dodevska and Mihic [15, p.17]*, augmented reality (AR) and virtual reality (VR) are gaining widespread adoption in the corporate landscape. Research suggests that they will transform workplaces and the way they operate shortly. Therefore, project managers must be prepared to embrace these changes and implement AR/VR in project management.

It is crucial to understand the difference between various types of virtual technologies; from *Dodevska and Mihic in [15, p.17 - 21]*, it is most important to distinguish the following technologies:

- Real Reality (RR) - the "real world" in which we live
  - Virtual Reality (VR) - an opposite world of RR - a 3D computer-generated digital environment.
  - Augmented Reality (AR) - blends real-world environments with computer-generated graphics, presenting virtual objects in real-time.
  - Cross Reality (XR) - a type of information exchange between the real and virtual worlds
- According to [15] and numerous studies, VR and AR are the most widely applied.

Virtual reality (VR) is fully integrated into the digital world with a complete sense of immersion. However, utilizing such technologies demands specialized hardware equipment, including dedicated software such as Microsoft HoloLens, Google Daydream, Google Cardboard, and others.

Augmented reality (AR) combines the digital and real worlds, creating an immersive user experience. Unlike desktop and laptop devices, smartphones, tablets, or smart glasses require cameras.

This research emphasizes the utilization of these technologies within the manufacturing industry. Therefore, AR is beneficial for delivering relevant and accurate information to workers on the production line during the production process. The main advantage of this implementation lies in efficiently reducing errors, costs, and time, as well as improving productivity. In addition to their application in the manufacturing industry, they are also present in:

- Marketing and sales
- Education
- Visual industries
- Automotive
- Manufacturing
- Healthcare
- Defense
- Service support
- Architecture, civil engineering, construction, and real estate.

Is it possible to implement AR/VR technologies in project management?

According to *Dodevska and Mihic [15]*, virtual and e-project management represent a complete revolution in project management. These advancements necessitate support from Information and Communication Technology (ICT), where software solutions facilitating collaboration and distributed project management will hold significant importance. In this regard, AR and VR are highly suitable for implementation in project management.

Implementing innovative AR/VR technologies and conducting virtual project management will increase the demand for managing such projects, requiring adequate training for all current and future project managers.

#### **4.3 COGNITIVE VIRTUAL SYSTEMS AND THE NOTION OF SINGULARITY**

By *Evgeniy Bryndin from [8, p.27]* the concept of singularization refers to the phenomenon wherein cognitive virtual systems progress to more complex patterns by analyzing accumulated intelligent big data, following the patterns established at preceding levels.

Cognitive ensembles consist of diverse mobile agents dispersed throughout the system, actively traversing it to locate pertinent data, knowledge, and procedures across technological platforms and analytical systems. These agents collaborate harmoniously toward achieving shared objectives.

The architecture of cognitive ensembles enables the use of agents that learn independently and whose principles are formed in problem-solving.

The primary features of agent interaction encompass orientation, selectivity, intensity, and dynamism. Each agent possesses a finite knowledge base essential for goal attainment. Obligations serve as a mechanism facilitating the coordination of individual actions among agents, allowing for the anticipation of others' behavior and future prediction. These obligations can be categorized into obligations towards other agents, obligations towards the group, obligations from the group towards the agent, and self-obligations of the agent.

In the process of teamwork, according to *Evgeniy Bryndin from [8, p.27-29]*, mobile diverse agents can solve many tasks, like:

- Possibility to recognize the necessity of collaboration;

- The action of selecting appropriate partners;
- The capability to consider the interests of partners;
- Organizing negotiations for collaborative efforts;
- Developing plans for joint actions;
- Coordinating joint actions effectively.
- Decomposing tasks and allocating responsibilities accordingly.
- Recognition of contradictory objectives

The hallmark of group dynamics among varied mobile agents is the emergence of a novel problem-solving quality resulting from their interactions, whether in addressing individual or shared tasks.

## 5. INDUSTRIAL ROBOTS AND THEIR APPLICATION IN THE MANUFACTURING INDUSTRY

According to Sordan and Chiabert [3], industrial robots are revolutionizing manufacturing industries worldwide, elevating efficiency, precision, and productivity to new heights. With sophisticated sensors, actuators, and AI-driven functionalities, these robots undertake diverse tasks, from assembly and welding to packaging and product pasteurization, exhibiting unparalleled speed and precision.

One primary benefit of industrial robots is their capacity to automate repetitive and dangerous tasks, diminishing the need for human involvement and enhancing workplace safety. By assuming mundane tasks, robots liberate human workers to concentrate on more intricate and supplementary duties, nurturing a more dynamic and inventive work atmosphere. Additionally, *Skobelev* [9] said that industrial robots offer scalability and flexibility, enabling manufacturers to quickly adapt to changing production requirements and tailor operations to specific demands. This agility allows companies to enhance their competitiveness.

Another significant advantage of industrial robots is their potential for continuous improvement through data and predictive analytics. By collecting and analyzing extensive data in real time, robots can optimize their performance, anticipate maintenance requirements, and avert costly downtime, guaranteeing uninterrupted operations and maximizing uptime.

Collaborative robots, or cobots, also emerge as a game-changer in manufacturing industry transformations. These robots work alongside human operators, enhancing collaboration and efficiency on the factory floor. With their user-friendly interfaces and safety features, coBots enable seamless interaction between humans and robots, opening up new possibilities for flexible and adaptable manufacturing processes.

Implementing industrial robots in manufacturing represents a transformative force that drives innovation, productivity, and competitiveness. With technological progress, robots are set to play an increasingly central role in shaping the trajectory of production, enabling companies to achieve heightened levels of efficiency, quality, and sustainability.

### 5.1 Amazon's Robot Revolution

The company Amazon has introduced revolutionary industrial robots. The first of these robots is Proteus, whose primary function is to transfer certain products and packages to delivery trucks. Following Proteus, in November 2022, the Sparrov robot was released, representing a step towards human dexterity. Amazon's newest robots have the potential to alter the equilibrium between automation and human labor within both the company and the broader industry.

Automated warehousing systems have empowered Amazon to store a greater volume of goods in equivalent spaces and expedite deliveries to customers, propelling the company to a leadership position in the e-commerce sector. From 2010 to 2020, Amazon's sales surged tenfold from \$34 billion to \$386 billion. Concurrently, the number of robots integrated into the workforce experienced a substantial rise. Between 2013 and 2020, Amazon's inventory of robots surged from 10,000 to 750,000 units. [18]

### 5.2 Elon Musk and Robot Optimus

In December 2023, Tesla unveiled its latest robot version, Optimus, through the media. Tesla produced this robot using the experience gained while producing AI chips for self-driving cars.

Optimus, Tesla's humanoid robot still in development, is expected, according to Elon Musk, to be able to perform nearly all human functions in the manufacturing industry by the end of 2024 and could hit the market by the end of 2025.

The current boom in artificial intelligence is helping advance this field, as widespread use is essential for humanoids to become a sustainable tool both in the manufacturing industry and everyday life. [17]

## 6. CONCLUSION

Project management is a complex task that requires making intricate decisions and managing many risks. Artificial intelligence (AI) brings new opportunities and tools to enhance these processes, from data analysis to risk identification and mitigation strategy development. Machine learning and deep learning enable projects to analyze large amounts of data and create realistic simulations of future scenarios, helping project managers make informed decisions and develop effective plans for emergencies.

Along with all AI's advantages come specific challenges and risks. Responsible AI implementation is crucial to ensure a positive and sustainable impact. This includes transparency and accountability, limiting bias and discrimination, protecting privacy and data security, establishing legal, ethical, and regulatory frameworks, and educating and empowering stakeholders. Through responsible AI use, project managers can enhance their decision-making and risk-management capabilities, ensuring the success of their projects in a dynamic and unpredictable business environment.

Elements of the latest industrial revolutions, such as "Industry 4.0" and "Industry 5.0," along with the influence of virtual reality, introduce novel paradigms to the manufacturing sector. These include automating production lines, deploying robotics, integrating human and artificial intelligence, and incorporating industrial robots. This leads to significant improvements in manufacturing companies' operations.

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# ARE YOU MATURE ENOUGH TO CREATE A PROJECT MANAGEMENT OFFICE?

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**Abstract:** *Despite the increasing number of organizations opting to establish and implement Project Management Offices (PMOs) to enhance competitiveness and efficiently manage extensive project portfolios, they continue to encounter challenges in realizing the benefits of PMOs. The goal of this research paper is to explore the application of Project Management Maturity Models (PMMM) as a tool to identify organizational areas in need of performance improvement following the implementation of Project Management Offices (PMOs). By utilizing PMMM, we aim to gain valuable insights into the effectiveness of PMO implementation and to propose strategies to address performance gaps within organizations. The paper focuses on examining how a selected PMMM is applied to evaluate PMOs in the Transport & Logistics sector. To gain in-depth understanding of the selected Transport & Logistics company, the research employed a case study approach. Results show that there are substantial benefits of implementing PMO within the Transport & Logistics sector. The collected data is utilized to provide useful recommendations for future application of PMMM<sup>sm</sup> in analyzed industry. These insights could assist project and strategic managers in reorganizing their operations to improve project management practices, thereby enhancing project success rates and overall business performance.*

**Keywords:** *Project Management Office, Project Management Maturity Model, Transport & Logistics*

## 1. INTRODUCTION

In today's fast-moving and challenging environment, organizations need to develop systems to keep their competitive edge (Ferreira, 2019). To do this, companies handle a large number of projects and have started implementing Project Management Offices (PMOs) into their structure to better manage these projects (Pellegrielli & Garagna, 2009). Interestingly, even medium and large-sized organizations now have a PMO (PM Solutions, 2022). Research indicates that presence of PMOs can consistently improve project success, for example Correia et al. (2018) demonstrated project quality can be enhanced by about 25%. PMOs are valuable because they help organizations manage projects more efficiently, with reports indicating that three out of four PMOs provide a more structured approach for project managers (Ichsan et al., 2022).

PMOs can help companies reduce or eliminate problems and weaknesses in their organizations (Kostalova & Tetreva, 2018). To achieve higher performance, organizations have to develop a deeper understanding of their deficiencies. Application of Project Management Maturity Models (PMMM) can help those companies to do so. PMMMs are used as tools to facilitate organization's assessment and outlining of exact maturity level of project management competences that were developed over time (Christoph & Konrad, 2014). Literature review performed by Gareeb and Rwelamila (2021) for period from 2000 to 2019 identified 60 PMMMs. However, maturity models cannot be used as universal for all types of industries (Grobler & Steyn, 2006).

The role of project management, specifically logistics project management, is increasingly recognised as an important topic in the Transport & Logistics sector (Hartel, 2022). The reason is industry's growing complexity and the need for efficient project execution. Global logistics market was valued at \$8.4 trillion in 2021 and is projected to surpass \$13.7 trillion by 2027, highlighting the sector's rapid expansion and the vital role of effective project management in sustaining this growth (Placek, 2023).

De Souza and Gomes (2015) found that while PMMMs are widespread in the information technology sector, their adoption in all other industries is noticeably lower. Although projects are integral to the Transport & Logistics sector, the general notion is that there is still lack of awareness about benefits of PMOs (Saedi, 2019). Literature review shows the scarcity of studies and documentation needed to understand and articulate the value of potential PMO implementation benefits and appropriate PMMM choice for Transport & Logistics industry which shows rapid growth.

This study is focused on following research questions:

- (1) Do Transport & Logistics companies need a PMO and how should it be implemented?
- (2) Which PMMM is appropriate and applicable for Transport & Logistics companies?

The paper is structured in five segments. Literature review provides understanding of research concepts that were used in the study and research findings other authors have previously discovered. Research design gives insight into chosen company and applied methodology. Research results and discussion present collected data and interpretation of results. Conclusion focuses on main findings and contribution of the paper. Limitations and future directions acknowledge study constraints and guidelines for further research.

## 2. LITERATURE REVIEW

### 2.1. Project Management Office

Project Management Office (PMO) has been defined by Project Management Institute as „organizational structure that standardizes the project-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques“ (PMI, 2017). PMO focuses on providing support to project managers and their teams, and to functional segments of organization, to achieve higher level of company's efficiency and effectiveness (Oliviera & Martins, 2020). PMO is described as an entity aiming to further develop and enhance project management competences and it represents a connecting point between organization and its projects (Khoori & Hamid, 2020).

According to PMI (2017), there are three types of PMO: supportive, controlling and directive. Supportive PMO has a consultant role in which it does not have authority to give orders. Its role is reflected through systematization and securement of standardized project templates, access to needed data and promotion of best practices. This PMO has the lowest authority level upon projects and project teams. Controlling PMO has a consultant role, but it has authority to control the extent to which some of the standardized methods and project templates are being implemented. Directive PMO has direct control over all organizational projects, and it directly manages and is responsible for successful project execution. This PMO type has the highest authority level over project governance (PMI, 2017).

Project management office should be viewed as dynamic structure, rather than static, since it helps exceed particular problems a dynamic organization faces (Aubrey et al., 2010). PMO can reach full potential only if organization understands that this entity makes progress in terms of its evolution over time and that its context needs to be acknowledged (Aubrey et al., 2008). Regardless of PMO type, PMO focuses on minimizing odds for organization to make same mistakes that have already been made. That is why PMO is considered as a key component in process standardization and knowledge transmission. Today, numerous organizations are implementing such entity in their businesses, while some companies have more than one PMO in their organizational structures (Müller et al., 2013). However, the process of implementing a PMO is not as simple as it may seem at first glance. To choose an appropriate form and create long lasting PMO, organization needs to assess which project management maturity level it has reached.

### 2.2 Project management maturity model

The Project Management Maturity Model (PMMM) is a framework that indicates the level of proficiency an organization has reached in terms of project management competencies. These models assist organizations in determining and assessing their maturity level and help pinpoint strengths and weaknesses, enabling them to define necessary actions to enhance their overall project management capabilities (Kostalova & Tetreva, 2018). In project management, "maturity" refers to achieving successful project execution through established procedures and demonstrated consistency in project delivery over time (Anantamula & Rad, 2018). The maturity model serves as a guide for a company to assess its existing organizational processes by comparing them to recognized best practices (Silva et al., 2021). According to Kerzner (2019), defining project management maturity requires considering factors such as the industry the organization operates in and whether the organization is project oriented.

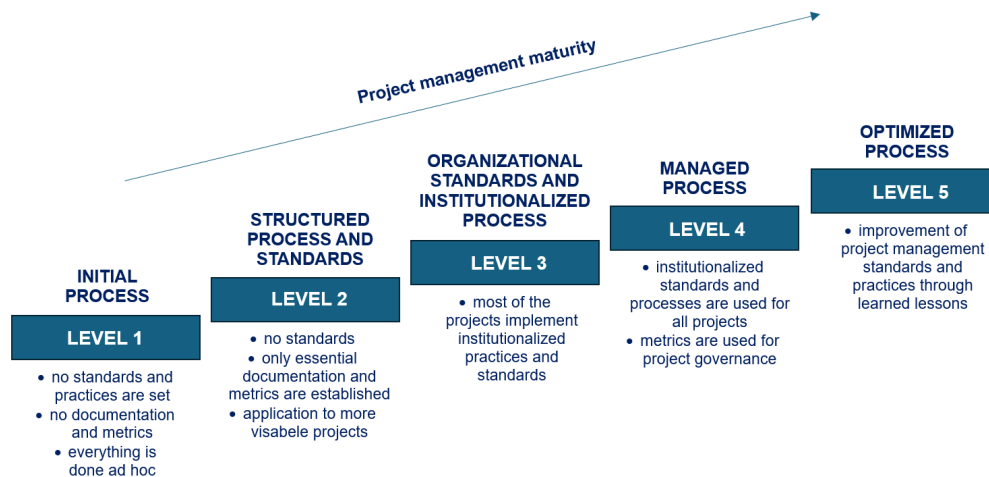
During literature analysis, various PMMMs were discovered. Research conducted by Gareeb & Rwelamila (2021) found there are 60 various PMMMs in the literature for the period 2000-2019, such as CMMI, OPM3, IPMA Delta, P3M3, NPM3, PMMM<sup>sm</sup>, SPM3, Prado's P2M3, Kerzner's KPMMM, MMM etc.

Simagunsong and Da Silva (2013) conducted research on widely used PMMMs across various industries, focusing on models like CMMI, PMMM<sup>sm</sup>, PM2, and ProMMM. Their findings indicated that PMMM<sup>sm</sup>, PM2, and ProMMM are suitable for project-driven organizations, whereas CMMI is better suited for the software industry. Their analysis revealed that PMMM<sup>sm</sup> and PM2 both feature five maturity levels, whereas ProMMM has four. PMMM<sup>sm</sup> and PM2 align with PMI's knowledge areas, unlike ProMMM. Further, PM2 focuses solely

on project management processes, while PMMM<sup>sm</sup> includes both project and program management processes (Nikolaenko & Sidorov, 2023; Fabbro & Tonchia, 2021). Based on these insights, this research aims to determine the relevance and applicability of PMMM<sup>sm</sup> for dynamic and fast-paced organizations in the Transport & Logistics industry.

## 2.3 PM Solutions project management maturity model

PM Solutions PMMM (PMMM<sup>sm</sup>) is a model that combines project management knowledge areas defined by PMI and five levels of maturity (Domingues & Ribeiro, 2023). PMMM<sup>sm</sup> allows a systematic review of project management maturity for different organizational aspects. Each maturity level features a certain point of standardization and application of patterns. This can be understood through Figure 1 (Miller, 2004; Vergopia, 2008).



**Figure 1:** Levels of PMMM<sup>sm</sup>

This model has been widely used for maturity level analysis because it comprehensively covers knowledge areas defined by PMBOK, through a predefined scale. Pennypacker & Grant (2003) set this model as the basis for their research, which focused on defining industry PM maturity level and included 123 respondents. Miklosik (2015) applied this model through his research for purpose of determining and understanding project management maturity in 25 information and communications technology (ICT) companies which are present in Slovakia. It was used by Göçmen Polat (2021) as a foundation for maturity evaluation of a company from logistics industry, in terms of sustainable project management.

## 3. RESERACH DESIGN

The aim of this study is to analyze the specific case of PMO implementation in Transport & Logistic company using selected project management maturity model. The sample company was selected as the regional leader with PMO overseeing more than 60 projects annually. This company was chosen for its exemplary performance in business innovations and efficiency in logistics operations, making it an ideal subject for studying the impact of PMO practices. With over 60 projects managed annually, the company's PMO provides a robust environment to assess the maturity and effectiveness of project management practices. Additionally, projects span various domains within transport and logistics, offering a comprehensive view of PMO capabilities across different types of initiatives.

The research employed a case study approach as a methodological framework to acquire a comprehensive understanding of the research subject, encompassing both theoretical and practical perspectives (Ebneyamini & Sadeghi Moghadam, 2018). The questionnaire utilized in the case study was based on PMMM<sup>sm</sup> and encompassed a hybrid approach, incorporating both qualitative and quantitative data collection methods. For quantitative data collection, Likert scale ranging from 1 (one) to 5 (five) was employed. Overall, this comprehensive approach allowed for a rich exploration of the research subject, capturing not only numerical data but also qualitative insights, opinions, and perspectives.

The questionnaire was structured in five sections. The first part of the questionnaire provides insights into general information and how the organization observes its projects, whether they are perceived and selected individually or placed within a broader strategic context. The second part of the questionnaire focuses on determining the foundational project management approach applied by the company. The third part of the

questionnaire aims to assess the project management maturity level across six areas: integration, scope, time, cost, quality, and resources. The fourth part of the questionnaire focuses on determining the implementation status of a PMO and further analysis of its functions. The fifth part of the questionnaire considers the presence of project management software solutions.

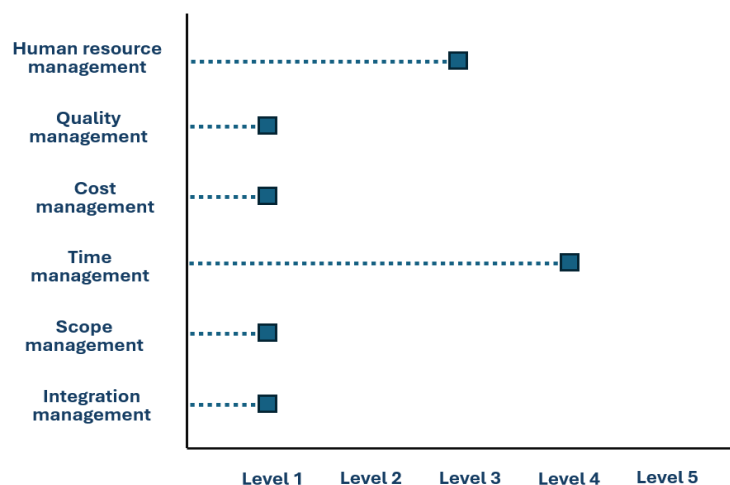
Analysis procedure included data interpretation, member checking and writing final report. First, data were interpreted and critically reviewed within the framework of the research objectives and theoretical perspectives. Second, the findings were reviewed by company member to ensure they accurately reflect their experiences and perspectives. Finally, the findings are synthesized and presented in a clear manner in the research report presented in the following section.

#### 4. RESEARCH RESULTS AND DISCUSION

The data collected using the questionnaire demonstrates that the selected company undertakes sixty projects in average on an annual basis, which are assessed as moderately complex. The value of these projects ranges from several hundreds to several millions of dollars. Projects are initiated internally as development projects and externally as a business and operational need. The average duration of project is around half a year. All projects are subject to rigorous analysis in portfolio context through prioritization process, using criteria defined by the company's PMO.

The company uses both traditional and agile approach and as a result project scope is defined at the beginning or further as the project progresses. Agile approach is applied when client requirements are unstable and prone to repeated changes. Project phase execution is carried out only once, which is inherent for traditional approach. Project success is assessed against project goals and desired levels of client satisfaction.

Project management maturity levels in defined areas are assessed as follows: integration management – level 1, scope management - level 1, time management level 4, cost management level 1, quality management level 1 and human resource management level 3. Figure 2 gives a systematic view of achieved maturity levels.



**Figure 2:** Maturity levels based on project management knowledge areas

In the selected company PMO is responsible for establishing processes, tools, methods, and patterns, as well as overseeing application monitoring. PMO does not hold any authority to manage projects and make decisions. The PMO is only involved in deciding whether an initiative is seen as a project or not. However, individual project executions require approval from higher management. The existing PMO provides access to tools and information while also overseeing the implementation of defined patterns. Project team members have responsibility towards their functional and PMO managers. The members of project teams show a lower level of awareness and consider adopted patterns and standards unnecessary to deliver value to the customers. This is due to the lack of project management competencies and experience in a project environment. In critical situations, PMO lacks decision-making authority. Currently PMO does use a software tool for improving portfolio management.

It can be stated that the company is prioritizing project portfolio management to create suitable combinations of projects and is implementing a hybrid project management approach. The company recognizes that the

potential benefits of portfolio management outweigh those achievable through individual project management alone.

Based on the PMMM<sup>sm</sup>, the company predominantly exhibits a lower level of maturity, except in the time and human resource knowledge areas. This indicates that the company places greater emphasis and priority on these aspects. Greater PM maturity developed in human resource segment can be explained through labor shortage and fluctuation noticed in logistics and supply chain industry in the Serbian market (Kilibarda et al., 2019). On the other side, time and cost became highly demanding factors for logistics industry (Mishra, 2018), which shows why the company focused on improving time management within project management, yet still reaches lower maturity level in cost management.

The company has implemented a controlling PMO type. The decision was taken to effectively handle a large volume of clients and development projects. Furthermore, the company introduced a single PM software solution to support its project management efforts. Key benefits highlighted included intuitive interfaces and a high level of functionality, enabling employees to manage their work and project progress through a single platform. An important advantage that was emphasized is the user-friendly perspective, which made it easier for employees to adopt and transition to this solution (Yamada, 2023). Additionally, the company could consider adopting other software solutions which could contribute to the further improvement of portfolio management.

## 5. CONCLUSION

The paper consisted of two main segments which are literature review and the case study from the industry. The answer to the first research question regarding implementation of PMO shows that Transport & Logistics companies need to develop PMO for governing a high number of complex projects (SCM Concept, 2014). To implement PMO in a successful way, Transport & Logistics companies basis needs to be considered and understood attentively. These companies undertake two types of projects: first group represents project for external and second group projects for internal needs. They conduct projects for clients and projects for business development purposes. In other words, Transport & Logistics companies execute business core projects and projects aiming technological development. Both of these are equally important yet have completely different nature. For that reason, they cannot be treated the same, but rather require patterns, methods and processes tailored according to their characteristics. Based on this research, it is proposed that Transport & Logistics companies establish two separate PMOs (Müller et al., 2013). One office would focus on core business projects, while the other would concentrate on fostering consistent technological advancement through projects. Thereafter, both PMOs must separately define appropriate patterns standardized for each project group.

The answer to the second question regarding appropriate PMMM for Transport & Logistics companies was demonstrated through conducted case study and showed that PMMM<sup>sm</sup> can successfully be applied for evaluation of these companies. This model does not give just perfunctory insight, but rather thorough and in-depth maturity level analysis. For companies that belong to such highly dynamic and technologically intense industry, it is immensely important to identify areas that have not been developed to an appropriate degree and based on that take further needed action (Domingues & Ribeiro, 2023), which is what they can comprehend and infer through PMMM<sup>sm</sup>.

This research showed that a Project Management Office (PMO) could simplify project management in the Transport & Logistics sector. The study also identified PMMM<sup>sm</sup> as the most suitable and useful model for this sector. These research results serve as a guide for project and strategic managers in the Transport & Logistics sector in making decisions about potentially restructuring the organizational structure to enable better project management and greater project success, ultimately leading to improved business outcomes for the entire company.

## 6. LIMITATIONS AND FUTURE DIRECTIONS

The scope of this research is limited by the small number of companies included. Future studies should examine more companies internationally for broader insights. Another limitation represents the number of knowledge areas that have been examined. Based on initial PMMM<sup>sm</sup>, six knowledge areas were considered through this study, but in the future research, all of the areas should be encompassed. Furthermore, expanding the study to include and validate multiple Project Management Maturity Models could deepen the research significantly.

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# CROSS-CULTURAL ANALYSIS IN INTERNATIONAL PROJECTS

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**Abstract:** *This paper examines the cultural variations in international projects and compares and contrasts Serbia and Germany to highlight the distinctions and similarities between the two nations. The paper examines cultural and social variables that may have an effect on the project team. Five primary cultural dimensions are examined in this paper: Power distance, individualism, masculinity, uncertainty avoidance, and long-term orientation. Working in a setting with a different culture can provide a variety of challenges, but it can also have advantages for all parties involved. In conclusion, a rapidly expanding global economy and the requirement for project managers and teams with cultural intelligence and awareness are essential. The paper attempts to comprehend distinctions, offering insights based on Germany and Serbia as examples.*

**Keywords:** *culture, project, project manager, differences, analysis*

## 1. INTRODUCTION

In today's markets, most of the projects are international and are conducted of teams that have different cultural background. The globalization of business and fast economic growth has led many countries to participate in international projects, which could have both opportunities but also many problems. This kind of project allows a country and the individuals who participate in the project to gain new knowledge and collaborate with colleagues from all over the world. Cultural differences such as language, different basic knowledge, values, and beliefs are the elements that could impact a project's success. Differences in leadership style, decision making, risk consideration etc. can impact on project results, and could lead to misunderstandings and tensions between project teams. On the other hand, working with people from different cultural backgrounds could give a project team and a project manager different perspectives on a project solution, If cross-cultural projects are effectively lead they can be a source of innovative thinking and could create an experience that could make an organization a competitive on a domestic market.

This essay will look at all the cultural differences and common problems that come up in international projects with various cultural teams by contrasting Germany and Serbia. The article will begin by highlighting the relationship between culture and project management, defining multicultural teams, and outlining the key challenges that international projects face. The best practices for international projects, as well as common mistakes made by project teams and how to avoid them, will be discussed in the paper's conclusion.

## 2. CULTURE AND PROJECT MANAGEMENT

Economic progress has allowed the development of international projects. Many international projects have achieved huge success, but many of them have problems that usually come from misunderstandings of the multicultural risks of overseas projects. The difference in thinking and understanding is the main problem that intentional projects have. Therefore, this kind of project has become an important topic for many researchers. Culture is connected to shared beliefs, values, and behaviors that a group has. The culture was developed through experiences from the past that led to solving problems, which were then passed on to the new members of the group (Anantatmula, 2010). Culture is a way of life for a particular group of people, understanding different cultures and their concepts can result in a decrease of project failure. There are several social obstacles that effect international projects (Lin & Hukan, 2020):

1. Political factors
2. Social factors
3. Religion
4. Legal system



Beside social barriers that effect projects that have cultural differences there are also personal barriers (Lin & Hukan, 2020):

1. Educational level – basic knowledge of team members is different which makes implementation process difficult
2. Professional ethics – Different working style, job responsibility, efficiency
3. Acceptance of foreign colleagues –Local project managers have an issue with accepting foreign co-workers and their way of work which could cause a problem among the staff and could also impact the project result

### **Multicultural teams**

Multicultural teams are teams that are conducted of a several people that have different culture background and are usually from different countries. The main issues for those teams are inequality and the misunderstanding of a differences between team members. Domestic projects have problems that are connected with task coordination, decision-making, motivation, but multicultural teams among those problems have problems that are cultural differences. The project manager has a crucial role in coordinating a multicultural team, which means that he or she needs to adapt their way of working towards team members. Different cultures have different ways of leading meaning that some cultures are stricter and inflexible than others. Issues of working in multicultural teams are (Bartolčić 2020):

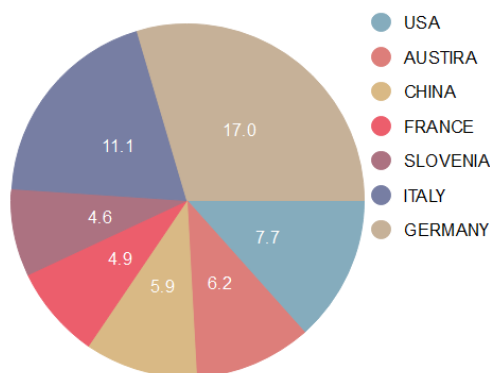
1. Communication – Different communication styles can affect project teams due to differences in verbal and nonverbal communication. For the project manager it is important to clarify what was discussed and to prevent any misunderstanding and protentional conflict in team
2. Problem solving and decision-making – In multicultural teams, members see solution of a problem in a different way. Usually the problem begins in different view of the moment when decision should be made or who in the hierarchy should make a decision due to cultural differences.
3. Leadership – Leadership styles are different due to a cultural background, for those reasons in multicultural teams' authority and the way that it is implemented can be difficult. Some of the team members are used to flexible leadership while others tend to comply to their leader.
4. Cultural intelligence – Working in a multicultural team implies that team members should have cultural intelligence, meaning that they can overcome differences and to effectively work and communicate with team members

### **3. SERBIAN INTERNATIONAL PROJECTS**

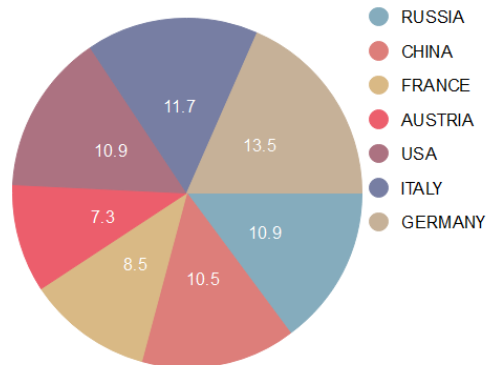
Serbia is a country in Eastern Europe that has 6 869 504 residents. Religion that dominates in Serbia is Christian religion, which 6 647 003 residents declare, in second place are Muslims with 278 212. The main language that is spoken in Serbia is Serbian language which is spoken by 5 607 558 residents of the country (stat.gov, 2022). Since 2007, Serbia has conducted more than 42 billion euros of foreign direct investment and has become one of the most attractive countries for international projects. Some of the companies that have been investing in Serbian projects are: Bosch, Siemens, ZF, Panasonic, Brose, Microsoft. In 2019. Serbia has signed over the 40-investment contract that has enabled residents of Serbia to find jobs in international companies and to have opportunity to work in international environment. (ras.gov.rs, 2020).

The biggest projects in Serbia are (ras.gov.rs, 2020):

1. Private sector development project – The project is financed by the United States government and is a part of an international development. Budget of a project is 4 159 987 \$.
2. Establishment and promotion of mentoring service for small and medium enterprises in the Western Balkans – The project is done in cooperation with the Japanese government and has the goal of increasing sales, creating better market presence, improving company organizations through a mentoring process that is conducted through an analysis of current activities and positions and defining future activities that can provide defined goals.
3. Swiss export promotion program – General project goal is networking and strengthening the capacity of exports from targeted sectors, the project is financed by the Swiss sector for economic relations



Picture 1– Largest foreign investors in Serbia (%), (ras.gov.rs, 2023 )



Picture 2 – Largest foreign investors in Serbia by value of projects (%), (ras.gov.rs, 2023 )

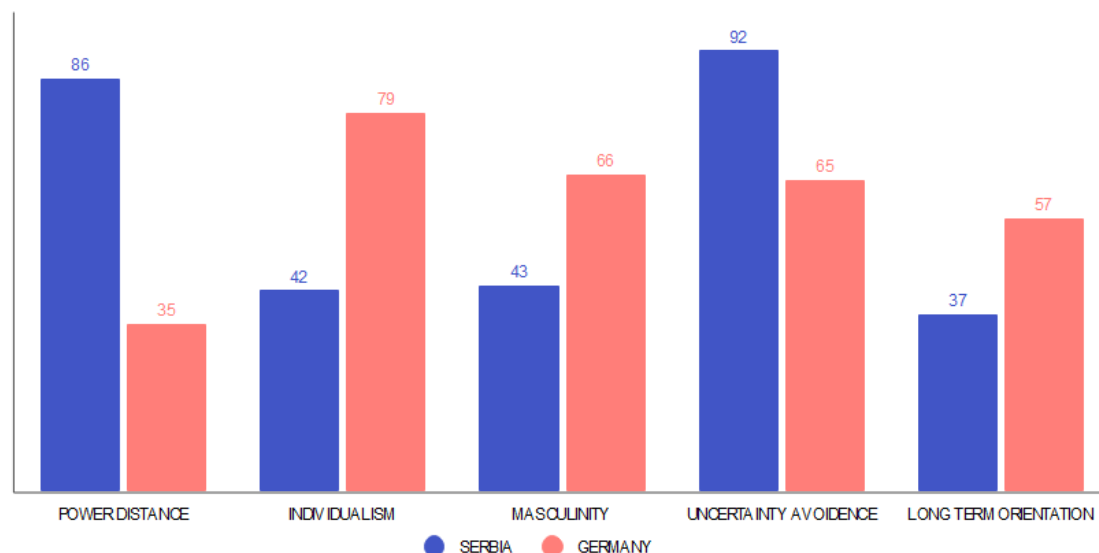
From the first picture, it can be concluded that the biggest investment that Serbia gets is from Germany, but when it comes to the value of the project it is visible that the biggest value Serbia gets from Germany, USA and China projects. Most of the investment goes to sectors (ras.gov.rs, 2023):

1. Agriculture, food and beverage (15,2%)
2. Automotive (17%)
3. Textile and clothing (7.5%)
4. Electrical and electronics (6,2%)
5. Construction (5%)
6. Machinery and equipment (4,7%)
7. Wood and furniture (4,3%)

Working on projects that are international and have foreign investors can impact on a project due to different cultures and ways of working. Since one of the biggest investors in Serbia is Germany the analyses of cultural differences in international projects will focus on this country. Hofstede defined five cultural dimensions (Hofstede,1994):

1. Power distance – In a team there are less powerful and more powerful members and those members who are in subordinate positions expect that the power isn't divided equally
2. Individualism versus collectivism – Dimension where individualism is focused on individuals who are oriented more on themselves than on others, on the other hand, collectivism is the opposite and is focused on creating strong society that should work together.
3. Masculinity versus femininity – In cultures in which masculinity is more represented, there are more gender differences in company hierarchy and company roles. In this case, men are more focused on success, leadership, and material success while women are modest, and focused on family, quality of life, etc.
4. Uncertainty avoidance – Refers to cultures where its members feel comfortable or uncomfortable due to surprising and unknown situations
5. Long term versus short term orientation – some cultures accept longer time to achieve material, social and other rewards. Long term cultures are focused on creating and developing stronger positions and are more tolerant when it comes to expecting a result.

Picture number three compares Serbia and Germany as the biggest investors in Serbian projects, in the context of cultural differences. Power distance in Serbia was measured by Hofstede and has shown that it is 86, meaning that authority in Serbia is connected with higher positions in hierarchy. Countries that were a part of Yugoslavia have high results when it comes to power distance, mostly because of the past political regime, on the other hand Serbian culture tends to resist authority. Serbian culture is defined in a way that team members expect from their managers to provide them with the information and tasks that they are obligated to do, which highlights differences in a position and their authority. Nevertheless, Germany has a lower power distance index, 35, meaning that there is a tendency toward equality and that position is not necessarily associated with authority. Germany still has a middle class and tends to adopt effective communication in projects because on the other hand it could demotivate project teams.



**Picture 3 Comparison between Serbia and Germany (hofstede-insights.com,2023).**

Individualism in Serbian culture is lower than in Germany, which implies that in Serbia there is an orientation to teamwork and collectivism. The culture believes in family values and respects tradition, which can lead to slower acceptance of different ways of working. For the Serbs it is common to be loyal to team members and to take responsibility for members of a group. In contrast Germany's culture has a high index of individualism, they are mostly focused on their small family circle. The German culture is stricter and tends to have honest and transparent communication even if it is negative, they tend to learn from their mistakes.

Serbia is country with higher feminist rate and is oriented towards balance, conflicts are resolved through conversation. German cultures have high masculinity index meaning that they are more competitive, from the early age children are raised to go to the best schools and be the best students so they can contribute to society.

Uncertainty avoidance in Serbia is high meaning that Serbian culture avoids risks and works in an environment that can change, the reason can be found in the past since Serbia is a country that has suffered many political challenges, wars, and changes throughout history, the fear of change is common in this culture. Germany has a lower uncertainty index than Serbia, and it is a country that prefers information before deciding. In Project Germany, people usually try to find a second opinion if there is any kind of uncertainty. They mostly rely on their expertise when they make any decision.

Long-term orientation is lower in Serbia mostly because of the lower income that families in Serbia have. Uncertainty from the past and an underdeveloped economy had an impact on this cultural phenomenon. Serbian culture is normative, they respect tradition and tend to focus on goals and results that can be achieved faster. On the other hand, Germany has a higher index than Serbia and tends to embrace changes and develop a country's economy. German society is pragmatic which is opposite to Serbia's, they tend to be flexible and adapt to a situation, and they easily adapt to new things and traditions.

Working with Germany on an international project can have a positive effect on Serbian teams, even though there are many differences in cultural dimensions. International projects with different cultures provide both sides with new knowledge and experience. Since Serbs consider it difficult to embrace new, unconventional methods and procedures in their work, Serbian teams can learn from German teams how to be more adaptable while accepting changes in the organization. However, German teams should benefit from a greater understanding of Serbian collectivism and teamwork, which could improve project performance and outcomes. Project managers and teams working on a project must become familiar with the cultural differences between Serbian and German cultures in order to avoid potential conflict or complications during the project. These cultures differ greatly in terms of beliefs, values, and working methods. To increase the team members' cultural intelligence, the organization must train a project team about cultural differences. In this way stereotypes and assumptions about different cultures can be prevented. Since communication in German cultures and Serbian cultures is different, the fact that Germans are more straightforward than Serbians can impact communication in a team and result in a conflict. A positive team environment can arise from training that addresses how these two cultures communicate. It is crucial to establish a working atmosphere between these two nations where both parties feel free to share their ideas and take criticism.

#### 4. CONCLUSION

Project managers should become more skilled so their knowledge and working methods can handle the many types of projects, as the global economy is changing quickly and individuals are dealing with more international projects. Global marketplaces are only going to get bigger, so managing cultural differences and changing environments will be essential to an organization's success in a global society.

Analyses that were carried out have shown that cultural differences are a big part of a project. Various approaches to leadership and communication styles can have an impact on how well a project performs; for this reason, project teams involved in various cultural contexts should receive appropriate training. Based on the examples of Germany and Serbia, it can be said that working in a diverse environment is feasible, but that both parties must accept one another's differences.

Working in an international environment can be beneficial for all parties involved, mostly because these teams are more innovative and have a broader perspective on the project. The analysis indicates that although Germans are primarily focused on their own performance and achievement, Serbians struggle with adapting. It is important to recognize the distinctions between these two cultures and to adapt them.

The main mistakes that are made in international projects are:

1. Applying domestic management strategies
2. Limited international project experience
3. Language barriers
4. Dominance of one culture over another
5. Historical, religious, and geographical differences
6. Low understanding of local communities, laws
7. Low understanding of social situations (Lin & Hukan, 2020).

To avoid mistakes, the project manager should minimize any stereotypes and misconceptions that could arise in a project team, and the team should be culturally aware. Teams that collaborate, accept criticism, and foster a positive work atmosphere can enhance the final results of a project.

In the paper was not possible to demonstrate the theoretical framework in the form of a model that could explain cultural factors, communication barriers, trust, and other issues due to word and page limitations, and how they affect a project that involves other cultures; also, there were certain restrictions on the methodology and data findings. A deeper analysis of the subject matter in relation to Serbian initiatives and the cultural distinctions among the teams involved in those projects could be undertaken.

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# EXTENDING THE SCRUM FRAMEWORK BY INTRODUCING CONCEPTS FROM THE TRADITIONAL APPROACH TO INFORMATION SYSTEMS DEVELOPMENT

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**Abstract:** *The study contains an analysis of IS development approaches, with a particular focus on the Scrum framework, which is one of the agile methods. The proposal is to extend the Scrum framework by adding activities from the traditional IS development approaches. According to the proposal to extend the Scrum framework, the simulation of IS development monitoring was performed in a project with two different approaches: Scrum and extended Scrum frameworks. The results of implementing the same system functionalities using these two approaches were recorded, and a comparative analysis was conducted.*

**Keywords:** *Scrum framework, extend the Scrum framework, the traditional IS development approaches, comparative analysis*

## 1. INTRODUCTION

The design process of IS (*Information System*) may use traditional or agile approaches. The chosen methodological approach should suit the organisation, depending on project size, development complexity, existing resources, and other factors.

Every particular approach brings some positives, but also limitations in practice. For example, more comprehensive projects need detailed user requirements analysis and documentation, and in that scenario, organisations typically use traditional approaches. In contrast, agile methods are used on projects with no mandatory comprehensive documentation, focusing on flexibility of delivery and good communication inside the team. The Scrum framework is one of the most popular and used representatives of agile approaches.

This paper aims to research and analyse the possibilities for Scrum extension with concepts from traditional approaches to overcome some of its limitations and broaden the domain of applicability. This paper contains detailed specifications of Scrum extension and a comparative analysis of practical application development using Scrum and extended Scrum.

The rest of the paper is organised as below. Chapter 2 contains characteristics of the Scrum and traditional approaches, like the Waterfall. Chapter 3 has detailed specifications of the Scrum extensions with elaborated newly introduced phases and activities. Chapter 4 presents a practical example of developing part of IS for housing loans. The simulation of IS development is shown from two angles: using Scrum and the extended Scrum framework, after which the comparative analysis was conducted using a group of indicators. The last chapter contains conclusions and further research directions.

## 2. AGILE AND TRADITIONAL APPROACHES OF DEVELOPMENT IS

In front of managers is the challenge to develop a software product with resource limitations in a certain time interval (Charvat, 2003). They should choose which model is appropriate for software development and achieving the best results on their project (Brewer, 2022). In past years, software development using the agile approach has more often appeared (Woodward et al., 2010). The Scrum framework is among the most popular software development approaches (Due Kadenic et al., 2022). It is considered that compared to traditional teams, agile teams create better software quality, which fulfils all business requirements and decreases costs (Cohn, 2010). Also, agile approaches do not dictate detailed planning in the beginning, and

agile approaches are already designed to adapt to changes in requirements during the project (Milošević, 2018).

On the other hand, traditional approaches are designed for projects that have exact requirements; the client exactly knows all needed functionalities, and there is no deviation (KPIPartnersNewsTeam, 2018). Details about the project are designed and defined before the beginning of the project (Scio, 2022). On projects where requirements are often changing, costs are higher because removing the deficiencies in later phases is complex (CaseStudy, 2022). For the final product, with the help of the agile approach, functionalities could be delivered often after smaller iterations. With the traditional approach, this is not the case, and the client waits for the results until the end of the project (Cohen, 2010).

## 2.1. THE SCRUM FRAMEWORK

Agile is a methodology, and Scrum is a framework (Stanley & Gross, 2020). The Scrum framework is used for incremental access in managing projects, which produces quick and flexible project completion (Lucid Content Team, 2014). The project is divided into smaller logical units with shorter execution iteration (usually 1 to 3 weeks). That iterations are called Sprints (Bibik, 2018). The Scrum has five phases: *Initiation, Plan and assessment, Implementation, Review and perspective, and Delivery (Production)* (Satpathy, 2016). Each phase contains different processes (Stanley & Gross, 2020).

Phase **Initiation** contains processes: Creating a project vision according to the business cases. In this phase, the project owner should be identified. The development team is a part of the Scrum team, which is responsible for organising their work by following assigned tasks (Schwaber & Sutherland, 2017).

The next phase is called **Plan and assessment**. It includes creating a User Story, usually made by the Product Owner and designed to imply clear and understandable client requirements. Further, the User Story should be approved, and the time is estimated (Satpathy, 2016).

The product value is created in the **Implementation** phase. The team creates results and delivers functionality at the end of the sprint (*Sprint Deliverables*), according to created tasks in Sprint Backlog (Schwaber & Sutherland, 2017).

The central part of phase **Review and perspective** is activity convocation of SoS (Scrum of Scrums) meetings, where team members meet and check project progress, impediments, and collaboration between teams. SoS is characteristic of projects with a few Scrum teams (Satpathy, 2016).

The last phase, **Delivery**, involves two processes: final product delivery (*Ship Deliverables*) means that the approved final product can be delivered to the client. The second process is project retrospective (*Retrospect Project*), which includes project member meetings to do project retrospectives (Satpathy, 2016). Every iteration adds a new little value on the way to the final result (Stanley & Gross, 2020).

In general, the Scrum framework resolves bugs faster and easier. However, project specifications and project adaptation to new needs should be updated often because the focus is not on the detailed analysis of requirements. One of the disadvantages of the Scrum framework is modest documentation. Despite this, the initial plan of design and software implementation in the first phase of Scrum is not widely represented. Because of that, it is important to conduct tests and validation according to business requirements after implementation to eliminate comprehensive requirements change. These identified disadvantages opened a space to extend the Scrum framework by introducing concepts and activities of traditional approaches.

## 2.2. TRADITIONAL APPROACHES FOR IS DEVELOPMENT

Unlike agile, traditional IS development approaches are based on a one-way flow of software development (KPIPartnersNewsTeam, 2018). The implementation phase has linear execution using a sequential approach. It means the next phase can only start when the previous phase is done.

Software development phases in traditional approaches are Collecting requirements and creating documentation, *System design, Programming and creating Unit tests, System testing, User interface testing, Resolving bugs, and Software delivery* (Scio, 2022). Every phase has specific results, and in each of them, project team members refresh and add new details about project flow in documentation (KPIPartnersNewsTeam, 2018).

One representative of traditional approaches to managing software development is the Waterfall model. The Waterfall model is the most convenient for projects that take less time and have clearly defined requirements created initially (Lucid Content Team, 2014). Project members are always notified about changes and

development flow, from building to closing. The documentation contains the user interface, user requirements, and all variations of outcomes (Adobe Communications Team, 2022).

Detailed analysis is done in the early project phase, reducing the probability that initial requirements are misunderstood or that requirements could be changed in the meantime (Academy Nis, 2017). The Waterfall model could also be used to deliver a specific version of the ERP system (Bjeladinović, 2018).

The first phase is vital to successful software development because the project is analysed in detail, and all needed information is collected (TeamGantt, 2020). More time is planned for this phase to get more precise user requirements. In the analysis and design phase, designers should create and design all project parts. Project specifications and information are in the documentation, as well as created diagrams.

At any moment, project members could get information about the project flow. During software development, the programmer follows documentation specifications for all project parts (Lucid Content Team, 2014).

In contrast to Scrum, the Waterfall model in the test phase specifies Unit tests for all code units. Nevertheless, testing features are realised following the documentation, which contains details about user expectations and technical information. The documentation is supplemented in each phase and at the end of the project as the organisation's knowledge. Based on that, it is easier to establish faster product delivery and product maintenance in the future. Further, the documentation contains time estimation, cost analysis, and the time spent on each activity. Previously mentioned activities are taken as the recommendations for the Scrum framework expansion.

### 3. THE SPECIFICATION OF THE SCRUM FRAMEWORK EXPANSION

The expansion of the Scrum framework is reflected in the adoption of activities from the Waterfall model, which would potentially improve the software development process. Based on the identified drawbacks of the Scrum framework, it is possible to improve the software development process using the extended Scrum framework. It is proposed to improve performance in the team, reduce waiting times between tasks and phases, create detailed documentation for the project, obtain information about project implementation more quickly and achieve greater satisfaction in the team.

Based on the conducted analysis, there are some activities from the Waterfall model that combine well with Scrum. These include *Completing documentation after each phase and sprint*, *Initiating the requirements collecting phase*, *Selecting the requirements collecting technique*, *Creating a documented list of all requirements*, *Modeling development flowcharts*, *Technical analysis of requirements*, *Creating an initial application design*, *Estimating time for User Stories and Tasks in the analysis phase*, *Sharing documentation internally*, and *Reviewing results based on the documentation*. Team members are kept informed of activities and implementation at all times based on the documentation.

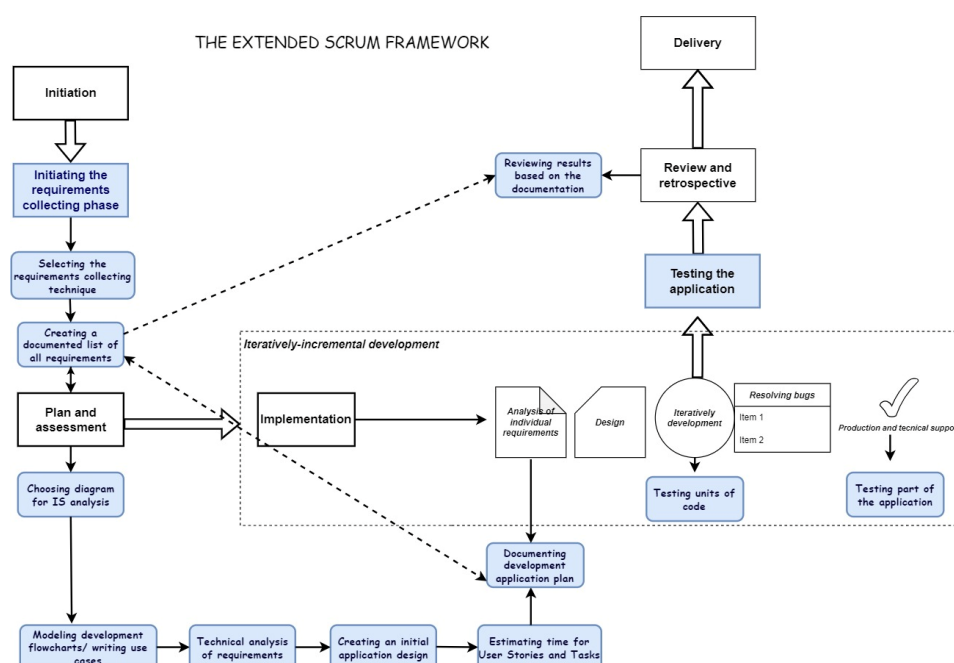


Figure1 – The extended Scrum framework diagram



Figure 1 shows the extended Scrum framework diagram, which contains new phases and activities adopted from traditional approaches. The adopted activities and phases are coloured blue, while the phases of the Scrum framework are coloured white. The phase names are in a rectangle, and the activities are in a round rectangle.

The diagram shows the project realisation process through the phases of the extended Scrum framework. **The requirements collecting phase** is adopted and refers to selecting the requirements collecting technique and creating a documented list of all requirements.

In the **Plan and Evaluate** phase, the activities are extended so that a selection of modelling diagrams can be made as part of the analysis of IS. A more detailed technical analysis is then carried out, the application's initial design is proposed, the time required for takes is estimated, and everything is documented. The application design plan in the documentation contains the entire analysis, logical modelling and design of the IS.

In the **Implementation** phase, parts of the software solution are developed iteratively. The activities are repeated in each sprint: individual requirements analysis, design, development of the functionality, testing of the code units, correction of errors, finalisation of the development and testing of this part of the application (one functionality).

The **Test** phase involves testing the entire application. Each functionality is tested, and all use cases are checked. The testing phase means that bugs are fixed faster and new versions of the software solution are made available.

Once all bugs have been fixed and the application has been thoroughly tested and approved, the **Review and Retrospective** phase follows, in which the results achieved are analysed using the documentation. An assessment is made of how much the documentation has helped with the development, whether and to what extent the project has proceeded " according to plan ", and whether the project has been successfully implemented in line with the expectations and requirements of the application users.

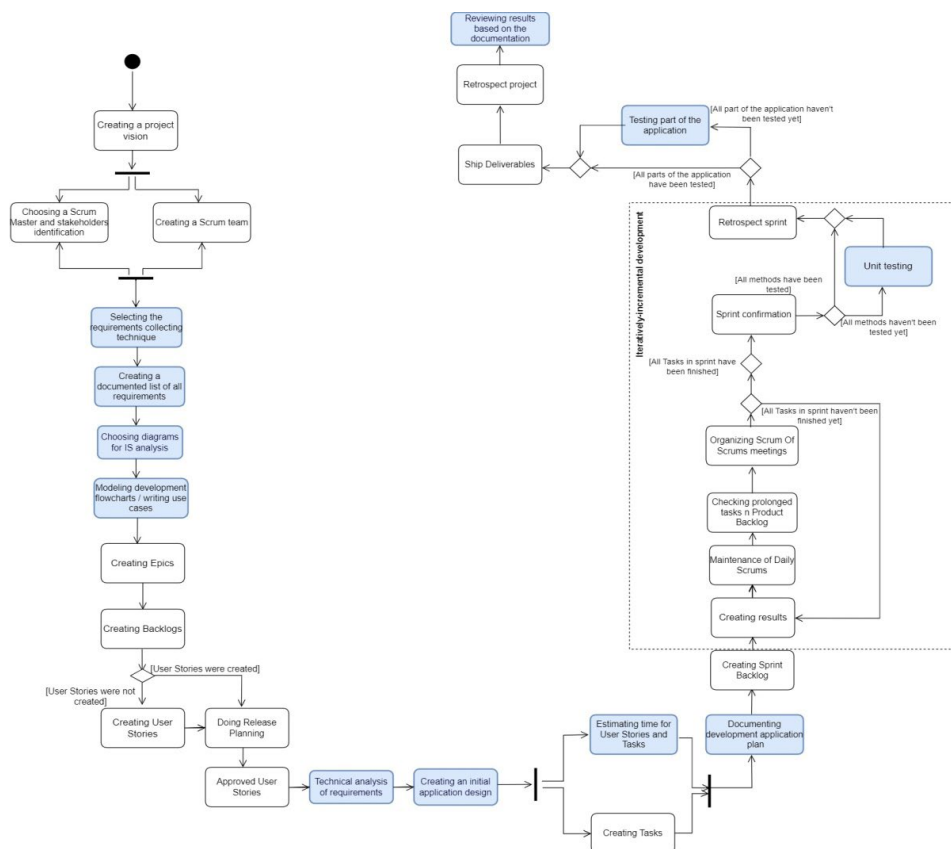


Figure 2 – The extended Scrum framework Activity diagram

Figure 2 shows all activities (without specifying phases) in the extended Scrum framework in detail. As in the previous diagram, activities introduced from traditional approaches are coloured blue and activities from the traditional Scrum framework are coloured white.

#### **4. COMPARISON OF THE USE OF THE SCRUM FRAMEWORK AND THE EXTENDED SCRUM FRAMEWORK USING THE EXAMPLE OF WEB APPLICATION DEVELOPMENT**

With the aim of simulating the use of the Scrum framework and the extended Scrum framework with identical requirements and a comparative analysis of the results obtained for both approaches, part of the IS is implemented for the following loan repayment plan. The performance evaluation of the two approaches is carried out using indicators: (1) the number of errors, (2) the time spent, (3) the number of meetings and communication effort, (4) the cost, and (5) the result achieved (functionalities implemented). The performance of these two alternatives (the original and the extended Scrum framework) based on the above indicators is explained in one of the following chapters.

##### **4.1. CREATION OF THE WEB APPLICATION**

Microsoft Visual C# is chosen for the development of the business logic within the application. C# is an object-orientated programming language for creating applications under Microsoft .NET (Sharp, 2007).

C# is used to create an API service (web service) in the background, with GET, PUT and DELETE methods that are called from the front side (Angular application). Each method in the API service calls a specific procedure in the Credit database where the data is manipulated, and the application form that users can see was created using the Angular framework.

The web application contains the main Credit form with the repayment schedule items and the Credit Search form, where users can search and edit existing loans in the banking system. A Gantt chart in Excel was used to track the application development results in both ways.

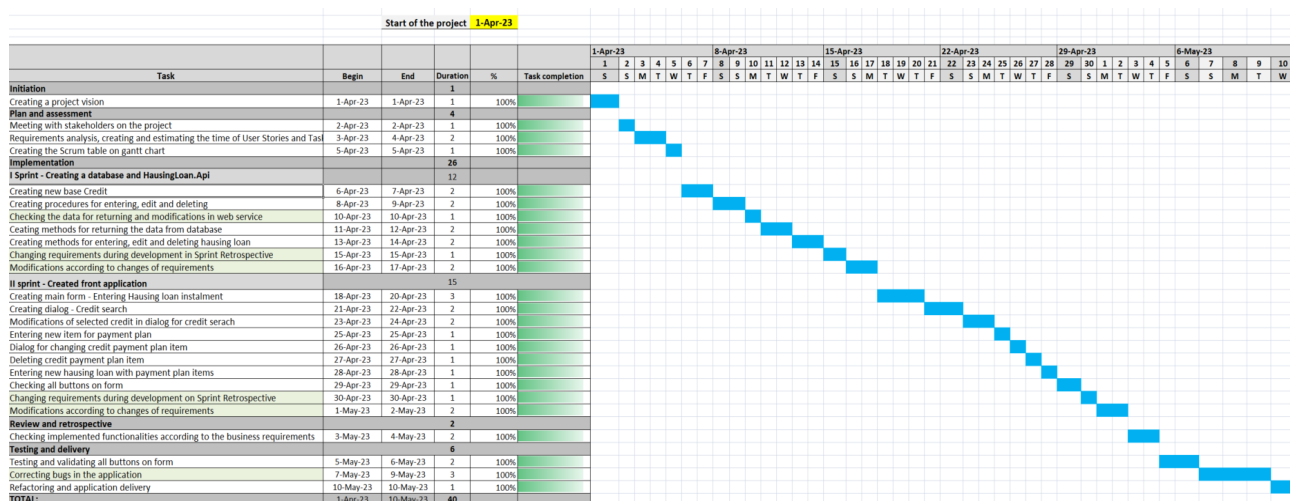
##### **4.2. APPLICATION DEVELOPMENT WITH THE SCRUM FRAMEWORK**

The application for a housing loan is created using the Scrum framework and implemented in five phases: Initiation, Planning and Evaluation, Implementation, Review and Retrospective, Testing and Handover. Initiation includes the creation of the project vision, i.e. the definition of what the creation of an application is all about.

The planning and evaluation phase begins with a meeting in which all those involved in the project participate and in which the goals and requirements of the application are defined. There are two sprints in the implementation phase. The first sprint lasts twelve days, the second fifteen days. Two meetings are organised (one in each sprint) to obtain additional information about the functionalities to be implemented. The requirements were unclear, and more time was wasted on research during implementation.

After the first sprint, the application part was still unknown, because the requirements were unfinished. Additional changes were made, which took several days. In the second sprint, which lasted fifteen days, the web application was created. In the beginning, the design of the application was exactly as it was understood in the meetings and as it was described in the requirements. It was, therefore, necessary to confirm at the meeting whether the user interface met the requirements.

As in the first sprint, in the second sprint, after the implementation of the functionality was completed, it was necessary to conduct a sprint retrospective, thanks to which feedback was obtained from the application users. Two changes were made to the form for the functionality of filling in and deleting new instalments, so additional work was required. In the review and retrospective phase, the implemented functionalities were compared with the original business requirements. All requirements were rechecked to see if there was anything that had not been implemented. In the final phase, the test and delivery phase, the application was tested, i.e. all functionalities. After the testing phase, five bugs were identified, all of which were fixed within three days.



**Figure 3 – Gantt chart – Development of the application using the Scrum framework**

Figure 3 shows a Gantt chart with the application development process for the instalment payment of a Hausing loan according to the Scrum framework. The dark grey lines contain the names of the phases. One programmer worked on this project, but the Scrum framework has three members (Scrum Master, Product Owner and Programmer). The project lasted forty days. It was predicted that the project would take thirty days, so the deadline was extended by ten days. The activities that were subsequently implemented and did not correspond to the plan were coloured light green in the Gantt chart.

### 4.3. APPLICATION DEVELOPMENT USING THE EXTENDED SCRUM FRAMEWORK

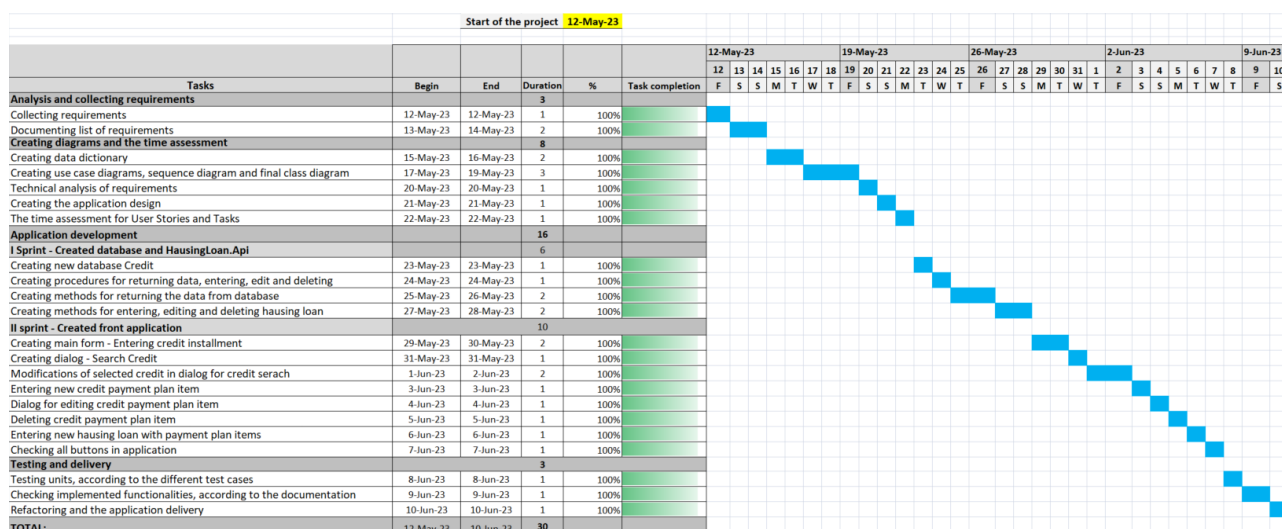
After the application development using the Scrum framework was completed, the same application development was started using the extended Scrum framework. After the development was completed in this way, the benefits of using the extended Scrum framework were also investigated.

Firstly, all activities were defined, and the time required was estimated. The development of the application was continued by monitoring all activities included in the extended Scrum framework. After project initiation, the first phase within the extended Scrum framework consists of analysing and gathering requirements, diagramming and time estimation (plan and assessment), application development, testing and delivery.

Most of the time was spent on the first two phases. If they are carried out properly, it can save time in the overall project implementation. If the requirements are more straight forward, the implementation phase is faster and takes less time. The development phase comprises the implementation of the application within defined sprints. Thirty days were needed to develop and test the entire application. The activities are divided into two sprints: Creation of the database and the HausingLoan.API and, in the second sprint, the web application creation. For the first sprint, six days were needed to create the new database credit with all tables and columns. The programmer created all procedures in the database using the defined tables. The procedures are called by the API service in a specific format. During the API development, unit tests were created for each method, and the web application was tested against the defined use cases. The aim of writing unit tests is to recognise disadvantages and errors during development and to rectify them in good time before the application is delivered.

The second sprint lasted ten days. During this time, the programmer implemented a web application in Angular. After a detailed analysis and documentation, which is mandatory in the extended Scrum framework, the implementation phase was accelerated, and two meetings were held: an initial meeting with questions for the application user and a meeting before the test phase to check all functions.

Figure 4 shows the Gantt chart used to develop the application according to the extended Scrum framework. The project was started on 12.5.2023 and was completed by 10.6.2023. The project was successfully completed according to the estimated plan. The duration of the individual tasks is indicated in the calendar. In addition, the project progress for each task was noted as a percentage during the project.



## 5. ANALYSIS OF THE RESULTS ACHIEVED

By applying these two approaches in parallel, performance was measured using selected indicators and the results were analysed.

**The errors** are the first indicator for comparing these two frameworks. Gantt charts show for both cases. In the case of extended Scrum, defects are less represented and are fixed during the testing phase. The number of bugs that occurred during application development with Scrum is five, while in the case of extended Scrum, two bugs were detected and fixed.

The Scrum framework was used to show the changes in the implementation phase. Initially, the requirements were unclear, and more meetings had to be organised to define the requirements better. After the retrospective and the two sprints, two changes were made. Six working days were spent on the corrections, so the conclusion is that the implementation phase was extended. The development went according to plan.

**Time** is the second indicator with which these two frameworks are compared. Thirty days were estimated for the application development according to the Scrum framework, but the development was completed in forty days. The time estimate did not coincide with the time required for application development, so the deadline for production was extended. On the other hand, according to the extended Scrum framework, the application was implemented in thirty days and estimated at such a time interval.

The number of **meetings and communication** between project participants was lower when using the extended Scrum framework than the traditional Scrum framework. Two meetings were held, one at the beginning of the first phase when the terms were agreed and the second before the testing phase. In the project where the Scrum framework was used, five meetings were organised, one at the beginning and two meetings in both sprints. Based on the analysis of the time spent on project development, the Scrum framework allows more time to be spent on application development. Accordingly, programmers are paid by the working day, and the costs are higher in this case, so the cost of ten programming diaries is higher when using the Scrum framework.

The implemented application aimed to simulate the use of these two analysed approaches and simultaneously offer support for the bank in its work, as it is easier to record the repayment rates for a household loan with this application. In both cases, the same application has been implemented with the same functions. These two frameworks, compared in terms of the result value obtained, both have the same performance.

**Result** implies the overall impression of the work on the project and the results delivered. The satisfaction of the employees, the quality of the delivered application, the simplicity of the solution, the number of delivered functionalities, the number of errors, the execution time, the cooperation and the availability of resources should be measured. By using the extended Scrum framework, the programmer was not under significant pressure as he was able to develop faster and without additional research due to the documentation.

When using the Scrum framework, the number of changes and consultations was more significant to complete everything required of the application. Also, with Scrum, additional effort and more considerable uncertainty for the programmer were present.

## 6. CONCLUSION

During the development of the Hausing loan application, it was found that developing the application with the extended Scrum framework took less time than with the standard Scrum framework. Based on this example and the simulation carried out, it can be concluded that costs and time are reduced with the extended Scrum framework. Assuming that it saves money and time in developing applications, organisations can consider using the extended Scrum framework when developing IS. Of course, these are only the results of a single simulation. The next step would, therefore, be to compare these two frameworks with several projects in practice.

One way to improve the Scrum framework and extend this work is to adopt the activities of the agile framework (Kanban, DSDM) or other representatives of traditional approaches, depending on which organisation would potentially increase their efficiency. Another way to extend the Scrum framework could be to add activities that do not belong to either approach. A possible extension of the Scrum framework could be to add new activities that relate to more frequent communication with the application users so that the successful execution of more miniature development stages in the project can be tracked more easily.

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# ANALYSIS OF THE MOST USED MODELS OF HYBRID PROJECT MANAGEMENT

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**Abstract:** *This paper explores hybrid project management, an approach combining elements from various project management frameworks to tailor them to individual project needs. This paper delves into the significance and concept of hybrid project management, examining various models and their main characteristics. In this paper, four primary hybrid models are scrutinized: Water-Scrum-Fall model, Waterfall-Agile model, Hybrid V-model, and Agile-Stage-Gate model. While hybrid project management offers numerous advantages, such as flexibility, adaptability, and improved project outcomes, it also presents challenges such as the need for methodological expertise, heightened administrative tasks, and comprehensive communication requirements. However, research suggests that the application of hybrid approaches often yields better results than using a single approach in every situation, especially in today's complex and evolving project environments. In conclusion, as environments, technologies, and client demands evolve, there is a growing need for further development of new hybrid project management models. This paper contributes to understanding the landscape of hybrid project management, providing insights into its strengths, weaknesses, and further development.*

**Keywords:** *Hybrid project management, Traditional project management, Agile project management, Project management approaches.*

## 1. INTRODUCTION

Hybrid project management is a dynamic approach which combines components from diverse project management frameworks, empowering customization to match the unique needs of each project. Integrating multiple approaches enables organizations to leverage the advantages of each while minimizing their limitations. This project management approach maintains essential structure while fostering creative decision-making, ultimately enhancing product quality and user satisfaction (Ostrowercha, 2023). Hybrid project management represents a combination of different project management approaches, such as Traditional (Waterfall) project management, Agile project management, Critical path method (CPM), PRINCE2, Six Sigma, Outcome mapping. The most common hybrid project management models represent a mix of traditional and agile project management (Boogaard, 2022). The traditional Waterfall approach is characterized by its linear and incremental nature, featuring well-defined phases. Its linearity entails progression from one phase to the next without revisiting previous stages. On the other hand, agile project management emphasizes seamless communication, active user participation, streamlined documentation, and iterative development to swiftly deliver outcomes in ever-evolving environments (Hillaire, 2018). The agile approach is more people-oriented than process-oriented, adaptive, and prioritizes adapting to changes over sticking to a plan. There are several frameworks within the agile approach: Scrum methodology, Dynamic systems development methodology, Extreme programming, Crystal, Adaptive software development, Lean development and Future-driven development (Miković et al, 2023). However, there are also hybrid models in which, instead of the Waterfall model, another form of traditional project management appears, such as the V-model and Stage-Gate model, which are similar to the Waterfall model, but involve a testing and evaluation phase by users after each stage to ensure the development of a product of appropriate quality and functionality. Hybrid project management has evolved due to shifts in the environment, advancements in technology, the growth of diverse industries, and evolving societal demands to enhance both project results and organizational performance (Bushuiev & Kozyr, 2020). Studies indicate that organizations, impacted by these transformations, are reshaping their approaches and adopting hybrid models. This adaptation of project management systems offers them flexibility, resilience in fluctuating conditions, and sustainable business strategies (Miković et al, 2023).

The subject of this scientific paper is the review of different hybrid project management models and their main advantages and disadvantages. At the beginning of the paper, in the introduction, the significance and concept of hybrid project management are described. The main part of the scientific paper outlines the main characteristics, similarities, and differences among various types of hybrid project management models.

Finally, the paper concludes with the main findings and reflections on further development of hybrid project management.

## 2. HYBRID PROJECT MANAGEMENT MODELS

The focus of the conducted qualitative research is to explore different types of hybrid project management models. Depending on how different elements of traditional and agile project management are combined, there are the following four models of hybrid project management (Reiff & Schlegel, 2021): Water-Scrum-Fall model, Waterfall-Agile model, Hybrid V-model and Agile-Stage-Gate (Scrum-Stage-Gate) model. All these models will be more closely in the paragraphs below.

### 2.1. Water-Scrum-Fall Model

The Water-Scrum-Fall approach melds the conventional Waterfall approach with agile Scrum practices. It operates on the behalf that a project needs a solid framework, which is provided by Waterfall approach, while incorporating agile steps. In this setup, Scrum guides the development phase, known for its iterative and adaptable nature (West, 2011). Waterfall is a well-known and straightforward sequential model in traditional project management, where each project phase is tackled sequentially. Each phase must be finalized before moving on, and revisiting previous stages for adjustments is not possible (West, 2011). Scrum, on the other hand, is a prominent agile framework, emphasizing iterations, incremental progress, self-managing teams, and adaptability to changing requirements (Fernandes et al, 2020). This framework breaks down the project into sprints – short, structured cycles lasting two to four weeks. Each sprint starts with planning, proceeds with feature development, and ends with a review session with the client. The client's involvement and feedback shape the project's direction throughout (Deregowski & Ziolkowski, 2014). In the Water-Scrum-Fall model, the initial phase involves planning using Waterfall, where time, budget, scope and requirements are defined. This phase sets the groundwork, creating documentation and establishing initial commitments. The subsequent phase employs agile methods for development, promoting flexibility and reducing risks, such as delays and rework (West, 2011). The model facilitates a distinct separation between testing and development, incorporating testing into the release process. Once all requirements are met, the agile phase concludes, transitioning to a traditional approach for the final stages of projects (West, 2011). Water-Scrum-Fall serves as a transitional bridge for companies moving from traditional to agile methods. It introduces Scrum roles that were previously non-existent within the company's structure, which is new to agile approach, like the Scrum Master and Product Owner and their specific responsibilities. The team is cross-functional, but its architecture remains flexible and undefined (Dukovska-Popovska et al, 2014).

The following image shows a graphical representation of the Water-Scrum-Fall model (Reiff & Schlegel, 2021):

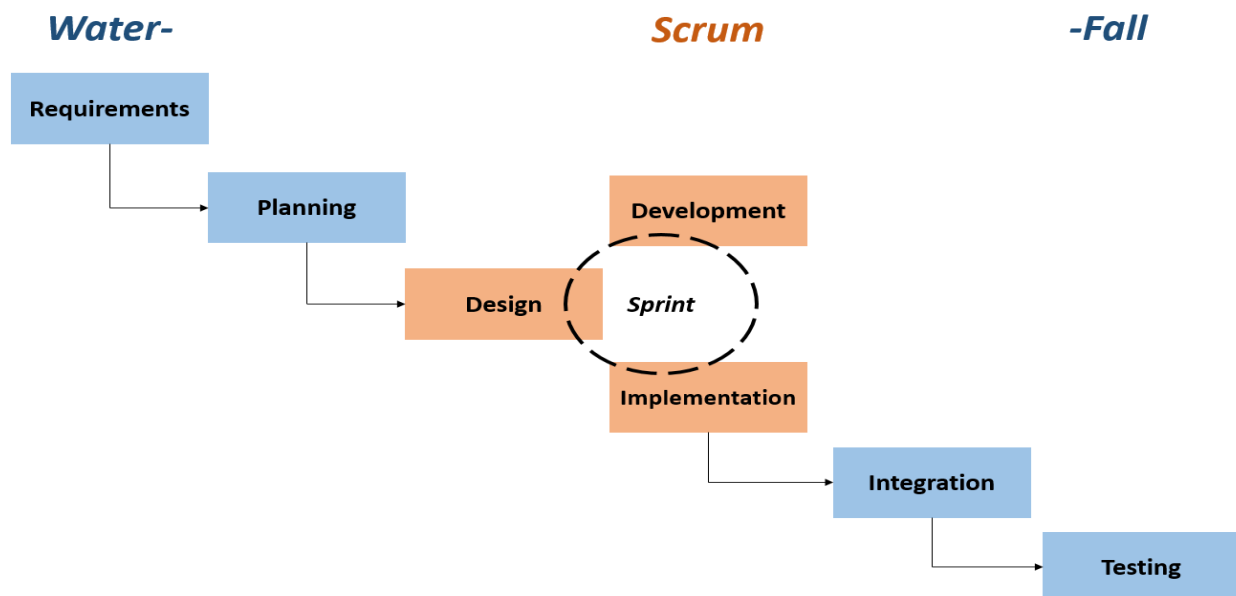


Image 1: Water-Scrum-Fall model (Reiff & Schlegel, 2021)

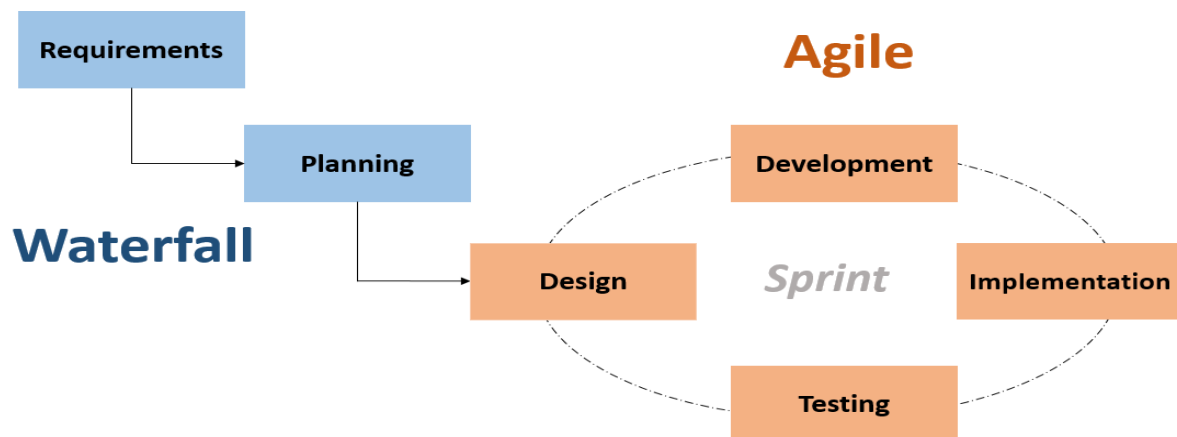
### 2.2. Waterfall-Agile Model

At first glance, the Waterfall-Agile model may seem similar to West's Water-Scrum-Fall model, but they diverge notably in their final phases. Unlike West's approach, which adopts a traditional project approach in



its final phase, the Waterfall-Agile approach maintains its agile principles throughout (Aboubdellah et al, 2018). In the Waterfall-Agile model, the project scope and the first agile sprint are planned before the project starts. Although the overall project plan is comprehensive, details for each sprint are only finalized after completing the initial sprint (Aboubdellah et al, 2018). Development, design, and implementation adhere to agile frameworks, with requirements defined and customer feedback sought at each iteration. Flexibility is maintained as project phases can be sensibly exchanged based on effort requirements. A formal and traditional approach guides outcome definition for each iteration, while implementation remains highly agile within individual phases. Agile frameworks accelerate product delivery and enable prompt feedback gathering to ensure alignment with customer needs (Reiff & Schlegel, 2021). Roles within the Waterfall-Agile approach encompass traditional project management responsibilities alongside agile implementation tasks. The project manager oversees planning and project management to ensure successful completion within defined objectives, costs, and deadlines. Developers take charge of individual work packages, while testers maintain a focus on quality and execute product testing (Aboubdellah et al, 2018). A notable characteristic of the Waterfall-Agile model is the blending of traditional planning and agile execution without distinct separation. This transition can vary on a project-by-project basis, with the possibility of projects being initially planned with an agile approach and later developed using traditional procedures, or vice versa (Aboubdellah et al, 2018). The Waterfall-Agile model is suitable for organizations that aim to shift towards agile practices, but the complexity involved is impending progress. Transitioning to agile can be challenging due to its multifaceted nature, requiring time for teams to adapt successfully. Incorporating Agile techniques gradually, alongside the established Waterfall method, may facilitate a smoother transition to a fully Agile methodology. Besides that, this approach is a good option when the project has predefined budget and delivery deadlines, but could benefit from Agile's rapid design, analysis, and planning capabilities (Aboubdellah et al, 2018).

The following image shows a graphical representation of the Waterfall-Agile model (Reiff & Schlegel, 2021):



**Image 2: Waterfall-Agile model (Reiff & Schlegel, 2011)**

### 2.3. Hybrid V-Model

The hybrid V-model, proposed by Hayata & Han, bears resemblance to the Water-Scrum-Fall model in its integration of traditional and agile approaches (Han & Hayata, 2011). However, it should be considered as a separate methodology, as it diverges from the Waterfall model as is instead based on the V-model, another traditional methodology. In this hybrid model, Scrum is integrated into the conventional software development and IT project management process. The primary approach is to implement high-level phases following the V-model, while managing detailed phases with Scrum. Scrum's emphasis on intense team communication supports iterative thinking during implementation (Han & Hayata, 2011). The V-model, similar to Waterfall, structures software development into phases, but incorporate feedback loops between them, enhancing quality assurance. By providing prototypes and conducting tests throughout development, the V-model ensures continuous improvement and quality assurance while minimizing project risks and providing better cost oversight (Reiff & Schlegel, 2021). In the Hybrid V-model, traditional methods are applied in initial and final phases, where meticulous planning is crucial. Agile approaches are then employed during development, implementation, and testing stages, where flexibility and agility are paramount (Han & Hayata, 2011). User and system requirements are collected, defined and analyzed at the beginning of the project to prevent goal misalignment (Han & Hayata, 2011). The agile approach is utilized for design, implementation, and unit testing, fostering an iterative working style to mitigate delays. Testing, based on specifications from



earlier phases, ensures product safety and quality. This hybrid approach combines the structured planning of traditional methodologies with the adaptability and iterative nature of agile practices to enhance project outcomes (Han & Hayata, 2011). The Hybrid V-model is suitable for use in the case of developing more complex software products, where constantly receiving feedback from the client is crucial to discover any potential product deficiencies and address them promptly (Han & Hayata, 2011)

The following image shows a graphical representation of the Hybrid V-model (Reiff & Schlegel, 2021):

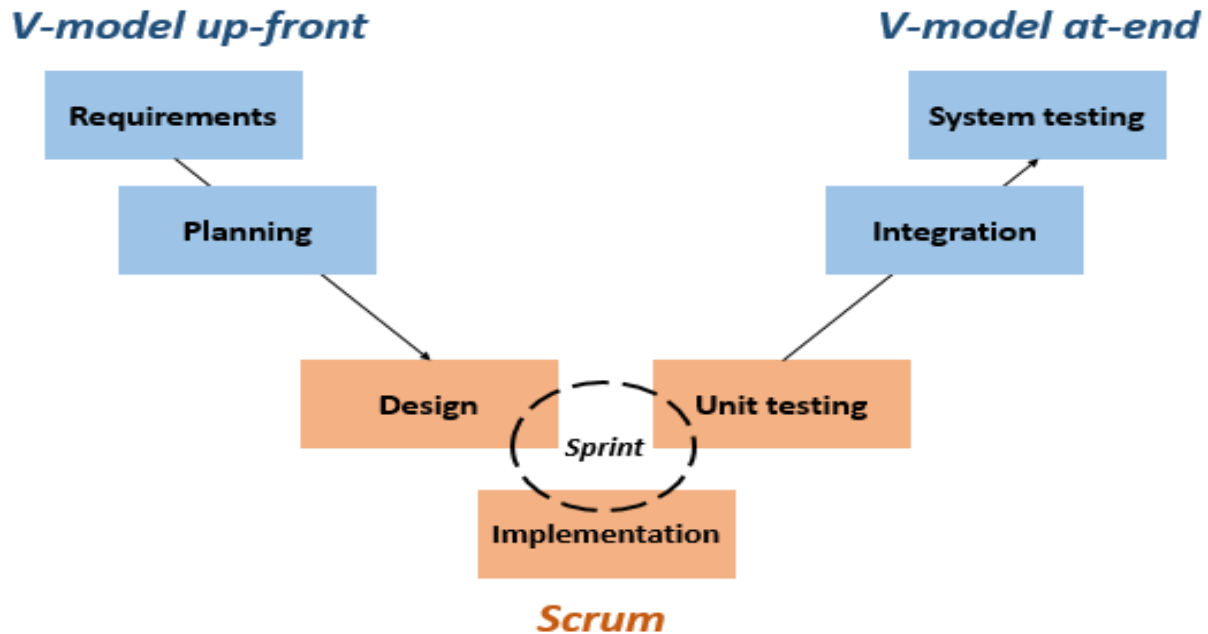


Image 3: Hybrid V-model (Reiff & Schlegel, 2011)

## 2.4. Agile-Stage-Gate (Scrum-Stage-Gate) Model

The traditional Stage-Gate process, pioneered by Cooper, has established itself as a global standard in product development (Cooper, 2016). Initially developed in the late 1980s to systemize and discipline new product projects, it prioritized sharp, early, and fact-based product definition. This methodology operates through multiple stages, each encompassing cross-functional activities from various company departments. After each stage, predefined criteria are evaluated in milestone analyses, ensuring alignment with customer requirements and maintaining process quality in innovation development (Cooper, 2016). Critics argue that the traditional Stage-Gate process, with its linear and rigid structure, struggles to accommodate today's innovative and dynamic projects. Its plan-driven nature requires early decisions and strict adherence to plans, limiting adaptability and responsiveness to changing project dynamics and increasing product complexity (Cooper, 2017). To address these limitations, the hybrid Agile-Stage-Gate model integrates agile sprints into the traditional Stage-Gate framework, infusing flexibility and speed while preserving the structural benefits of Stage-Gate. Agile tools and processes replace traditional project management tools, allowing for short-term, minimal planning and iterative development cycles within each stage (Ays et al, 2019). This hybrid approach combines the focus, structure, and control of Stage-Gate with the speed, agility, and productivity of agile practices (Patrucco et al, 2021). Each stage comprises time-boxed sprints, with strategic decisions guided by the Stage-Gate process and operational activities driven by agile frameworks. The process follows the conventional five phases of idea generation, prototype, development, validation, and launch, with Scrum iterations embedded within stages. Agile roles, such as Product Owner, Scrum Master, and development team enhance ownership, motivation, communication, and knowledge sharing within the project team (Cooper, 2016). While some literature may reference a Scrum-Stage-Gate methodology, it essentially refers to the same approach as Agile-Stage-Gate, with the distinction lying in the use of Scrum for agile sprints. However, the Agile-Stage-Gate model remains flexible, allowing for the adoption of various agile frameworks depending on project requirements (Cooper, 2016). The benefits of Stage-Gate include discipline, structured stages, decision-points, clear expectations, and built-in best practices (Copola, 2011). This model effectively balances the strengths and challenges of the agile approach and Stage-Gate approach, offering advantages such as ensuring product accuracy through early prototyping, adaptability to changing requirements, and early resolution of technical issues (Cooper & Sommer, 2018). It accommodates uncertainty by allowing for experimentation rather than predefined requirements. Time-boxed sprints accelerate development by fostering a sense of urgency and teams focusing on essential deliverables.

Dedicated project teams ensure adequate resources and improve communication, resulting in increased success of new product development (Haigh & Hoffman, 2011). The Stage-Gate model is suitable for use in cases when there are a large number of teams simultaneously performing their tasks during project implementation (Reiff & Schlegel, 2021). At the end of each stage, the results of all teams are analyzed, evaluated, and merged into one common outcome. This process is repeated until the project is completed.

The following image shows a graphical representation of the Agile-Stage-Gate model (Reiff & Schlegel, 2021):

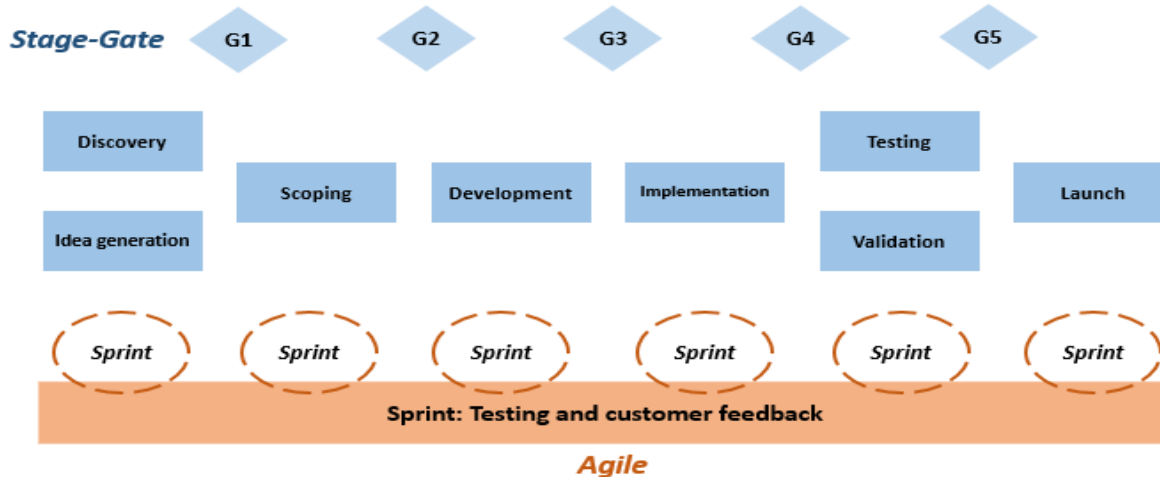


Image 4: Agile-Stage-Gate model (Reiff & Schlegel, 2021)

#### 4. COMPARATIVE ANALYSIS OF HYBRID PROJECT MANAGEMENT MODELS

The following table shows the main differences between described hybrid project management models, summarized from the previous descriptions of each model:

Hybrid project management model	Product complexity	Project size	The organization's familiarity with the agile approach
<i>Water-Scrum-Fall model</i>	Low	Smaller projects	The organization is completely unfamiliar with the agile approach.
<i>Waterfall-Agile model</i>	Medium	Smaller, medium and larger projects	The organization is slightly familiar with the agile approach.
<i>Hybrid V-model</i>	Medium	Smaller, medium and larger projects	The organization has had experience with the agile approach on certain projects.
<i>Agile-Stage-Gate model</i>	High	Larger projects	The organization has had experience with the agile approach on certain projects.

Table 1: Comparative analysis of hybrid project management models

#### 5. CONCLUSION

This paper provides insight into the concept of hybrid project management, as well as its main types. Based on the characteristics of different models of hybrid project management, it can be concluded that this approach has numerous advantages, but also several disadvantages. The main advantages include the ability to apply it to projects of different types and sizes, the ability to quickly respond to risks and issues, minimal dedication to documentation and focus on work, focus on continuous improvement, implementation of lessons learned, focus on incremental and iterative development, constant involvement of the client in the process, an integrated approach that provides integrated communication, process simplicity, a new and fresh approach, the likelihood of yielding better results than the traditional approach, ensured clear leadership and vision, and assistance in risk management (Grey, 2011). On the other hand, there are certain disadvantages

such as the requirement for extensive methodological expertise in both project management and the team. Every team member involved in the project must possess a high degree of methodological proficiency. The challenge lies in selecting the appropriate tool initially and ensuring its correct application afterwards. In order to ensure the benefits of using hybrid project management, there has to be comprehensive communication. This consequently results in heightened administrative tasks, through corresponding reports and documentation (Copola et al, 2021). Based on conducted research in this field, it can be concluded that the application of a hybrid approach and adapting project management models to a given situation typically yields better results than applying a single approach in every situation. This research also suggests that hybrid approaches are increasingly common and are naturally favored by project managers (Gemino, 2021). Considering all the above, and the fact that the environment, technology, and client demands are becoming increasingly complex, it follows that there is potential for further development of new hybrid project management models.

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# **QUALITY MANAGEMENT AND STANDARDIZATION**

# ETHICAL ASPECTS OF AI AND THE ROLE OF STANDARDISATION IN IT: ARE WE FACING THE BRUSSELS EFFECT?

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**Abstract:** *AI-based technologies have rapidly increased and changed how industries and businesses operate. The ethical aspects of Artificial Intelligence (AI) are complex, with many different understandings and without universally acceptable solutions. Many national, regional, and international efforts address the ethical aspects of AI. A growing sensitivity to AI's social and economic adverse effects caused the hyperproduction of initiatives toward addressing ethical aspects of AI-based products, which confused manufacturers of AI-based products and services. Reaching a common understanding and common agreements on the ethical aspects of AI are now needed more than ever. The current study aims to contribute to the systematisation of the existing literature on the ethical aspects of AI and the role of standardisation in it. Based on the existing solutions, the study aims to explore if standards and other deliverables may serve as a means to address the ethical aspects of AI. Building upon the GDPR success, the study examines whether the Brussels Effects will manifest again.*

**Keywords:** *AI, ethics, standards, standardisation, Brussels Effect*

## 1. INTRODUCTION

The economic potential of Artificial Intelligence (AI) is enormous. Globally, AI adoption is about 2.5 times higher today than in 2017, investments in AI are increasing, and AI leaders are expanding their competitive advantage, with no evidence that others are catching up (McKinsey & Company, 2022). AI creates increasingly global economic value, and ethical concerns related to cyber-security, privacy, explainability (ability to explain how AI models come to their decisions), regulatory compliance, reputation, well-being, and physical safety are rising.

To date, the ethical aspects of AI have gained the attention of many actors, such as governments, societies, companies offering AI-based products and services, and organisations that are potential buyers of AI-based products and services. Consumer faith in responsible AI hinges on what companies do today. However, pressure to provide more objective evidence of AI's trustworthiness leads to many initiatives advocating for AI regulations.

The study aims to contribute to the systematisation of the existing literature on the ethical aspects of AI and the role of standardisation in it. Drawing upon the existing solutions, such as global and international AI initiatives, several country-specific solutions, the GDPR, the newly released European Union (EU) AI regulatory regime, and the liability rules for the digital age, as well as the ethics guidelines for trustworthy AI – the study aims to explore if standards and other deliverables may serve as a means to address ethical aspects of AI. Building upon the GDPR success, the study examines whether the Brussels Effects will manifest again.

## 2. LITERATURE REVIEW

What Floridi (2013) said in the context of information technologies can be paraphrased into the context of AI – AI has been growing “much more widely, rapidly and chaotically than its conceptual, ethical, and cultural roots”. The disruptive nature of AI is evident – it is dramatically changing how both industries and businesses operate. The ethical aspects of AI are complex and, in many cases, confusing (who should be protected and from whom). What is AI ethics? AI ethics may be defined as the ethical impact of AI technologies on human life and society (Floridi et al., 2018). Additionally, the terms “Artificial Intelligence (AI)” and “Machine Learning (ML)” and related considerations (i.e. AI/ML Ethics) are often used interchangeably (W3C, 2022). Also, a growing sensitivity to both social and economic adverse effects of AI caused the hyperproduction of initiatives toward addressing ethical aspects of AI-based products and services, leading to the fact that joint actions and common understanding are needed now more than ever. Reaching common agreements on what AI ethics is and how it can be achieved in many different contexts of AI is a process. However, a critical problem may be that many

national, regional, and international initiatives related to AI, as well as, AI-related regulations and standards will eventually lead to a loss of focus and manufacturers of AI-based products and services remain confused.

## **2.1. There are many global and international AI initiatives**

The OECD developed Recommendations on Artificial Intelligence with principles for responsible stewardship of trustworthy AI, which include “inclusive growth, sustainable development, and well-being; human-centred values and fairness; transparency and explainability; robustness, security, and safety; and accountability” (OECD, 2019). Drawing upon “the OECD Recommendation on Artificial Intelligence”, “the Global Partnership on Artificial Intelligence (GPAI)” brings together experts from science, industry, civil society, and governments to foster international cooperation supporting research and various applied activities on AI-related priorities (GPAI, 2023). In addition, the United Nations (UN) has several AI-related initiatives, including “the AI for Good Global Summit”, “the UNICRI Centre for AI and Robotics”, and “the UNESCO Report on Robotics Ethics” (UNESCO, 2021). Furthermore, UNESCO developed “a Roadmap for the UNESCO Recommendations on the Ethics of Artificial Intelligence” to delve into the different regulatory approaches to AI worldwide (UNESCO, 2021). Other international AI initiatives that cover ethical principles include “the G7 Common Vision for the Future of AI”, “the Nordic-Baltic Region Declaration on AI”, and “the World Economic Forum’s Global AI Council” (Bird et al., 2020). All the initiatives are significant, but one may get the impression that there is an overlap in the multitude of efforts. Focus and clarity are lost, and many initiatives do not reach their full potential.

## **2.2. Country-specific solutions are growing**

As the technology behind AI continues to advance unexpectedly, many countries are starting to launch their national strategies on AI (Bird et al., 2020). Canada was the first to establish the AI national strategy in March 2017, followed by Japan, Finland, Denmark, France, Germany, Sweden, and the UK (see Bird et al., 2020). At the European level, the European Commission (EC) released “the Communication on AI”, thus encouraging the development of national strategies of individual Member States (EC, 2018). Finland was the first Member State to establish a national programme on AI (Bird et al., 2020). Finland’s national programme on AI was established and modelled based on two reports – “Finland’s Age of Artificial Intelligence” (MEAE, 2017) and “Work in the Age of Artificial Intelligence” (MEAE, 2018). As a result, several other Member States (e.g. Denmark, France, Germany, Sweden, and the UK) have developed AI national strategies (Bird et al., 2020). For example, Denmark’s national strategy on AI was published in March 2019 (Danish Government, 2019), following “the Strategy for Digital Growth” (Danish Government, 2018). France launched its “AI for Humanity” in March 2018 to establish an ethical framework for AI (Villani, 2018). Germany’s national strategy on AI was established in November 2018 (Die Bundesregierung, 2018). Sweden’s approach provided guidance on education and research and innovation (R&I) for AI (Bird et al., 2020). The UK released “The AI Sector Deal” in May 2019, as a part of a larger “Industrial Strategy based on five foundations: ideas, people, infrastructure, business environment, and places” (UK, 2019). Several Member States have also announced their national strategies for AI (Bird et al., 2020). National strategies may signal that regulations are going to be developed. Still, based on these country-specific solutions, it can be said that they cover ethical aspects of AI unevenly, in a variety of contexts.

## **2.3. The case of the GDPR as a global solution might be repeated**

The General Data Protection Regulation (GDPR) is one of the most powerful EU regulations in the last decade. It changed business practices within the EU and caused a Brussels Effect abroad (Siegmann & Anderljung, 2022). It caused a de facto Brussels Effect – by encouraging changes of products offered outside the EU and a de jure Brussels Effect – by influencing regulations adopted by other countries (Siegmann & Anderljung, 2022). It seems likely that we will be witnessing the adoption of the recently released EU AI regulatory regime within the US, especially California, which has recently adopted several data protection laws similar to the GDPR, but also China, which has recently adopted the Personal Information Protection Law (in 2021) (Siegmann & Anderljung, 2022). This may be why the EU hopes that “the Brussels Effect will manifest once more” (Gstrein, 2022).

## **2.4. The recently released EU AI regulatory regime**

Building upon the GDPR success, several regulations have been proposed and partly adopted by the EU, such as “the Digital Services Act (DSA)” and “the Digital Markets Act (DMA)” (Gstrein, 2022). The DSA aims to ensure a safe digital space to offer digital services across borders (EC, 2023c), while the DMA aims to establish a level playing field for businesses around the globe (EC, 2022c). It does so by establishing so-called ‘gatekeepers’ (such as large, systemic online platforms) so businesses, innovators, and technology start-ups may compete on an equal footing without having “to comply with unfair terms and conditions limiting their development” (EC, 2022c). Gatekeepers and the DMA shall protect small and medium-sized enterprises (SMEs), given that gatekeepers cannot use their power to enhance the visibility of their products and services

(Bendiek & Stuerzer, 2023). Building upon the GDPR and the DSA and the DMA, “the Digital Governance Act (DGA)” and “the Digital Act (DA)” were established, “culminating with the proposal of the AI Act (AIA) in 2021” (Codagnone & Weigl, 2023). The DGA seeks to enhance trust in data sharing, strengthen mechanisms to enhance data availability and overcome technical obstacles to the use of data (EC, 2023b). Similarly, the DA will “ensure fairness in the digital environment, stimulate a competitive data market, open opportunities for data-driven innovation and eventually make data more accessible for all” (EC, 2023a). As the last building block of the Digital Strategy and the Digital Compass, the AIA takes a risk-based approach, assigning AI-based systems to several risk categories based on whether they create an unacceptable, high, or minimal AI risk (EC, 2021).

## **2.5. The liability rules for the digital age**

In September 2022, the EC proposed two additional directives that offer “the liability rules for the digital age” (Wagner, 2023). The first directive, the AI Liability Directive, remains related to AI-based systems and offers liability rules for the systems (EC, 2022a). The second proposal, the reform of the Product Liability Directive (85/374/EEC), aims to upgrade the current framework for product liability within the EU market (EC, 2022b). Although the current Product Liability Directive builds upon the model of the US law, the revised one not only covers digital goods and services but “targets new intermediaries of e-commerce as liable parties” (Wagner, 2023). A new Product Liability Directive breaks new ground and “certainly has what it takes to trigger the Brussels Effect”, still the question remains whether a second directive is required in this case (Wagner, 2023).

## **2.6. Ethics guidelines for trustworthy AI**

The EC has acknowledged the potential of AI technologies and has set up a High-Level Expert Group on AI (HLEG-AI) to advise on its AI Strategy (HLEG-AI, 2019a). In 2019, the HLEG-AI developed “Ethics Guidelines for Trustworthy AI” (HLEG-AI, 2019). According to the Guidelines – “trustworthy AI should be – (1) lawful – respecting all applicable laws and regulations, (2) ethical – respecting ethical principles and values, and (3) robust – both from a technical perspective, considering social and environmental aspects” (HLEG-AI, 2019a). The second deliverable, titled “Policy and Investment Recommendations for Trustworthy Artificial Intelligence” provides experts’ advice on using trustworthy AI to build a positive impact in Europe and gives suggestions on leveraging Europe’s enablers for trustworthy AI (HLEG-AI, 2019b). Similarly, the European Parliament (EP) developed “the EU Guidelines on Ethics in Artificial Intelligence (AI): Context and Implementation” (Madiaga, 2019).

## **2.7. Standards and other deliverables as a solution**

As AI rapidly develops, the question of means to incorporate ethics in the development process and, subsequently, the use of AI technologies arises. To fulfil this objective, many organisations worldwide have recently developed standards for AI (Frost et al., 2021). On one side, AI technologies are evolving faster than the standards set in this field. On the other hand, the problem arises in so many existing initiatives related to the ethical aspects of AI, which creates confusion among manufacturers of AI-based products and services. Additionally, AI systems must ensure Trustworthiness, Explainability, Transparency, Bias, and Accountability (Frost et al., 2021).

## **2.8. Standards and other deliverables developed by IEEE**

The Institute of Electrical and Electronics Engineers (IEEE), as the world’s largest technical professional organisation dedicated to “developing standards that enable technology for the benefit of humanity”, develops standards considering an ethical aspect of AI through “the Global Initiative on Ethics of Autonomous and Intelligent Systems”. The Initiative consists of several working groups developing standards in these areas. Standards (and other documents) developed by the IEEE are: “IEEE Ethically Aligned Design” (IEEE, 2019b), “IC18-004 – Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS)” (IEEE, 2019a), “IEEE Trusted Data and Artificial Intelligence Systems (AIS) Playbook for Finance Initiative” (IEEE, 2019c), “IEEE P2840 – Standard for Responsible AI Licensing” (IEEE, 2023a), “IEEE P2842 – Recommended Practice for Secure Multi-party Computation” (IEEE, 2021a), “IEEE P2863 – Recommended Practice for Organizational Governance of Artificial Intelligence” (IEEE, 2023b), “IEEE P7000 – Standard for Model Process for Addressing Ethical Concerns During System Design” (IEEE, 2021b), “IEEE P7001 – Standard for Transparency of Autonomous Systems” (IEEE, 2022), “IEEE P7003 – Standard for Algorithmic Bias Considerations” (IEEE, 2023c), “IEEE P7008 – Standard for Ethically Driven Nudging for Robotic, Intelligent and Autonomous Systems” (IEEE, 2023d), “IEEE P7014 – Standard for Ethical Considerations in Emulated Empathy in Autonomous and Intelligent Systems” (IEEE, 2023e).

## 2.8. Standards and other deliverables developed by ISO/IEC

The International Organisation for Standardisation (ISO) and the International Electrotechnical Committee (IEC) established the Joint Technical Committee (JTC) 1 for information technologies as a consensus-based, voluntary international standards group. Within the ISO/IEC JTC 1, the Sub-Committee (SC) 42 was established to develop standards in the area of AI and provide guidance to JTC1, ISO, and IEC committees developing AI-based applications. The ISO/IEC JTC1/SC42 consists of several Working Groups (WG). The JTC1/SC42/WG3 related to the Trustworthiness of AI-based systems published a standard “ISO/IEC 23894 – Information Technology – Artificial Intelligence – Risk Management” to provide guidelines on managing risk during the development and application of AI techniques and systems (ISO/IEC, 2023). They also published two Technical Reports (TRs): “ISO/IEC AWI TR 24368 – Information Technology – Artificial Intelligence – Overview of Ethical and Societal Concerns” (ISO/IEC, 2022), and “ISO/IEC TR 24028 – Information Technology – Artificial Intelligence (AI) – Overview of Trustworthiness in Artificial Intelligence” (ISO/IEC, 2020).

## 2.10. Are we facing the Brussels effect?

The Brussels Effect was coined initially by Professor Anu Bradford and describes “Europe’s unilateral power to regulate global markets” (Floridi, 2013). Drawing upon “the Delaware Effect” which was used to address the devolution of standards within the US and “the California Effect” which captures the opposite phenomenon, Professor Bradford argues that “rules and regulations originating from Brussels have penetrated many aspects of economic life within and outside Europe” (Floridi, 2013), thus resulting in the globalisation of standards. Considering that usually only large economies may become the source of global standards, the Brussels Effect could easily give way to “the Washington Effect” or “the Beijing Effect” (Bradford, 2020). Will the Brussels Effect be undermined as the EU market’s size diminishes and some of the most powerful nations, such as the US and China grow? Will it be able to face internal challenges (e.g. Brexit)? Will it endure external challenges? These questions will determine whether the Brussels Effect will manifest once more or will it fade into history – as new rules and regulations emerge (Bradford, 2020).

## 3. CONCLUSION

AI is indicated to deliver many benefits. However, ethical aspects of its application, regulatory policy, end users, and society must first be undertaken (Frost et al., 2021). AI-based technologies have been increasing rapidly and changing forcefully how industries and businesses operate. The question of ethical aspects of AI is complex, with many different understandings, and without universally acceptable solutions. Also, there are many national, regional, and international efforts addressing the ethical aspects of AI. Moreover, a growing sensitivity to the social and economic adverse effects of AI caused the hyperproduction of activities toward addressing ethical aspects of AI-based products and services. Also, efforts to regulate this area are arising and standards-developing organisations and standards-setting organisations have recently been trying to find their place in this area. Still, a critical problem might be that many national, regional, and international initiatives, regulations, and standards as solutions to address ethical aspects of AI lead to a loss of focus, and manufacturers of AI-based products and services remain confused. Reaching a common understanding and common agreements on the ethical aspects of AI are now needed more than ever. While all efforts are essential and welcomed, the outcomes of the race between strong AI development and attempts to regulate AI ethically are unpredictable. Criticality is necessary in every human activity, but when great technological leaps are taking place in areas such as AI, it is necessary to understand that it is not easy to develop either perfect regulations or excellent standards. It seems that what is missing in many areas of AI is a common understanding of the basics of AI ethics – who should be protected and from whom? So simple, yet often unattainable.

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# QUALITY 5.0 ACHIEVEMENTS OF HEIs – THE BALANCED SCORECARD CUSTOMER PERSPECTIVE

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**Abstract:** Increased interaction between humans and machines, known as Industry 5.0, is a relatively new research area of particular significance in higher education. Considering that higher education institutions are the drivers of societal development as a whole, Industry 5.0, as a new paradigm, should be supported in the field of higher education. In the global era of challenges, higher education institutions face increasing competition, making significant efforts to improve their institutional position. Based on this, the Balanced Scorecard model is used to measure and enhance organisational performance. The aim of this research is to explore the factors of the Balanced Scorecard Customer Perspective as achievements of Industry 5.0 within higher education institutions. The results show that the highest-rated variable relates to a direct connection with student satisfaction, recognising that student satisfaction is a crucial indicator of the quality level of higher education institutions.

**Keywords:** Industry 5.0, quality 5.0., HEIs, customer perspective

## 1. INTRODUCTION

In recent years, quality in higher education has become an increasingly significant research area and poses a challenge for all higher education institutions worldwide (Bravo et al., 2022; Fu & See, 2022). The rise in competition in the field of higher education necessitates systematic changes aimed at improving and enhancing quality (Li & Xue, 2022). Higher education is a key driver for the development of society and communities (Meier & Schiopu, 2020). However, measuring the quality of higher education institutions is a highly complex task, as is the development of indicators for measuring the level of quality of higher education institutions (Matosas-López et al., 2019). Considering that higher education is the cornerstone of societal development, the quality of higher education institutions becomes imperative for positioning at higher ranks, both domestically and internationally (Meier & Schiopu, 2020). During the preceding period, profound technological changes have occurred across all sectors, including higher education (Broo et al., 2022). Global technological advancement has significantly altered the way knowledge and competencies are acquired, shifting from traditional to a new modern approach to learning and knowledge transfer (Núñez-Canal et al., 2022). The same authors further note that this was largely influenced by the Covid-19 pandemic, when all higher education institutions had to rapidly adapt to the new situation. Rapid technological progress has led to an industrial revolution known as Industry 4.0; however, immediately following that, a new industrial revolution known as Industry 5.0 emerged, aiming to increase organizational efficiency and effectiveness (Tiili et al., 2023). As a result of Industry 5.0, the concept of Quality 5.0 emerges as a new paradigm for quality control and assurance (Frick & Grudowski, 2023). Industry 5.0, as a new paradigm, can provide higher education institutions and their stakeholders with prosperity and sustainable development (Hashim et al., 2024). Unlike Industry 4.0, which focuses on technology and artificial intelligence, Industry 5.0 takes a step further and is focused on the interaction between humans and machines (Barata & Kayser, 2024). In this way, Industry 5.0 can enable higher education institutions to integrate traditional and online methods of conducting the teaching process (Broo et al., 2022). In order to enhance competitive advantage, the creators of the model (Kaplan & Norton, 1992) devised a method for organizations to measure organizational performance. This approach allows organizations to adopt a strategic approach, combining financial and non-financial indicators to translate long-term strategic goals into operational objectives (Kiriri, 2022). Among the non-financial indicators, perspectives relating to customers (Customer perspective), internal business processes (Internal business process perspective), and learning and growth (Learning and Growth perspective) are included, as well as the financial indicator known as the Financial perspective, which serves as a measure of future success in organizations (Kaplan & Norton, 1992). In this sense, higher education institutions can use the Balanced Scorecard model to measure organizational performance (Kiriri, 2022). In the field of higher education, which

is a specific service sector, the customer perspective is at the top of the hierarchical ladder, whereas in profit-oriented organizations, it is typically the Financial perspective (such as in the banking sector) (Stejskal et al., 2022). By using these four perspectives, organizations can measure organizational performance and effectiveness (Kiriri, 2022).

## 2. COMPOSITION

Industry 5.0 represents the agility of technologies to meet user needs, relying primarily on society and societal sustainability (Miao et al., 2024). Following Industry 4.0, which encompasses technological advancement, Industry 5.0 emerges as a driving mechanism for economic prosperity and overall well-being (Hashim et al., 2024). While the application of Industry 4.0 is still widely debated across geographical regions, a completely new line of thinking is emerging, which encompasses Industry 5.0 (Broo et al., 2022). Industry 5.0 is focused on increased interaction between humans and machines in collaborative work to enhance productivity, efficiency, and effectiveness in organizational systems (Hashim et al., 2024; Miao et al., 2024). Although Industry 5.0 has been extensively researched in recent years as an application in organizational systems, there is still a lack of literature and empirical evidence on how Industry 5.0 contributes to sustainable production (Hashim et al., 2024). Currently, Industry 5.0 is the latest form of industrial revolution (Frick & Grudowski, 2023). Considering the importance of higher education institutions, industrial revolutions must be supported by institutions of higher education (Hashim et al., 2024; Carayannis & Morawska-Jancelewicz, 2022). It is known that the Balanced Scorecard can be used in the field of higher education as a widely accepted model. The Balanced Scorecard can be used as a strategic framework for improving the quality of higher education institutions (Stejskal et al., 2022). The widely recognized Balanced Scorecard model for measuring organizational performance has applications in various fields (Hammood & Dammak, 2023). Researchers (Soysa et al., 2019) applied the Balanced Scorecard model in healthcare organizations. In the field of higher education, authors (Makki et al., 2023; Kiriri, 2022; Stejskal et al., 2020) have also implemented the Balanced Scorecard model. One of the strategic tools that higher education institutions can use is the Balanced Scorecard model for measuring organizational performance (Makki et al., 2023). The implementation of the Balanced Scorecard enables higher education institutions to create a mechanism for meeting the expectations of all stakeholders in the field of higher education (Kiriri, 2022). The application of the Balanced Scorecard provides valuable feedback for decision-makers because decisions are based on facts (Makki et al., 2023). Quality 5.0 represents quality in the era of Industry 5.0, essentially relying on increasing the level of quality, integrating quality with production processes based on societal sustainability (Frick & Grudowski, 2023). Focusing on users (students) in higher education is directly related to user satisfaction, while the precondition for satisfaction is meeting user expectations (Marimon et al., 2020). The quality of teaching and the teaching process is the most important factor influencing student satisfaction; however, it is important to emphasize that a key factor is also the image of the higher education institution and reputation, which have a significant impact on the overall perception of the institution (Masserini et al., 2019). For measuring the quality of higher education institutions, measuring student satisfaction is crucial and very important because it will not result in students transferring to other higher education institutions. Therefore, if the quality of the higher education institution is high, it will produce high levels of student satisfaction (Borishade et al., 2021). Considering that the teaching process is the primary process of higher education institutions, the authors (Chen et al., 2014) note that when considering respondents' attitudes, it is necessary to include teaching staff in order to obtain a comprehensive picture. Therefore, the aim of this paper is to identify variables within the customer perspective for achieving quality in higher education institutions in the context of Industry 5.0 in the Republic of Serbia.

## 3. METHODOLOGY

The aim of this research is to identify factors of the Balanced Scorecard for the achievements of higher education institutions in the concept of Quality 5.0 - quality in the era of Industry 5.0, which could serve as advantages and have positive effects on the quality of higher education institutions with a focus on the customer perspective. The corresponding research question is: "What are the best-rated variables based on descriptive data related to the customer perspective?" Evaluated variables within the customer perspective in higher education institutions are being considered. The survey included 374 correctly completed responses from higher education institutions in research conducted in the second half of 2023 in the Republic of Serbia. In terms of sample structure, male respondents accounted for 47%, while female respondents accounted for 53%. Analysing the structure according to the founder of the higher education institution, respondents employed in higher education institutions founded by the Republic of Serbia accounted for 91%, while those from private higher education institutions accounted for 9% of respondents. Out of the total number of respondents who are teachers and teaching associates, the distribution according to the educational-scientific field is as follows: natural sciences and mathematics field teachers accounted for 7%, technical-technological 32%, social-humanistic 52%, medical 7%, and arts field 2% of teachers. Regarding the position in the higher education institution, 83% of teachers and teaching associates participated in the research, while 17% of

administrative staff were included in this study. Regarding the implementation of ISO 9001 or other management systems in higher education institutions such as ISO 14001 or ISO 45001, 6% of higher education institutions have implemented the standard less than 3 years ago, 24% of higher education institutions have implemented it 3-6 years ago, 46% of higher education institutions have implemented it more than 3 years ago, and 24% of higher education institutions do not have implemented management system standards.

#### 4. RESULTS

The Balanced Scorecard variables from the Customer Perspective group that have been considered in this research, along with their mean values, are presented in Figure 1.



**Figure 1.** The evaluated variables from the Customer Perspective

#### 5. CONCLUSION

Research results show that the highest-rated variable related to student satisfaction with the application of acquired knowledge for Industry 5.0 needs has a mean value of 3.48, which is consistent with the initial claims of this research, as stated by (Marimon et al., 2020), that student satisfaction is fully meeting expectations, representing a direct link to the level of quality in higher education institutions. Employers and the general economy require graduates with acquired knowledge and skills who can adapt relatively quickly to all market challenges, as stated by (Hashim et al., 2024), which aligns with the results of this research with an average mean value of 3.40. Slightly lower values are recorded for variables related to the number of awards and recognitions received by students as well as higher education institutions, with values of 3.08. This research can be beneficial to the academic community as well as the managerial structures of higher education institutions as a systematic overview of important strategic pathways towards sustainability. However, this study also has some limitations. It encompasses employees in higher education institutions. Future research directions should include other stakeholders such as students and employers to obtain a comprehensive understanding. Higher education institutions have many stakeholders, including those with direct impact such as students and faculty, as well as indirect ones such as society as a whole (Stejskal et al., 2022). Furthermore, it would be beneficial to compare the obtained results of the stakeholders. Recommendation for future research may include further exploration of the Customer perspective within the Balanced Scorecard, as well as confirming the relationships highlighted in this study. Developing performance metrics for the Customer perspective could be crucial for understanding the key success factors of higher education institutions. Given

the significant gap in the literature related to this topic, additional empirical evidence could serve to provide a clearer understanding of success factors at the institutional level, as well as more broadly in the field of higher education.

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# IDENTIFICATION OF FACTORS OF INDUSTRY 5.0 ACHIEVEMENTS IN HIGHER EDUCATION

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**Abstract:** Industry 5.0, as an interaction between humans and machines, can significantly impact increasing efficiency and effectiveness in organizations. Its application has a wide range of implications in the field of higher education, given that higher education institutions are key drivers of societal development. In an era of global challenges and adaptation to market trends, higher education institutions face numerous challenges in striving to achieve competitive advantage. In this context, the strategic framework of the Balanced Scorecard was used to measure organizational performance in the domain of exploratory factor analysis (EFA) of Industry 5.0 achievements in higher education in the Republic of Serbia. The research results indicate the adequacy of sampling according to the Kaiser-Meyer-Olkin (KMO) test, which shows a value greater than 0.5, confirming the appropriateness of the analysis.

**Keywords:** Industry 5.0, Balanced scorecard, HEIs, exploratory factor analysis, achievements

## 1. INTRODUCTION

It is known that Industry 5.0, as a balance between humans and machines, can have an impact on improving organizational efficiency. The rapid technological advancements led to Industry 4.0; however, soon after, a new industrial revolution known as Industry 5.0 emerged, aiming to improve efficiency and effectiveness in organisational systems (Tiili et al., 2023). Industry 5.0 focuses on enhancing collaboration between humans and machines, establishing a balance that results in improved efficiency and effectiveness in organisational systems (Babkin et al., 2022). That Industry 5.0 places humans and machines at the centre, emphasising the enhancement of organisational capabilities, is confirmed by the authors of a research study (Leng et al., 2024). This relatively new research area or paradigm, called Industry 5.0, is aimed at changing digital thinking while increasing interaction primarily based on digital transformation in all organisational systems (Babkin et al., 2022). While Industry 4.0 was exclusively focused on the development of technologies and technological advancements, process automation, and the use of artificial intelligence (AI), Industry 5.0 goes further, fundamentally relying on the social and societal aspects (Miao et al., 2024). In this way, Industry 5.0 poses a challenge for all organisations as it brings benefits to society, ensuring prosperity and sustainable development (Hashim et al., 2024). Transformation in industrial systems can be stimulated by Industry 5.0 initiatives (Babkin et al., 2022). The well-known Balanced Scorecard model can be applied across all fields (Hammood & Dammak, 2023). The Balanced Scorecard can be used to measure organisational performance at the institutional level, and it can also be applied to processes with the aim of improving performance (Kaufman et al., 2021). The Balanced Scorecard is a strategic tool for measuring organisational performance created by Kaplan and Norton (1992). The purpose of applying the Balanced Scorecard model is to translate strategy into operational activities, which, based on the results of the model's application, allows all stakeholders to gain insight into performance outcomes (Hammood & Dammak, 2023). The Balanced Scorecard model consists of a mix of financial and non-financial indicators and includes four perspectives: Customer Perspective, Internal Business Process Perspective, Learning and Growth, and Financial Perspective, as stated by the creators of the model (Kaplan & Norton, 1992). In an era of global challenges, higher education institutions face increasing challenges. During this era, higher education institutions must continuously strive to raise quality to a higher level, implement continuous improvements, and enhance their operations to achieve competitive advantage (Borishade et al., 2021). Quality in higher education is multidimensional and variable due to constant market changes and the need to adapt to shifting market trends. Consequently, higher education institutions must establish mechanisms to improve overall performance, achieve prosperity, and ensure sustainable development (El Alfy & Abukari, 2020). Balanced scorecard in higher education is used as a strategic framework for measuring organizational performance (Kiriri, 2022). Considering the strong potential that higher education institutions have for Industry 5.0, they are expected to be prepared for the new challenges brought



by Industry 5.0 (Hashim et al., 2024). Increasing competition in higher education requires the evaluation of higher education institutions based on performance measurement using the Balanced scorecard model as a tool for improving performance that higher education institutions can use (Nazari-Shirkouhi et al., 2020). Hence, the aim of this research is to explore the factors of implementing the Balanced scorecard for the achievements of higher education institutions in Industry 5.0, which could serve as advantages and have positive effects on the quality of higher education institutions.

## 2. COMPOSITION

Although Industry 5.0 as the latest form of industrial revolution has many unknowns, its fundamental feature is the integration of user and industrial aspects, creating confidence that digital technologies adapt to users, not by creating ideas for new production processes but by making existing processes more efficient, establishing a balance to optimize production processes (Miao et al., 2024). In this way, relying on sustainability, society, and people, Industry 5.0 represents a change in thinking and an approach to systemic changes in organizational systems (Hashim et al., 2024). Industry 5.0 is focused on improving manufacturing processes (Leng et al., 2024). Additionally, there is still a lack of literature on the benefits of implementing Industry 5.0 in the field of higher education (Hashim et al., 2024). In response to the many challenges faced by higher education institutions in improving their competitive advantage, the Balanced Scorecard model can be used as a strategic framework for enhancing the performance of higher education institutions (Kiriri, 2022). Higher education institutions can utilize the Balanced Scorecard model to identify factors for improving organizational performance and to better position themselves in the global competitive market (Serdar Asan & Tanyaş, 2007). The implementation of the Balanced Scorecard provides feedback that is crucial for all stakeholders (Kaplan & Norton, 1992). The Balanced Scorecard represents a modern way of managing performance in higher education (Kiriri, 2022). However, it is important to note that the implementation of the Balanced Scorecard does not guarantee business excellence for organizations but rather serves as a means to translate strategy into operational objectives (Kaplan & Norton, 1992). Organizations worldwide are making significant efforts to improve their organizational performance and to be leaders in competition, and higher education institutions are no exception, given the increasing competition (Al Jardali, 2020). Decision-makers, as well as all stakeholders in the field of higher education, require information on financial and non-financial indicators, as facilitated by the implementation of the Balanced Scorecard (Kaplan & Norton, 1992). Non-financial performance indicators, such as the perspective of learning and development, internal business process perspective, and customer perspective, are of great importance not only for students as direct users of higher education services but also for other interested parties (Lin et al., 2016).

## 3. METHODOLOGY

The research was conducted among employees at higher education institutions in the Republic of Serbia. A survey methodology was used to analyses the potential that higher education institutions have for Industry 5.0. The survey included 374 properly completed responses in the second half of 2023, which consisted of 50 questions. The questions were structured based on a review of relevant literature, selecting 50 variables related to the perspectives of the Balanced Scorecard. The data collected was statistically analyzed using a specialized software for statistical processing data, SPSS v.25. For the purposes of the research, an exploratory factor analysis (EFA) was performed, which aims to reveal the basic structure within a set of variables, with the aim of identifying latent factors that explain the correlations between the observed variables. For this purpose, EFA divided the set of variables into four factors, which represent the dimensions of the Balance Scorecard.

## 4. RESULTS

For the purposes of this research, exploratory factor analysis (EFA) was applied to extract Balanced Scorecard dimensions quantitatively with empirical data. To examine the measurement scale using EFA, it was employed the Principal Component Analysis technique with Varimax rotation and the breakpoint to derive factors with Eigenvalue greater than 1. Additionally, it was utilized Cronbach's alpha to evaluate the internal reliability of each factor on the measurement scale. The EFA analysis results are related to the Balanced Scorecard dimensions for higher education institutions' achievements in Industry 5.0, which are divided into four independent factors. Each extracted factor has a KMO test coefficient value of over 0.5, and the Bartlett test with Sig. = 0.000 ( $< 0.05$ ), indicating that the EFA analysis is suitable. In addition, with coefficients of Cronbach's alpha exceeding 0.7 for all factors, it can be inferred that the questionnaire's scales demonstrate satisfactory reliability, providing recommended values.

## 5. CONCLUSION

Exploratory factor analysis (EFA) is used to identify latent variables and reduce the number of observational variables, preparing a large amount of data for further processing. The adequacy of sampling according to Kaiser-Meyer-Olkin (KMO) has a value greater than 0.5, indicating that the analysis is appropriate (Williams et al., 2010). Additionally, with Cronbach's alpha coefficients exceeding 0.7 for all factors, it can be concluded that the questionnaire scales have demonstrated satisfactory reliability (Cronbach, 1951). In order to achieve the research objective, the strategic management framework of the Balanced Scorecard is used in higher education institutions, providing a solid basis for assessing organizational performance as noted by (Nazari-Shirkouhi et al., 2020). In order to gain a competitive advantage in the field of higher education, institutions should adopt the Balanced Scorecard model for measuring and improving organizational performance (Kiriri, 2022). In addition to more intense competition in the global era of challenges faced by higher education institutions, which also brings the new paradigm of Industry 5.0, considering the strong potential of higher education institutions, Industry 5.0 must be grounded in higher education, taking into account the fact that there is a lack of knowledge about the application and adoption of this relatively new research area (Hashim et al., 2024). Industry 5.0 must establish its foundation in higher education institutions as well as all previous industrial revolutions. Given that Industry 5.0 can impact performance improvement in higher education and considering that Industry 5.0 must be supported in higher education as highlighted by authors (Hashim et al., 2024), it is important to investigate the extent to which the achievements of Industry 5.0 have been realised, as demonstrated in this study based on exploratory factor analysis (EFA) and the application of the Balanced Scorecard model. Exploratory Factor Analysis (EFA) is a method used in multivariate statistics, often utilizing the Cronbach's alpha reliability test for assessing reliability (Farradonna et al., 2023). The application of the Balanced Scorecard model enables the measurement of organisational performance, as noted by the model's creators (Kaplan & Norton, 1992), and its implementation can serve as an advantage and have positive effects on the performance of higher education institutions. The model can be applied at both the institutional level and individually at the process level, as indicated by researchers (Kaufman et al., 2021) who studied the application of the Balanced Scorecard model to human resource management and job positions. This research is important from both a theoretical and practical perspective. There is a gap in the literature regarding the application of Industry 5.0 in higher education and the benefits it brings (Hashim et al., 2024). Theoretically, it fills the literature gap related to Industry 5.0, which is not sufficiently researched as a relatively new area, and from a practical standpoint, it facilitates management structures in developing roadmaps that can lead to sustainable development. As support for the sustainability development of higher education institutions, this paper provides conclusions on how management structures, particularly in higher education but also more generally, can use this research as insights into the achievements of Industry 5.0 and the application of the Balanced Scorecard model. The conclusions of this study can be used to understand the significance of applying the Balanced Scorecard for achieving Industry 5.0 and the advantages it brings in the new era, creating a clear roadmap for adapting to market trends. Future research directions could focus on the institutional level of higher education institutions. Additionally, research could encompass other stakeholders of higher education institutions.

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# IMPLEMENTATION OF STANDARD ISO 9001 IN LOCAL SELF-GOVERNMENT – EXAMPLE OF MUNICIPALITIES IN REPUBLIC OF SERBIA

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**Abstract:** *In modern society, the functioning of a country relies heavily on the evolving activities and role of public administration. Implementing the ISO 9001 standard for Quality Management System demands significant effort and organizational capacity. This paper evaluates the implementation of ISO 9001 in local self-government institutions in Serbia, focusing on municipalities. It also examines the ISO 18091 standard, offering guidance for applying ISO 9001 in local government. Analysis was conducted using a questionnaire from ISO 18091's Annex A, enabling self-evaluation. Employees from various Serbian municipalities filled out the questionnaire, allowing local government authorities to assess performance across 39 indicators.*

**Keywords:** *local government, standard ISO 9001, standard ISO 18091, municipalities*

## 1. INTRODUCTION

The modern society of a country follows the constant changes, life and work of its citizens. Accordingly, the ways of implementing activities in an expanded scope and the role of public administration are of great importance for the state. According to Gębczynska & Wolniak, (2018), there is "a growing awareness among the citizens of a country about their rights and duties of the Government. In this situation, the role and scope of actions carried out by the public administration evolves in response to the changing needs and demands of society".

In the existing matrices of the public administration system, the output is the efficiency of the process and the result of the undertaken activities. In addition to a large number of approaches, according to Ćwiklicki, et al. (2021) "is also ISO 9001 - Quality Management System, which is one of the most recognized systems". Implementing Quality Management System according to the requirements of the ISO 9001 standard (QMS) requires a certain effort and the capacities of organizational resources. That is why, according to Ćwiklicka, et al. (2021), "the notion of organizational resource capacity (or, in short, organizational capacity) is particularly crucial for local governments that have fewer resources than regional and national public administration bodies.

It should be borne in mind that the importance of factors that support the implementation of ISO 9001 may differ among different business sectors (Almeida et al. 2018). Furthermore, even companies from the same industry assess the importance of barriers to ISO 9001 certification differently (Sfakianaki & Kakouris 2018). The aim of this work is to evaluate and identify the implementation of the QMS according to the requirements of ISO 9001 in the local self-government institutions of Republic of Serbia, that is, in the Serbian municipalities. Application of ISO 18091 standard, which provides guidelines for the application of the ISO 9001 standard in local self-government, is presented. The analysis was carried out on the basis of the questionnaire found in Annex A of the ISO 18091 standard, which represents a diagnostic system that can be used for self-evaluation and thus the highest local government authorities have possibility to identify the level of performance for each of the 39 indicators that are given in questionnaire, which, in this case, was filled out by employees in different Serbia municipalities.

## 2. QUALITY MANAGEMENT

Throughout history, the world has undergone constant transformation, accelerated by advancements in technology, markets, and the economy. Over the past two decades, companies have faced mounting pressure from stakeholders to address their environmental impact (Abbas & Sagsan, 2019). Concerns about climate change and pollution have prompted a shift towards renewable resources (Li et al., 2018; Ji & Zhang, 2019). International, national, and local regulations aimed at environmental preservation have compelled companies to adopt greener production processes (Fernando et al., 2019). Quality management has evolved since Schuhart's time in 1931, with new tools emerging to meet changing market demands. Processes of globalization and the knowledge-based society, as well as the transition of the economy, open questions for organizations, "how to improve quality of their products/services and consistently meet the expectations of their customers".

Mentioning quality, according to the ISO 9000:2015 standard (ISO, 2015), this term represents "degree to which a set of inherent characteristics of an object fulfils requirements." According to the same standard, management (ISO, 2015) "implies coordinated activities to direct and control an organization." This standard also states that quality management is "management with regard to quality". Therefore, it can be said that quality management implies, according to ISO 9000:2015, "coordinated activities to direct organization in relation to quality and control organization in this sense" (ISO, 2015).

Quality management encompasses various methods tailored to specific contexts and issues (Klochkov & Tveryakov, 2020). Techniques like Six Sigma, Kaizen, and Quality Control are being common choices (Potkany et al., 2020). However, achieving excellent quality requires a cultural shift within organizations, prioritizing understanding and adoption of quality principles over blind adherence to techniques (Gunasekaran et al., 2019). Namely, numerous international, regional and national organizations and governments have raised the issue of sustainable business and social responsibility (European Commission). Accordingly, Delerid & Fundin (2015) proposed the concept of quality 5.0, which will have a focus on sustainability. Also, in accordance with the Agenda 2030 of the European Commission, there is talk about Quality 2030 and the ways in which the goals of this Agenda will be applied in relation to quality (Fundin et al., 2020).

## 3. LOCAL SELF-GOVERNMENT

There are several concepts that can be correlated with local self-government and between which it is necessary to make a distinction. These are the concepts of public administration, public sector and local self-government. According to Vukosavljević et al. (2021:41), "the public sector is a means by which each state acts on the most important areas of joint work and activities of all its citizens." In modern states, citizens expect comprehensive services and protection, which public administration delivers through various social and regulatory measures, while managing state-owned and regulating private industries. Further, local self-government "is the right of citizens to manage public affairs of direct, common and general interest to the local population, directly and through freely elected representatives in local self-government units, as well as the right and ability of local self-government bodies to, within the limits of the law, manage affairs and manage public affairs that are within their jurisdiction and of interest to the local population" (Law on Local Self-Government, 2021).

The internationalization of local self-government began in 1985 with the adoption of the European Charter of Local Self-Government by the Council of Europe, effective in 1988. Since then, the Council has continuously supported its development. An additional protocol (CETS No. 207) supplements the charter, guaranteeing rights such as local referendums and participation in governance. Multi-level governance, recommended by the Committee of Ministers in 2022, promotes cooperation between central, regional, and local governments, and civil society. This fosters participatory policymaking and coordination.

According to Pittaway et al. (2020), local governments are ideally positioned to integrate government, private, and citizen data for innovative public services. To achieve this, managers need training in leading the implementation of integrated enterprise systems. Andrews et al. (2020) highlight the entrepreneurial activities of local self-government bodies, such as establishing companies for public service provision, reflecting diverse global approaches. This underscores the significant role of local government in society, particularly in the economy and citizen services.

### **3.1 Local self-government in Republic of Serbia**

In the late 18th and early 19th centuries, Serbia established local self-government, with villages governed by princes. This evolved over time, with changes in structure and funding. In 1990, the Serbian Constitution solidified the municipality as the basic unit of local governance. The 2006 Constitution further guaranteed citizens' right to local self-government, with laws detailing organization and activities. The Ministry of State Administration and Local Self-Government, founded in 2014, oversees this, including managing citizen registers and supporting local government capacity and funding.

## **4. QUALITY MANAGEMENT AND LOCAL SELF-GOVERNMENT**

The introduction of quality management in public services aims to improve organizational quality and enhance national competitiveness (Lee Yong Wook et al., 2014). Public sector is expected to constantly improve the quality of its services, in order to meet the needs and expectations of its end users - citizens. In this situation, the role and scope of actions of the public administration evolves in response to the changing needs and demands of society (Gębczyńska, & Wolniak, 2018). There are numerous methods, as well as numerous standards and models of excellence that provide requirements and guidelines for the implementation of quality management systems. Certainly, the most widely used method is ISO 9001 standard. According to data of the International Organization for Standardization - ISO (2022a), in 2022, number of certificates of the ISO 9001 standard was 1,265,216 and represents the largest number of certificates of all standards covered. Number of certificates in the public administration sector was 4512. The complexity of applying this standard to all processes of the organization is also indicated by the fact that there are different standards with guidelines for organizations to apply ISO 9001 depending on their activities. For public administration, there is a standard ISO 18091:2022 - Quality management systems - Guidelines for implementation in local self-government.

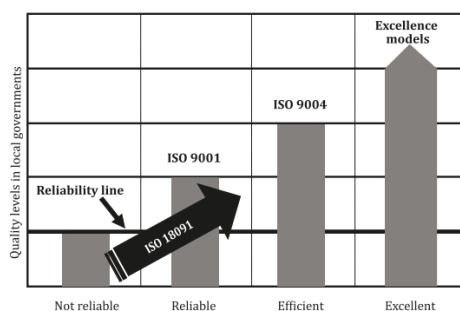
Various authors highlighted benefits and importance that ISO 9001 can have on various local self-government organizations (Cho & Pyun., 2022). Although it should be emphasized that the certificate in itself means nothing, if this standard is not really applied in practice. Thus, Mizuno (2002) investigated the implementation of ISO 9001 in Japanese local governments and came to the conclusion that local governments can achieve same benefits as private companies from the application of this standard. However, the authors (Löffler & Vintar, 2004; McAdam & Valke, 2003) agree that this standard has a greater effect if it is integrated with other management systems, such as ISO 14001 - Environmental Management System.

Citizens' increasing awareness of public administration has prompted global local self-government organizations to focus on enhancing operational efficiency and quality management systems.

## **5. STANDARD ISO 18091 - QUALITY MANAGEMENT SYSTEM – GUIDELINES FOR IMPLEMENTATION IN LOCAL SELF-GOVERNMENT**

Organizations, irrespective of size or activity, often turn to ISO 9001 certification to implement and regulate their quality management systems (QMS). This standard outlines requirements for establishing a QMS, considered a benchmark of "good practice." Additionally, for organizations seeking further improvement and excellence, there is ISO 9004:2018-Quality management-Quality of an organization-Guidelines for achieving sustainable success.

The ISO 18091:2022 standard aims to bridge quality management concepts from ISO 9000 series with local self-government practices and terminologies, assisting local governments in implementing effective quality management systems (ISO, 2022). These guidelines align with ISO 9001 requirements and apply to all local government processes across strategic, tactical-management, and operational levels, ensuring a comprehensive quality management system focused on achieving local administration goals (see Figure 1).



**Figure 1:** Role of the standard ISO 18091:2022 (ISO, 2022)

By applying this standard and its guidelines, local governments can improve their operations and strive for excellence. However, as shown in Figure 1, this standard does not lead to excellence. To assure that, local self-governments can utilize models like the European Model for Quality Management or the Malcolm Baldrige Excellence Model. Compliance with ISO 9001 standard be considered the ultimate goal. So, when local government achieve a level that allows consistent providing of compliant products and services to local community, it should consider using ISO 9004 and/or other models of excellence to enhance overall effectiveness and efficiency. (ISO, 2022).

ISO 18091 has four appendices. Annex A, which is used for this research, provides a diagnostic model that can be used as a starting point for implementing a comprehensive quality management system for responsible local government. It also has Annexes B, C and D.

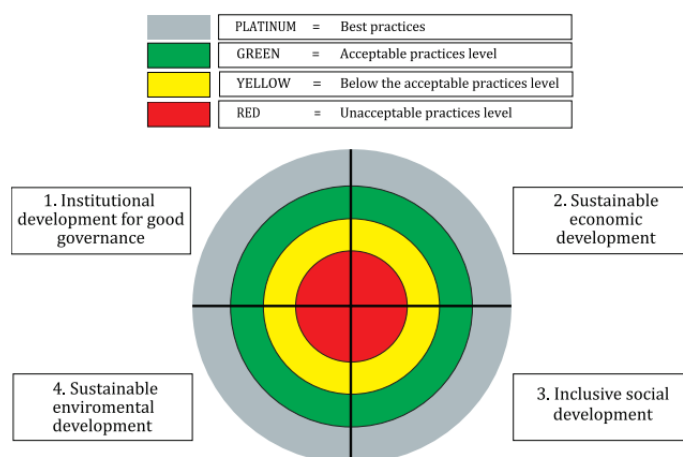
## 6. METHODOLOGY

For the research, its been used questionnaire found in Annex A of the ISO 18091. According to the ISO 18091 (2022) standard, this is a diagnostic system that can be used for self-evaluation and in this way the highest local government bodies have the possibility to identify the level of performance for each of indicators. This questionnaire contains 39 management indicators that are supported by about 130 United Nations documents and are classified into four groups of questions:

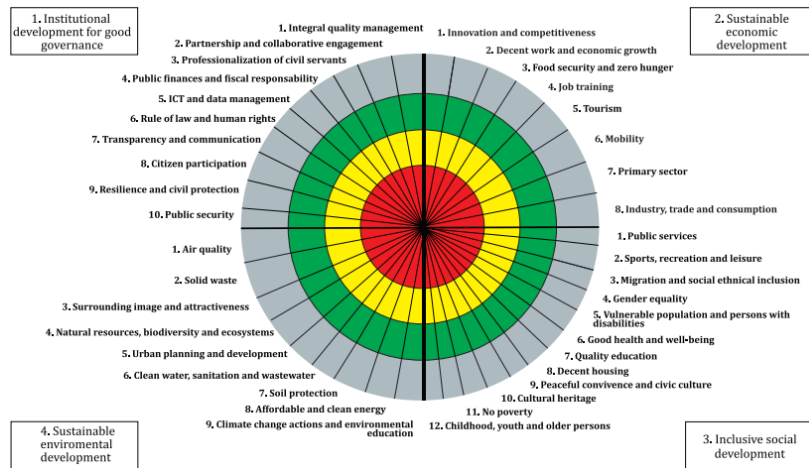
1. Institutional development for good governance;
2. Sustainable economic development;
3. Inclusive social development;
4. Sustainable development of the environment.

These indicators include products/services that a typical local self-government should provide to its users - citizens in order to be considered reliable.

As shown in Figure 2, there are three possible answers for each indicator: "red", "yellow" or "green". "Red" indicates essential practices are missing or are performed in an inadequate way by the local self-government to be considered reliable. "Yellow" cells indicate that the local government has made some efforts to implement the essential elements and is capable of providing the product/service as required. "Green" cells indicate that the minimum acceptable conditions have been met and that the local government can be considered reliable. Additionally, a "grey" level denotes best practice but isn't shown in the questionnaire, as this standard doesn't cover it. Figure 3 illustrates the indicators.



**Figure 2:** Local government assessment tool for integral quality management (ISO, 2022)

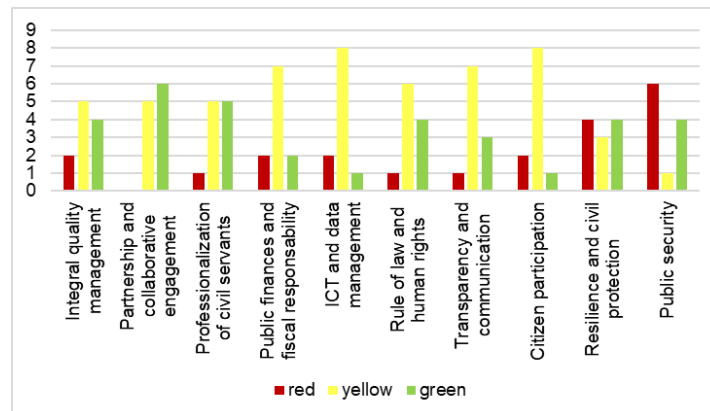


**Figure 3:** Local government assessment tool for integrated management system (using 39 indicators) (ISO, 2022)

For the purposes of this research, it was taken a sample of 11 respondents from different municipalities in the Republic of Serbia. According to the data of the Ministry of State Administration and Local Self-Government, there are 174 units of local self-government in the Republic of Serbia. Thus, this sample constitutes 6% of the total population. The answers given by the respondents are shown on the graphs, while the indicators on the graphs are grouped according to groups of questions.

## 7. RESULTS

### First group of questions: Institutional development for good governance

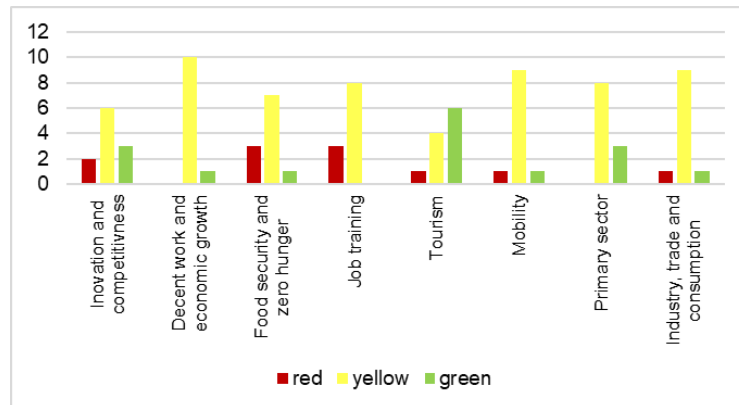


**Figure 4:** Institutional development for good governance

Figure 4 displays respondents' answers to the first group of questions. The "integral management system" indicator shows that most responses fall into the "yellow" category, indicating a below-acceptable level of practice. Conversely, for "partnership and collaborative arrangement," the majority of respondents fall into the "green" category, meeting an acceptable level. "Professionalization of civil servants" has an equal number of responses in the "yellow" and "green" categories. However, indicators 4 to 8, covering areas like public finances and citizen participation, mostly fall into the "yellow" category, indicating subpar performance. "Resilience and civil protection" has responses split between "red" and "green," suggesting a mix of acceptable and unacceptable practice. Indicator 10 shows the largest number of responses in the "red" category, indicating an unacceptable level of practice for most municipalities.



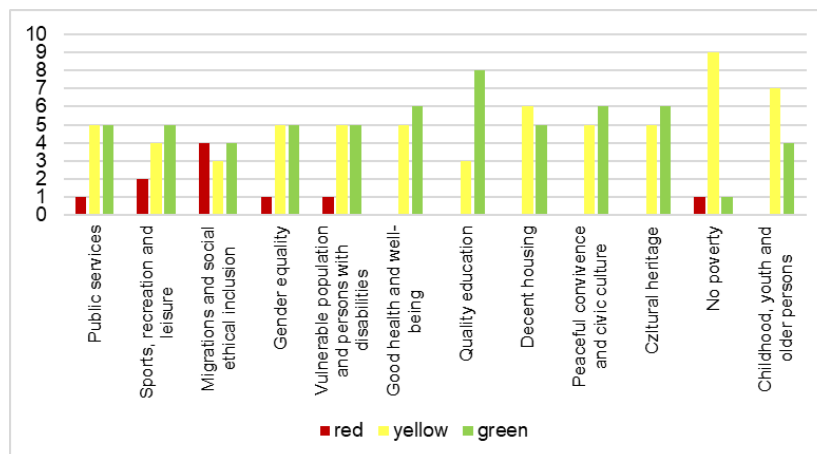
## The second group of questions: Sustainable economic development



**Figure 5: Sustainable economic development**

Figure 5 displays respondents' answers to questions from the second group. Only the fifth indicator, "tourism," shows the majority of responses in the "green" category, indicating an acceptable level of practice for most municipalities. However, indicators 1-4 and 6-8, covering areas like innovation, decent work, and industry, predominantly fall into the "yellow" category, suggesting municipalities do not meet acceptable practice levels.

## The third group of questions: Inclusive social development



**Figure 6: Inclusive social development**

Figure 6 presents respondents' answers to questions from the third group. The first indicator, "public services," shows an equal number of responses in the "yellow" and "green" categories, indicating varied practice levels among municipalities. "Sports, recreation and leisure," the second indicator, has the majority of responses in the "green" category, suggesting most municipalities meet acceptable practice levels. For "Migration and socio-ethnic inclusion," responses are split evenly between "red" and "green," highlighting differing levels of practice. "Gender equality" and "Vulnerable population and persons with disabilities" have equal numbers of responses in the "yellow" and "green" categories. Indicators 6, 7, 9, and 10, including "good health and well-being" and "cultural heritage," predominantly fall into the "green" category, indicating acceptable practice levels. However, indicators 8, 11, and 12, such as "dignified housing" and "childhood, youth, and the elderly," primarily fall into the "yellow" category, suggesting subpar performance.

## The fourth group of questions: Sustainable development of the environment

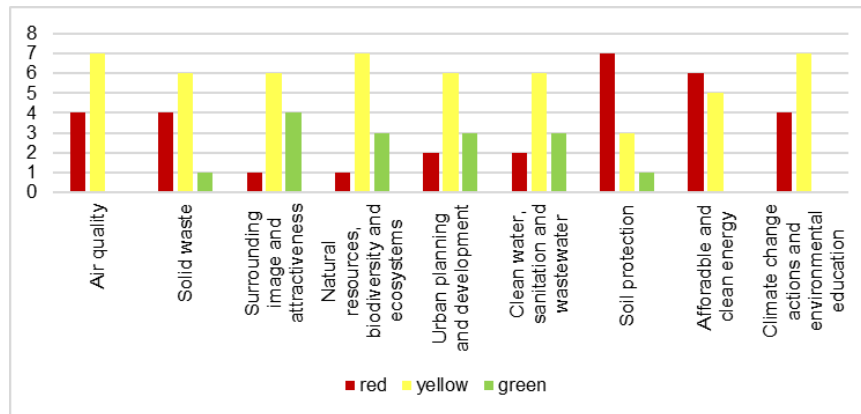


Figure 7: Sustainable development of the environment

Figure 7 depicts respondents' answers to the fourth group of questions. The first six indicators, such as "Air quality" and "Urban planning," mostly fall into the "yellow" category, indicating municipalities generally don't meet acceptable practice levels. "Soil protection" has the majority of responses in the "red" category, representing the highest level of unacceptable practice. Similarly, "Affordable and clean energy" also falls predominantly into the "red" category. The ninth indicator, "Measures related to climate change and environmental education," primarily falls into the "yellow" category, suggesting subpar performance across most municipalities.

## 8. DISCUSION

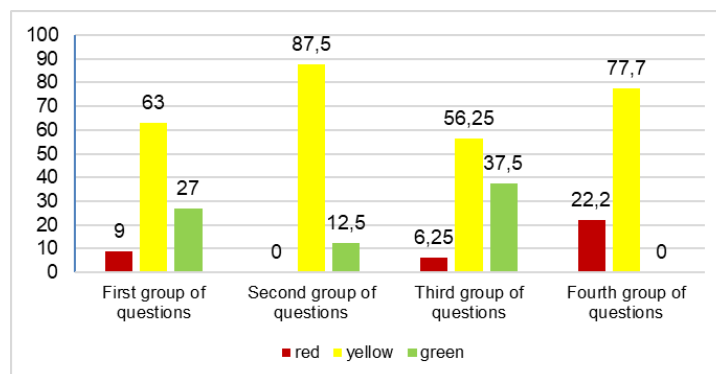


Figure 8: Results summary in percentage

Based on the results of the research, which included about 6% of organizations from the total population, it is possible to give certain guidelines for undertaking adequate activities aimed at fulfilling the requirements from Annex A of the ISO 18091 standard.

**Institutional development for good governance**, its better practice, in about two-thirds of organizations can achieve through a higher level of activities for integration of management systems, the professionalization of civil servants, public finance and fiscal responsibility, ICT and data management, the rule of law and human rights, transparency and communication and participation of citizens. Finally, a number of organizations, through the indicator of resilience and civil protection and public safety, show either a lack of conditions for their implementation or perform them in an inappropriate manner, which could be determined by additional research.

**Sustainable economic development**, a group of issues that opens up the opportunities to invest additional effort in all indicators and determine action guidelines, because it is obvious that organizations show a certain ability to maintain the processes in the mentioned indicators, but also that they are insufficient for the minimum acceptability of good practice.

**Inclusive social development** as a group of issues is the area that is obviously being worked on the most because organizations show the ability to carry out activities, but also that it is necessary to systematically raise the level through various new guidelines in order to reach the result of a minimum of good practices.

Given that Inclusive Social Development actually means the inclusion of users, as well as participation, then the level of all services and activities should be minimally satisfied.

**Sustainable development of the environment** group of indicators, the results of which generally indicate in part the ability of local governments to undertake certain activities regarding all indicators, but that they are not at a sufficient level to qualify as a minimum of good practice. It is also indicative that soil protection and affordable and clean energy are in the zone of no activity or no adequate activity. Sustainable development of the environment refers either to an underdeveloped awareness of the environmental problems of the planet, our country and the local area, or to the absence of material and financial resources.

## 9. CONCLUSION

It can be concluded that most local government organizations are in the zone of insufficient reliability, that is, that they should make efforts to apply essential elements, but also that they are capable of providing the product/service as required, but that the level of results is still inadequate. A special review should be made on issues of environmental sustainability as well as the inclusion of less interesting groups such as ethical groups and people with poverty problems as very sensitive segments of society. System integration must be a key activity for institutional development, because research has shown that local self-government organizations still have fragmented management systems, and their integration would bring greater benefits than the implementation of these systems. The limitations of this research should certainly be taken into account, first of all the small sample. For further research, they should include a larger number of respondents from the population and the possibility of expanding the questionnaire given within the ISO 18091 standard.

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# APPLICATION OF THE 8D METHODOLOGY IN THE AUTOMOTIVE INDUSTRY

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**Abstract:** *In the context of the rapidly changing and complex automotive industry, the 8D methodology stands out as a vital tool for continuous process improvement through a systematic approach to problem-solving and quality management. This paper offers an exposition of the 8D methodology, a highly effective quality management tool for addressing internal and external problems, specifically focusing on its practical application in the automotive industry. By analysing real-world case studies, we demonstrate how this methodology is effectively applied in practice, outlining the steps involved in problem identification and resolution and the long-term benefits of its implementation. This paper underscores the critical role of quality in ongoing operations and the necessity for dedicated implementation and oversight of the quality management system to ensure long-term success in the automotive industry in Serbia.*

**Keywords:** *8D methodology, quality management, automotive industry, case study*

## 1. INTRODUCTION

As one of the key sectors of the world economy, the automotive industry represents a complex and dynamic field that constantly strives for innovation and optimization. In its pursuit of excellence, quality management has become a central pillar that enables manufacturers to meet high standards and their users' expectations. When it comes to suppliers of final car manufacturers, products come out of one line in an average of three seconds, that is, an average of 20 products per minute. If those products do not comply with the specifications and cannot be finished, whatever the selling price of that product is, the quality losses are measured in thousands or hundreds of monetary units. For this reason, it is necessary to apply methods that will prevent when the slightest non-compliance, whether internal or external, occurs, that the problem does not escalate further, and the losses in that situation are the least possible. Therefore, the 8D methodology stands out as one of the most effective solutions that quality management can offer.

The 8D methodology represents a comprehensive approach to solving problems and improving quality in production and business processes (Glogovac & Ruso, 2023). Its roots date back to the middle of the 20th century and were developed to address and eliminate complex problems in production processes. Initially, Ford Motor Company played a key role in formulating and promoting the 8D methodology, optimising its production lines and improving its vehicle quality (Ionescu et al., 2022). Each of the eight steps has its own specific goal and set of tools which are used to analyse and solve problems (Banica & Belu, 2019).

Based on the aforementioned, this paper aims to show the application of the 8D methodology in the automotive industry in Serbia (production of cable sets and window lifters on cars). The importance of continuous quality management in the automotive industry has been proven through detailed analysis and study of real scenarios. It is clear that integrating quality methodologies helps maintain product quality and efficiently identifies and solves problems while guaranteeing the safety and satisfaction of end users.

## 2. THE 8D METHODOLOGY

This 8D methodology, which has its roots in the middle of the 20th century, was developed to address and eliminate complex problems in production processes. The U.S. government initially employed the 8D method during World War II under the designation of Military Standard 1520 (Aichouni et al., 2021). Later, Ford Motor Company played a key role in formulating and promoting the 8D methodology, using it to optimise its production lines and improve the quality of its vehicles (Ionescu et al., 2022).

The key to the success of the 8D methodology lies in its eight disciplined steps that are systematically followed in the problem-solving process. These steps include (Divanoğlu & Taş, 2022; Realyvásquez-Vargas et al., 2020; ):

- Team formation;
- Problem Description;
- Implementation and verification of temporary measures;
- Identification and verification of the cause of the problem;
- Selection and verification of corrective measures;
- Implementation of corrective measures;
- Take preventive measures;
- Congratulate your team.

The first phase involves the formation of a team that should consist of experts with different skills and experiences relevant to the problem being solved (Kaplík et al., 2013). In the second phase, a detailed description of the problem is developed using comprehensive data and information. The goal is to understand the problem down to the smallest detail, laying the groundwork for the next steps in the process (Adelekan, 2020). The third phase involves developing and implementing temporary solutions that can control the problem until a final solution is developed (ASQ, 2020). The next, fourth stage, is perhaps one of the most important. In this phase, the team tries to identify the root causes of the problem. This process uses methodologies such as the Ishikawa diagram or the "5 Why" technique. After identifying the root causes, the team moves to the fifth phase, where permanent solutions are developed and verified (Savković et al., 2021). The selected solutions are implemented in real working conditions in the sixth phase. The team must closely monitor this process to ensure that the solutions are implemented correctly and work as planned. The seventh phase focuses on preventing future problems and analyzing processes and systems to identify and eliminate potential problems before they occur. Finally, the eighth stage is an opportunity for the team to be rewarded and recognized for their efforts and success. Here, the team needs time to reflect on the process and learn from the experience, setting the stage for future success (Savković et al., 2021). Through all these stages, the 8D methodology promotes systematic, disciplined and team-based problem-solving, helping organizations effectively face and overcome challenges in a dynamic and competitive business environment. One of the disadvantages of using the 8D methodology is that it is often used as a one-page problem-reporting process, with the requirement that the report must be completed within 24 hours. However, some steps can be completed within a few hours, while others may take weeks.

One of the disadvantages of using the 8D methodology is that it is often used as a one-page problem-reporting process, with the requirement that the report must be completed within 24 hours. However, some steps can be completed within a few hours, while others may take weeks (Aichouni et al., 2021). Nevertheless, following cases show long-term benefits for the automotive industry such as improved product quality, enhanced customer satisfaction, cost savings, increased efficiency, supplier relationship improvement, knowledge retention and organizational learning, and regulatory compliance and reputation (Rathi et al., 2022; Phanden et al., 2022; George et al., 2021).

## **2.1. Case study on the example of cable production in Serbia**

An international Japanese company produces and distributes cable sets and wire systems for the automotive industry. It employs 1,700 workers in Serbia and is headquartered in an industrial zone in the west of Serbia. A customer of Mercedes-Benz (Rastatt, Germany) objected that the 60 packaging of the product XCV MB-23 did not correspond to the ordered specifications (instead of different coloured cables, black ones were supplied). The acceptance inspection indicated a problem with the colour of the plastic for the final coating and joining of the PLC ST2 product, but it was decided to accept it and use it in production.

In the first phase, a team was formed from the quality, procurement, receiving control, production, and logistics sectors. The team leader was from the quality department. The role of the person in the quality sector is to create 8D reports and troubleshoot. The procurement person is in charge of communication with suppliers, and receiving control refers to raw materials. The role of the production person was to oversee production, while the logistics person was in charge of inventory management. This first step defined the original deadlines for solving the problem. In the second step, we defined the problem, which was preceded by the 5W2H is/is not analysis shown in Table 1.

**Table 1:** 5W2H – Defining the problem

5W2H	√	X
Who? To whom?	Who affects the problem? <i>Procurement, production, receiving control.</i> Who first noticed the problem? <i>User.</i> Who did he report the problem to? <i>To the sales manager.</i>	Who is not affected by the problem? <i>Transportation.</i> Who did not notice/find the problem? <i>Warehouseman.</i>
What? Which?	What kind of problem is that? <i>Wrong colour of cables on delivery.</i> Who has a problem? <i>The colour of the plastic used to cover the XCV MB-23.</i> What happens to the process and the correction - containment of the problem? <i>Urgent procurement of necessary raw materials and finishing of cable sets.</i> Do we have physical evidence of this problem? <i>Complaint, order and receipt, email confirmation.</i>	What does not have a problem? <i>Cable reliability.</i> What could happen but did not? <i>The cables, in addition to the wrong colour, were also defective.</i> What could be a problem but is not? <i>Besides "Mercedes-Benz", other partners (users) receive the wrong delivery.</i>
Why?	Why is it a problem (quality of work)? <i>Because the color of the cables defines its use</i>	Why is that not a problem? <i>Because it was noticed in time and a larger scale problem did not occur.</i>
Where?	Where was the problem noticed? <i>User code - "Mercedes Benz".</i> Where did the problem occur? <i>Plant for the production of cable sets i wire systems.</i>	Where could the problem be located but is not? <i>At the warehouse (logistics).</i> Where else could the problem be located but is not? <i>At the supplier</i>
When?	When was the problem first noticed? <i>November 2, 2018, 5 p.m.</i> Until when was the problem noticed? <i>2.11./3.11./4.11.2018.</i>	When the problem could have been noticed, but was not? <i>Before delivery to the user, 20.10.2018</i>
How much?	Amount of problem (unit of measure)? <i>60 packs of XCV MB-23 and 30 packs in stock (unused).</i> How much is the cost problem in money, people, and time? <i>- Shipping costs,</i> <i>- The cost of keeping the goods in stock until delivery to the new user.</i>	How much of a problem could it be quantitatively, but isn't? <i>600 packs for all partners (users).</i> How big of a problem could it have been, but wasn't? <i>That all partners were sent the wrong colour of cables.</i>
How often?	What is the trend of the problem (continuous, random, cyclical)? <i>By accident.</i> Has the problem occurred before? <i>It's not.</i>	What would that trend be, but it's not? <i>Repeat wrong order by procurement.</i>

The receiving control received the raw materials and pointed out the problem that the colour of the raw materials was not in accordance with the specification and purchase order. Due to the delivery deadline, the production supervisor received cables that were not in accordance with the specification for further production, in which he consulted with the production manager and the sales manager. In the third step, we moved on to defining urgent corrective measures. The results of the meeting in the form of an action plan are shown in Table 2.

**Table 2:** An action plan for solving the problem of delivery of wrong cables

Action	Problem	Corrective measures	How is it verified?	Action	Responsible person	Planned	Accomplished	Status
A1	XCVMB-23	order correction	corrected order	delivery of goods that are in accordance with the specification and order in the shortest	Procurement Officer	10.11.2018	10.11.2018	executed

				possible time				
<b>A2</b>	XCVMB-23	production and delivery of cables in the shortest possible time	production report delivery report	production of cables according to specification and order	head of the production shift	11.11. 2018	14.11. 2018	In progress
<b>A3</b>	XCVMB-23	finding the user for the returned goods, but also its control before that	report on the performed control bid sent	search of the database of potential users. Controlling raw materials and products within tolerance limits	marketing; quality control	10.11. 2018	12.11. 2018	executed
<b>A4</b>	XCVMB-23	check whether there are suitable goods in stock for Mercedes-Benz	electronic inspection	checking the system for insight into the state of goods in stock	warehouseman	05.11. 2018	05.11. 2018	executed
<b>A5</b>	XCVMB-23	increase the level of safety stocks of raw materials and finished products	inventory status report	ordering supplies when they reach their minimum	warehouseman; Procurement Officer	06.11. 2018	11.11. 2018	executed

The assembled team, after defining the problem, observed the following causes:

- inadequate order;
- tolerated release of raw materials into the production process by management;
- inadequate inventory management;
- non-reaction of the control when identifying the problem.

After that, we got into the depth of the problem and, through the "5 why" method, answered three questions:

- "Why does the problem exist?";  
Because the user filed a complaint  
Because the delivery was inconsistent with the order.  
Because the supplied cables are the wrong colour.  
Because the receiving control tolerates errors, procurement, and sales.  
Because there was not enough stock in the warehouse.
- "Why was the problem not discovered?"  
Because the purchasing manager did not place the right order.  
Because he had no insight into the current situation.  
Because their inventory database was out of date  
Because the storekeeper did not make changes to the database.  
Because the storekeeper is on sick leave, his replacement was not informed about the changes.
- "What is the systemic main cause?"  
Approving the sending of an inadequate delivery to the customer  
Production of one type of cables  
Receiving control released only one colour of plastic into production.  
Lack of multi-coloured plastic.  
Mismatch of raw material stocks and production needs

After identifying the cause of the problem, the team moved on to defining its corrective measures. The following corrective measures are defined:

- Increase the level of safety stocks of raw materials;
- Increase the level of safety stocks of finished products;
- When sending the purchase order via email, put it in CC procurement supervisor to review the order;
- Certificate of training of the replacement worker, as well as the presence of the competent person
- persons and work control of replacement workers;
- Checking whether the workers are instructed in the content of the procedure for reacting in disputed situations.



In relation to previously defined measures, the meeting also created action plan where the status of measures will be monitored. The action plan is shown in table 3.

Action	Problem	Corrective measures	How is it verified?	Action	Responsible person	Planned	Accomplished	Status
A6	XCVMB-23	increase the level of safety stocks of raw materials	inventory status report	ordering supplies when they reach their minimum	warehouseman procurement officer	06.11.2018	11.11.2018	executed
A7	XCVMB-23	increase the level of safety stocks of finished products	report on the stock of finished products	produce an inventory of finished goods that will represent the authorized inventory level	Production Manager	06.11.2018	11.11.2018	executed
A8	XCVMB-23	when sending the purchase order by e-mail, put the procurement supervisor in the cc to check the order			sales supervisor	05.11.2018	05.11.2018	executed
A9	XCVMB-23	confirmation of the training of the replacement worker, as well as the presence of the competent person and the work controller of the replacement worker	training certificate	conducting training	HR manager	05.11.2018	05.11.2018	executed
A10	XCVMB-23	checking whether workers are instructed in the content of the procedure for responding in disputed situations	verification certificate	checking the knowledge of the workers in the procedure; simulation of the mentioned situation	Quality Controller	05.11.2018	05.11.2018	executed

After the implementation of corrective measures, the next step was the implementation of measures that would check and ensure the effectiveness of corrective measures. The following validation measures are defined:

- The procurement supervisor conducts unannounced safety stock checks of raw materials and finished products at least two times per month, comparing the checks with the users' purchase orders.
- The procurement supervisor must verify the e-mail by comparing it to the user's purchase and raw material orders.
- Confirmation of the training of the replacement worker, as well as the presence of competent persons and control of the work of replacement workers.
- Checking whether the workers are instructed in the content of the Procedure for reacting in disputed situations.
- When formatting the lines with equations, the number of the equation should be aligned right, and the equation placed in the centre.

Within the next step of the method, preventive measures are additionally defined and preventive measures so that the same problem would not be repeated on other lines or with other products. The defined preventive measure is to show the employees the production plan for the next two weeks and provide insight into the stock status using the application.

As part of the final step, the team is commended for the results achieved, and the complaint is officially closed.

## **2.2. Case study on the example of window lifters on cars in Serbia**

A company producing electric motors for raising window lifters on cars faced a customer's complaint that after installation in the vehicle, the raisers were very noisy, 10 decibels above the upper tolerance. A team of experts from the company immediately approached this problem very seriously using the 8D methodology:

- D1: Formation of the team - A multidisciplinary team of engineers was assembled from the company and from the same company from other countries, as well as experts from the field of quality and production.
- D2: Description of the problem—In the second step, a serious analysis and collection of facts and evidence related to the problem were undertaken.
- D3: Temporary measures—As part of the protective measures, additional noise testing was immediately introduced for all new products on the line itself. For existing products in stock, in the company, at the customer's place, and in transport, an urgent inspection was organized to see if they are within tolerance limits when it comes to noise. Everyone on the line and all relevant participants were informed of the problem.
- D4: Identification of the cause of the problem - Further detailed analysis revealed that the problem arose because the screw on the armature, which is an integral part of the engine, was damaged, which in contact with the gear, produces greater vibrations and noise when under load. The problem was caused by the machine that processes the main screw of the armature, making the auger. The problem was not detected because the lifters are tested on the line itself without load, while under load, they are tested in the laboratory by sampling.
- D5: Selection of corrective measures - Corrective measures were defined, which were related to the repair of the machine tool for processing the screw worm, and its frequent checks were defined. When it comes to detection, the noise check under load is significantly increased.
- D6: Implementation of permanent solutions - All solutions were implemented within the given period. The customer agreed with the technical and management solutions.
- D7: Preventive measures—The same solutions have also been implemented on other lines to ensure that a similar problem does not occur again.
- D8: Teamwork and recognition—The technical director praised the team for their quick response and successful solution to the problem, after which this complaint was officially closed and signed.

## **4. CONCLUSION**

This paper focused on the complex and dynamic field of quality management in the automotive industry context, with a special focus on the methodology used globally and in Serbia. After the introductory part, the 8D methodology is described, and its history, development stages, and problem-solving application are discussed. Two case studies show how this methodology can be used in practice, highlighting its advantages and the challenges companies may face during implementation. The importance of continuous quality

management in the automotive industry has been proven through detailed analysis and study of real scenarios. The 8D methodology helps maintain product quality and identify and solve problems efficiently while guaranteeing the safety and satisfaction of end users. Although, in any case, it is a better option for the company itself to implement preventive methods to do everything to prevent the problem from occurring, it is important that it also knows several methods, which, when a problem (internal or external) occurs, it will be able to get out of it. For the mentioned reason, the 8D methodology, which is the main topic of this paper, has been proven to contain steps that will help the company overcome any challenge it faces. By skipping any step or applying it inadequately, the company risks neglecting some important aspects of defining or solving the problem. This can lead to the repetition of the same problem because it was not solved correctly, as the method requires.

Future research can play a key role in refining and expanding the application of the 8D methodology. This will help ensure that it remains relevant and effective in a rapidly changing industrial environment. Such research can enhance the methodology and offer valuable insights for its implementation in various settings, ultimately leading to improved quality management practices in the automotive industry and other sectors.

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# APPLICATION OF EXACT METHODS FOR FINDING THE OPTIMAL SOLUTION OF ORGANIZATIONAL RESILIENCE IMPROVEMENT

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**Abstract:** *This paper investigates the application of branch and bound algorithms to determine the optimal solution for enhancing organizational resilience. Faced with an increasingly dynamic and uncertain business environment, organizations seek effective methods to fortify their resilience against disruptions. Our study focuses on identifying a set of management methods that can improve key resilience factors while considering constraints such as execution time and costs. Through rigorous analysis, the branch and bound algorithm efficiently navigates the vast solution space, yielding a curated set of methods including Flowchart (generic), Mind map, Stakeholder analysis, Brainstorming, Brainwriting, 5W2H, and Importance–performance analysis. These methods offer diverse approaches to resilience enhancement, each with its unique strengths. By incorporating time and cost constraints, our approach ensures practical feasibility for real-world implementation. It can be concluded that leveraging branch and bound algorithms provides valuable insights for organizations to proactively adapt to challenges and seize opportunities in an ever-evolving landscape of disruptions.*

**Keywords:** *organizational resilience, heuristic algorithm, optimization*

## 1. INTRODUCTION

In the contemporary landscape of business operations, the imperative of organizational resilience stands out as a critical determinant of sustained success (Kerr 2016). Defined by its capacity to adapt, withstand, and recover from disruptions, organizational resilience encapsulates a multifaceted array of factors, including adaptability, agility, robustness, and recovery capabilities. In response to this imperative, organizations increasingly seek strategies to fortify their resilience posture through targeted interventions (Tasic et al. 2020).

A prevailing approach involves the implementation of diverse management methods aimed at fortifying specific resilience factors (RFs). Yet, the challenge persists: how can organizations optimize the allocation of resources to maximize resilience enhancements, particularly when faced with constraints such as limited budgets and varying applicability of management methods?

In response to this challenge, this paper introduces a novel approach leveraging the branch and bound algorithm for optimizing organizational RF improvement. The objective function of the algorithm is to maximize the integration of management methods aimed at enhancing RFs, with constraints including a predefined budget and the applicability of each management method. The input data for the calculation is provided by Decision Makers (DMs).

The branch and bound algorithm, a classic optimization technique, offers a systematic approach to exploring the solution space of combinatorial optimization problems (Lawler & Wood 1966). By iteratively partitioning the solution space into smaller subspaces and bounding the objective function within each subspace, the branch and bound algorithm efficiently identifies the optimal solution or proves optimality within a given tolerance.

This paper contributes to the burgeoning literature on organizational resilience by proposing a novel application of the branch and bound algorithm to address the complex optimization problem of RF improvement. By harnessing the computational power of the branch and bound algorithm, organizations can gain insights into optimal resource allocation strategies for enhancing resilience while navigating resource constraints and method applicability considerations.

The subsequent sections of this paper are organized as follows: Section 2 provides an overview of related work in the fields of organizational resilience and optimization algorithms. Section 3 outlines the methodology employed in developing and applying the branch and bound algorithm for RF improvement. Section 4 presents the experimental setup and results of applying the proposed algorithm to a real-world case study. Finally, Section 5 offers conclusions and avenues for future research.

## 2. LITERATURE REVIEW

Organizational resilience has attracted attention in both academic and practical domains in recent years. This section provides an overview of pertinent literature spanning organizational resilience and heuristic optimization, laying the groundwork for the development and application of heuristic algorithms in optimizing RF improvement.

Organizational resilience is a multifaceted concept that encompasses an organization's capacity to anticipate, prepare for, respond to, and recover from disruptions while maintaining essential functions and adapting to changing circumstances (Hollnagel 2010). Resilience factors, such as awareness, preparedness, flexibility, and redundancy, play a crucial role in determining an organization's ability to withstand and thrive amidst adversity (Macuzić et al. 2016).

Scholars have emphasized the dynamic and interconnected nature of RFs, highlighting the need for holistic approaches that consider the interplay between organizational structures, processes, culture, and external environments (Vogus & Sutcliffe 2007). Various frameworks and models have been proposed to conceptualize and assess organizational resilience (Shirali & Nematpour 2019).

Optimization algorithms offer valuable tools for addressing the complex resource allocation challenges inherent in enhancing organizational resilience. While a variety of optimization techniques exist, the focus here is on the branch and bound algorithm, a classic method for solving combinatorial optimization problems (Little et al., 1966).

The branch and bound algorithm systematically explores the solution space of an optimization problem by partitioning it into smaller subspaces and bounding the objective function within each subspace. Through a process of iterative refinement and pruning, the algorithm efficiently identifies the optimal solution or proves optimality within a specified tolerance. This makes it particularly well-suited for optimization problems with discrete decision variables and complex constraints, such as those encountered in resilience enhancement efforts.

Recent research has demonstrated the potential of the branch and bound algorithm in optimizing resource allocation for organizational resilience improvement. By formulating the resilience enhancement problem as a combinatorial optimization problem and applying the branch and bound algorithm, organizations can identify optimal strategies for allocating resources to maximize RFs while adhering to constraints such as budgetary limitations and method applicability.

While the literature on the integration of the branch and bound algorithm specifically for organizational resilience optimization is relatively scarce, studies in related fields such as project scheduling, portfolio optimization, and resource allocation provide valuable insights into the efficacy and applicability of the algorithm (Pardalos et al. 2013). These studies highlight the versatility and effectiveness of the branch and bound algorithm in addressing complex optimization problems across diverse domains.

The literature reviewed herein underscores the critical importance of organizational resilience and optimization algorithms in contemporary business contexts. Building upon this foundation, the subsequent sections of this paper introduce a novel application of the branch and bound algorithm for optimizing organizational RFs improvement, offering a practical and effective approach for organizations seeking to enhance their resilience capabilities in the face of uncertainty and disruption.

## 3. THE PROPOSED MODEL AND ALGORITHM

In this section, the proposed methodology is presented. It is used to evaluate the suitability of the method whose application leads to the improvement of RFs, which is further propagated to increase the resilience of the company. Assessment of the method suitability for the RFs enhancement is presented as a fuzzy group decision-making problem. DMs use pre-defined linguistic expressions which are modeled by TFNs. The time and costs of applying the method are assessed by the Operations manager who forms the opinion on the personal competence, experience, and evidence data. The rest of the DM's team could consist of different senior management members, such as the manager of the production process, quality manager, or top manager according to the specific characteristics of the treated enterprise.

In order to make the proposed Algorithm easier to understand, the notation of variables is given in Table 1.

**Table 1** Notation

Notation	Description	Notation	Description
$J$	The total number of RFs	$\tilde{x}_{jm}^e$	Fuzzy rating of the method's suitability $m, m = 1, \dots, M$ for unapređenje RF $j, j = 1, \dots, J$ at the level of DM $e, e = 1, \dots, E$
$j, j = 1, \dots, J$	Index of RF	$\tilde{x}_m$	The aggregated values of method's suitability $m, m = 1, \dots, M$ for the RFs enhancement
$M$	the total number of methods used for the RFs enhancement (Tague 2023)	$T$	The total amount of time needed for the enhancement of RFs
$m, m = 1, \dots, M$	index of the management method for RFs enhancement	$t_m$	The amount of time needed for the execution of the management method $m, m = 1, \dots, M$
$E$	the total number of DMs	$G$	The total planned budget needed for the enhancement of RFs
$e, e = 1, \dots, E$	index of DM	$\gamma_m$	The costs of the management method execution $m, m = 1, \dots, M$

### 3.1. Linguistic terms for describing the methods' suitability for the RFs enhancement

It is widely acknowledged that DMs find it more intuitive to express their evaluations using linguistic expressions rather than conventional measurement scales. The conceptual framework of fuzzy sets, pioneered by Dubois and Prade (1980) and further refined by Zimmermann (2010), has provided a robust mathematical foundation for representing these linguistic expressions in a quantitative manner. This framework facilitates the modeling of linguistic expressions through fuzzy numbers, characterized by key attributes such as membership function, granularity, and domain.

Numerous studies in literature advocate the efficacy of Triangular Fuzzy Numbers (TFNs) in capturing uncertainties and imprecisions inherent in natural language without necessitating complex mathematical computations. TFNs offer a pragmatic approach to addressing linguistic uncertainties, effectively bridging the gap between qualitative assessments and quantitative analyses.

Determining the appropriate granularity for linguistic expressions remains an open question, devoid of universal guidelines or directives. Typically, the selection of linguistic expressions is contingent upon the intricacy of the problem at hand. Notably, a prevalent convention observed in scholarly discourse involves the utilization of seven linguistic expressions (Lootsma 1988). The predefined linguistic expressions, along with their corresponding TFNs, are elucidated as follows:

extremely low applicability-V1 = (1,1,2.5)  
 very low applicability -V2 = (1,2,3)  
 low applicability -V3 = (1.5,3,4.5)  
 medium applicability -V4 = (3.5,5,6.5)  
 high applicability-V5 = (5.5,7,8.5)  
 Very high applicability -V6 = (8,9,10)  
 extremely high applicability -V7 = (8.5,10,10)

Domains of defined TFNs are presented on real line into interval  $[1 - 10]$  as in referent literature (Saaty 2013). A value of 1 indicates that the applicability of the method is almost negligible. On the other hand, a value of 10 indicates that the applicability of the method certainly leads to the improvement of RFs.

### 3.2 The proposed Algorithm

The proposed Algorithm can be realized through the following steps, which are further detailed.

Step 1. Let us construct the matrix for suitability analysis of management methods for enhancement of each RF:

$$[\tilde{x}_{jm}^e]_{J \times M}$$

The values of this matrix,  $\tilde{x}_{jm}^e$  can have value 0 if DM  $e, e = 1, \dots, E$  believes that there makes no sense to use that method for the RF enhancement, or those values can be described by using one of seven pre-defined linguistic expressions, where:

$$\tilde{x}_{jm}^e = (a_{jm}^e, b_{jm}^e, c_{jm}^e)$$

Step 2. Let us determine the aggregated value of the method suitability  $m, m = 1, \dots, M$  at the level of each RF  $j, j = 1, \dots, J$  by applying the operator of fuzzy square mean,  $\tilde{x}_{jm}$ :

$$\tilde{x}_{jm} = \left( \sqrt[E]{\prod_{e=1, \dots, E} a_{jm}^e}, \sqrt[E]{\prod_{e=1, \dots, E} b_{jm}^e}, \sqrt[E]{\prod_{e=1, \dots, E} c_{jm}^e} \right) = (a_{jm}, b_{jm}, c_{jm})$$

Step 3. Let us determine the total suitability of the method  $m, m = 1, \dots, M$ ,  $\tilde{x}_m$ :

$$\tilde{x}_m = \left( \frac{1}{J} \cdot \sum_{j=1, \dots, J} a_{jm}, \frac{1}{J} \cdot \sum_{j=1, \dots, J} b_{jm}, \frac{1}{J} \cdot \sum_{j=1, \dots, J} c_{jm} \right) = (a_m, b_m, c_m)$$

Step 4. The representative scalar TFN  $\tilde{x}_m, x_m$ , is obtained by applying center gravity method (Wang & Luoh, 2000), so that:

$$x_m = a_m + \frac{c_m - a_m + b_m - a_m}{3}$$

Step 5. The choice of the optimal set of methods to be applied in order to improve RFs is set as a classic model of combinatorial optimization:

Fitness function:

$$\max_{m=1, \dots, M} x_m$$

Subject to:

$$\begin{aligned} \sum_{m=1, \dots, M} t_m &\leq T \\ \sum_{m=1, \dots, M} \gamma_m &\leq \mathcal{G} \end{aligned}$$

#### 4. CASE STUDY

This paper advances the state-of-the-art in organizational resilience research by introducing a novel approach that leverages the branch and bound algorithm for optimizing RFs improvement. Through empirical validation and case study analysis, we demonstrate the efficacy and practical applicability of the proposed approach in aiding organizations in their pursuit of enhanced resilience capabilities.

The proposed algorithm is tested in a complex international company that operates at different locations worldwide. The company is an international leader in high-precision equipment for quality management in industry. The input data is obtained through the interview with the DMs team. As mentioned in the section explaining the methodology, the DMs' team can consist of the different managers. In the treated company, it is decided that the DMs' team consists of (e=1) manager of integrated management systems, (e=2) operations manager, and (e=3) maintenance process manager.

The proposed Algorithm (Step 1 to Step 2) is illustrated for RF ( $j = 3$ ) at the level of the method ( $m = 1$ ). Fuzzy rating of method's suitability ( $m = 1$ ) is assessed by DMs in a following way:

$$V3, V3, V4$$

The aggregated value of the method's suitability calculated:

$$\tilde{x}_{31} = (\sqrt[3]{1.5 \cdot 1.5 \cdot 4.5}, \sqrt[3]{3 \cdot 3 \cdot 5}, \sqrt[3]{4.5 \cdot 4.5 \cdot 6.5}) = (1.99, 3.56, 5.09)$$

Each method's suitability is calculated in a similar manner for each RFs.

The total method's suitability ( $m = 1$ ) is calculated by applying the proposed Algorithm (Step 3):

$$\tilde{x}_1 = \left( \begin{array}{c} \frac{1}{10} \cdot (1 + 4.07 + 1.99 + 1.14 + 1.14 + 1.31 + 6.23 + 1.14 + 8.18 + 1.99), \\ \frac{1}{10} \cdot (1.59 + 5.59 + 3.56 + 2.29 + 2.29 + 2.62 + 7.61 + 2.29 + 9.32 + 3.56), \\ \frac{1}{10} \cdot (2.82 + 7.11 + 5.09 + 3.43 + 3.43 + 3.93 + 8.97 + 3.43 + 10 + 5.04) \end{array} \right)$$

$$\tilde{x}_1 = (2.82, 4.07, 5.33)$$

The crisp value of method's suitability ( $m = 1$ ) is given by center gravity method (Step 4 of the proposed Algorithm):

$$x_1 = 2.82 + \frac{5.33 - 2.82 + 4.07 - 2.82}{3} = 4.07$$

The values of other methods' suitability whose application may enhance the values of RFs are calculated in similar manner. The selection of methods to be applied is based on the following proposed KP problem:

Fitness function:

$$\max_{m=1, \dots, M} x_m$$

Subject to:

$$\begin{aligned} \sum_{m=1, \dots, 49} t_m &\leq 240 \\ \sum_{m=1, \dots, 49} \gamma_m &\leq 190\,000 \end{aligned}$$

By applying the software solution ([https://developers.google.com/optimization/cp/cp\\_solver](https://developers.google.com/optimization/cp/cp_solver)), the optimal set of methods whose application will enhance the values of RFs is obtained. Simultaneously, the optimal set of methods satisfy constraints in terms of time and costs. The obtained solution is given after 0,01458 seconds. The obtained set of methods include: Flowchart (generic) ( $m = 6$ ), Mind map ( $m = 9$ ), Stakeholder analysis ( $m = 15$ ), Brainstorming ( $m = 20$ ), Brainwriting ( $m = 21$ ), 5W2H ( $m = 23$ ) and Importance–performance analysis ( $m = 24$ ).

## 5. CONCLUSION

In this paper, we have explored the application of branch and bound algorithms in determining the optimal solution for improving organizational resilience. Our objective was to identify a set of management methods that, when applied, would enhance the values of RFs. Through rigorous analysis and implementation of the branch and bound algorithm, we were able to effectively navigate the complex landscape of available methods and their associated costs and time requirements.

The results of our study reveal a curated set of methods that hold significant promise for bolstering organizational resilience. Among these methods are Flowchart (generic), Mind map, Stakeholder analysis, Brainstorming, Brainwriting, 5W2H, and Importance–performance analysis. Each of these methods brings unique strengths to the table, offering diverse approaches to addressing the multifaceted challenges of organizational resilience enhancement.

Furthermore, the authors consider the methods presented to be comparatively "easy" to implement in a business context. This is mainly due to the fact that they are already widely recognized in organizations and the necessary competences are either already available or can be developed quickly. This supports implementation in terms of organizational resilience - in which the speed of implementation can be an elementary key. Nevertheless, there should be a discussion as to whether the proposed methods are equally suitable for organizations in different sectors in treated company or how flexible they are in order to adapt to constantly changing market conditions and technologies. Are the methods also long-term enough to be able to map future scenarios.

By incorporating constraints related to both time and cost, we ensured that the identified methods are not only effective but also feasible within real-world organizational contexts. This dual consideration is crucial for practical implementation, as it allows decision-makers to make informed choices that align with their resource constraints and strategic objectives.



As we move forward, it is essential to recognize that the pursuit of organizational resilience is an ongoing journey rather than a finite destination. While the methods identified in this study represent valuable tools for improvement, they are by no means exhaustive. Continued research and innovation in this field will be paramount for staying ahead of evolving challenges and opportunities.

The application of branch and bound algorithms has proven instrumental in uncovering actionable insights for organizational resilience enhancement. By leveraging these insights, organizations can proactively adapt to disruptions, seize new opportunities, and thrive in an ever-changing environment. We hope that this research serves as a catalyst for further exploration and advancement in the vital domain of organizational resilience.

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# ENHANCING PATIENT SAFETY: LESSONS FROM RISK MANAGEMENT IN CLINICAL TRIAL FOR APDS SYNDROME

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**Abstract:** *Clinical trials are of significant importance for the advancement of discovering drugs for various diseases. They are conducted in multiple phases and can last for several years. The key element is the safety of patients during the drug trial and the actual effects of its action. A study has been conducted on the risks that may arise during the clinical trial of a drug for APDS Syndrome, an extremely rare disease. Through the methodology, previous methods of mitigating these risks have been identified. For the purposes of the study, an interview was conducted with a Senior Project Leader to gather necessary data and information that are not publicly available. Through theoretical knowledge of potential risks, practical ways of mitigating them have been identified.*

**Keywords:** *clinical trial study, APDS Syndrome, Contract Research Organization, patient safety*

## 1. INTRODUCTION

The aim of this study is to gain a better understanding of the risk factors influencing the success of clinical trial studies. Understanding and improving patient safety is a growing concern (Piantadosi, 2024). Nevertheless, research and knowledge on patient safety have increased rapidly and improved many aspects of acute medical health care systems.

APDS Syndrome, Activated PI3K delta syndrome, is a very rare disease. Patients with this condition are prone to numerous infections and have a shortened lifespan. Close to 300 people in the world suffer from APDS Syndrome. Patients with APDS Syndrome show recurrent sinopulmonary and chronic herpes virus infections, immune dysregulation, including cytopenia, arthritis, inflammatory enteropathy, and a predisposition to persistent non-neoplastic splenomegaly, lymphoproliferation, and lymphoma.

The significant aspect of the investigation of the drug APDS Syndrome therapy is the exceedingly low incidence of this condition. Consequently, conducting trials for a novel medication proves challenging, given the scarcity of individuals afflicted with this syndrome. Moreover, due to the rarity of APDS Syndrome, identifying suitable countries and patients for research purposes presents considerable difficulty. The prevalence of APDS Syndrome is remarkably low, estimated to affect up to 1-2 people per million of the global population (interview). Nowadays, Food And Drug Agency (FDA) and European Medicines Evaluation Agencies (EMA) support clinical trials, investigations in the area of rare disease, such as APDS Syndrome.

Conducting clinical trials for APDS Syndrome is of huge importance for the patients, due to the fact that the cure has not yet been found and in order to improve a patient's life quality (interview). The current clinical trials are under investigation for this helpful drug. According to the clinical trials, it is concluded that the patients' lives with APDS Syndrome are of lower quality, and their lifespan is shorter.

## 2. APDS SYNDROME CLINICAL TRIAL: RISKS & MITIGATIONS

In order for the Clinical Trial for the APDS Syndrome to be seen as significant for future research, it is necessary to involve more companies with the clinical research service for future cooperation.

Senior Project Leader (interview) claims that the importance of identifying potential risks and the way that could be mitigated are of huge relevance. It is advised (PMI, 2017) to reveal the risks of each study before the beginning of it in order to be prepared to react and mitigate them. Risks are identified at the beginning of the

clinical trial but also during the duration of the clinical trial. After clinical study completion, lessons learned are shared within a company in order to improve future clinical trials and be ready to mitigate risks in advance.

Clinical trials cannot draw representative samples from any population (Piantadosi, 2024). Therefore, for different kinds of illnesses and Syndrome, the same result cannot be expected. According to that statement, for each clinical trial, there are not the same risks and mitigations for them, especially knowing the fact that APDS is extremely rare disease.

In this research, the risks and mitigations for clinical trials for APDS Syndrome are investigated and will be listed.

### **3. RESEARCH METHODOLOGY**

With the hypothesis of the possibility of no cure but an improvement in the quality of life for patients with APDS Syndrome, an interview was conducted. Considering the rarity of the named disease, clinical studies examining it are scarce. Through the research, it was found that there is a company specialising in clinical trials (CRO, Contract Research Organization), which has already conducted a study on the drug's effects on improving patients' conditions with APDS Syndrome.

To investigate the established hypotheses, an interview was conducted with the Senior Project Leader of the APDS Syndrome clinical trial. The Senior Project Leader is responsible for overseeing the entire project, monitoring the effects, overview financial part, mitigating established hypotheses, achieving predefined KPIs, and communicating with the Project Sponsor (PMI, 2017).

The interview was conducted online via the Google Meet platform, with precisely formulated questions. Since the theme of the interview was risk mitigation during the clinical drug trial, the opening question for discussion was: What were the risks during the study that required devising a mitigation strategy? This was followed immediately by the question: What was the impact of these risks on the conduct of the study and how were they mitigated?

Considering the information obtained in the completed study, one of the main questions was: Why was the study terminated before the final phase of clinical trials? As a conclusion to the discussion, an answer was obtained to the question: What are the lessons learned from the past study?

Due to the fact that further and more precise information about the study and the patient was confidential, there was no need for another interview. All the necessary information about the research were provided during the one interview that lasted for an hour.

In the following, hypothesis would be stated:

- 1) Leveraging theoretical knowledge on potential risks acquired in previous immunology clinical trials and clinical trials in APDS to identify key areas of concern that may not be applied on the current APDS Syndrome study.
- 2) Incorporating practical mitigation strategies suggested by experienced clinical trial leaders will address specific safety and efficacy challenges unique to rare diseases like APDS Syndrome.
- 3) Collaborative approaches between theoretical and practical insights will facilitate the development of more robust and comprehensive risk management plans for clinical trials involving rare diseases.

### **4. RESEARCH RESULTS IN CLINICAL TRIAL STUDY**

At the outset, there is a potential risk of encountering issues in obtaining the necessary documentation from the study sponsor on time. This risk is of paramount importance, as without the required documentation needed for obtaining regulatory and ethical approval for conducting clinical trial, the drug trial cannot commence its phase. The risk of study rejection from regulatory authority or ethical committee in the given country means that the targeted countries will not participate in the clinical trial.

Furthermore, delays in drug delivery to the clinical centre are a risk of great significance. If the medication is not provided within the required timeframe, the patient will be unable to receive the drug, thereby disrupting the protocol. Each deviation from the protocol is considered as protocol deviation (could be major or minor) and might jeopardize study results, and in some countries require submission to regulatory authorities. If the number of participants is insufficient, statistical analyses might not be completed, thus increasing the possibility of the drug being rejected for market registration. The adverse effects of the drug during the study are a real

risk. The patient's decision to withdraw from the study is of significant importance for the study, given the exceptionally low number of people afflicted with the mentioned syndrome worldwide. The information described in the following table (Table 1.) refers to the conducted interview with the Senior Project Leader. Examples of possible risks and their impact on detectability as well as consequences for clinical trial study:

Table 1. Risk identification in clinical trial studies – overview of research results

Risk	Impact on Detectability	Consequences
1. The issue of securing the necessary documentation from the study sponsor on time.	Easy 100%	The impossibility of delay in study startup and obtaining regulatory and Ethical committee approval.
2. The risk of Clinical study rejection by Regulatory authority or Ethical committee in the given country.	Moderate 50%	The inability to conduct the trial in the targeted country.
3. Delays in drug delivery to the clinical center.	Easy 100%	The patient will not receive the medication on time.
4. Insufficient number of patients for study enrollment.	Moderate 80%	The inability to perform statistical analyze.
5. Adverse effects of the drug during the study.	Easy 100%	Patient dissatisfaction, potential study discontinuation.
6. The decision of a patient to withdraw from the study.	Moderate 50%	The patient withdraws from the trial, patient data lost.

## 5. DISCUSSION

According to the conducted interview, the answers to the key questions were about the strategies for the mitigation of the potential risks in the clinical trial for the APDS Syndrome. In this section, a description of the mitigation approach to the challenges that may arise is presented. (Interview with the Senior Project Leader)

When it comes to the issue of securing the necessary documentation from the study sponsor, regular meetings with the sponsor and constant updating on the progress of obtaining the necessary documentation for project execution are of huge importance for the study. Therefore, creating a clinical trial plan based on the timeline for receiving documents for submission to the regulatory and ethical committee should be implemented. Based on the dates when the necessary documentation would be received, further steps would be formulated. Regulatory authorities may require amendment to study documents, which may extend study document finalization and getting regulatory approval. Regulatory authorities in some countries may reject entire study. (Example: In some countries clinical trials that enroll minors are not allowed. Reference (senior project leader interview))

The risk of study rejection by Regulatory and Ethical committee in the given country could be mitigated if CROs (Contract Research Organizations) target countries with fast document review and issuance processes. Starting from 2023 in EU (European Union) submission for regulatory approval is done via EU-CTR (European Union Clinical Trial Regulation) for all countries and in that way this uniform submission reduce time for approval. They also pay attention to countries with registered cases of people suffering from APDS Syndrome.

The solution to the delays in drug delivery is the development of a robust logistical system. Logistical system is requested for blood transport and drug delivery. Dedicated companies should be able to ship on dry eyes

and within requested temperature. Also, study documents (protocol, investigator brochure, different patient questionnaires) should also be delivered to the site. Nowadays, in order to mitigate risk for delays in study document delivery, different platforms are organised, and study documents are available only to authorized study team members. Advance identification of all holidays in all countries and identifying backup personnel during their holidays. (PMI, 2017)

The solution for the insufficient number of patients for the study, is to identify centres that have confirmed patients with APDS Syndrome. Previous experience and collaboration with the hospital in the selected country for conducting the trial are essential. Key opinion leader for APDS Syndrome, should communicate with other sites in the country where clinical trial is ongoing and inform other investigators via: „dear doctor letter” about the study and possibility for their patients suffering from APDS Syndrome to join the study.

Identifying adverse drug effects in the early stages and monitoring the patient's reactions to adverse effects are risk mitigation measures (Seema et. al 2016). The major importance of all clinical trials is patient safety and data integrity. If there are too many adverse effects, the clinical trial is halted.

When it comes to the patient's decision to withdraw the study, CROs cover transportation costs to the hospital, if patients are minors costs are recovered for caregivers as well. Medical supplies and necessary medications, as well as analyses and regular check-ups by doctors, are provided to the patients. Meals are provided to them when they come to the hospital for check-ups. Nowadays, in order to retain enrolled patients in the clinical study non-dosing visits (visits on which drug is not despenzed) are performed remotely. If study protocol allows, study-nurse travels to patient's home in order to collect blood samples.

## 6. CONCLUSION

The initial hypothesis with leveraging theoretical knowledge on potential risks acquired in previous immunology clinical trials was of a great support and applied mitigation actions to successfully lead APDS trial. All specific and safety challenges from previous clinical trials in rare disease area were implemented. Creation of risk management plan before the beginning of clinical trial and also updating it during the course of trial helped Project Leader to lead the project (on time on budget) until the moment it was stopped. The aim of this study was to highlight potential risks and mitigation strategies so that the clinical trial could proceed further. In this way, risks and mitigations were identified, that could be utilized in further drug research for APDS Syndrome.

The conclusion drawn after the conducted trial is that it's necessary to more thoroughly identify and examine the market competition, as it can lead to significant risks, as seen in this case where the clinical trial was terminated. This particular issue was not previously identified. With this insight, the drug trial budget could be redirected to other medications where there is currently no competition.

## 7. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

The potential limitations identified through the study included the possibility of only one interview with the Senior Project Leader. Additionally, there was no opportunity for physical meetings and communication with patients to gain insight from their perspective regarding the investigational drug. Due to the confidentiality of clinical study-related data, access to information was extremely limited.

It is advised that the direction of this investigation in the future, should focus on finding relevant data that is currently inaccessible. Conducting interviews with a larger number of individuals involved in the same study would also be highly beneficial.

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# WORK MEASUREMENT IN THE NEW ERA: LITERATURE REVIEW OF STANDARD TIME ESTIMATION WITH ANN

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**Abstract:** Machine learning methods are gaining popularity in prediction and mathematical calculation operations thanks to the advances it brought through enhanced computational capacity and data handling. This paper presents a literature review of artificial neural network-based (ANN-based) approaches as a tool to standard time determination for work measurement and process management purposes. Where direct measurement might not be practical particularly for batch, complex, protracted production processes, the existing body of knowledge was examined in detail to exhibit the potential of neural network-based approaches to compute the standard times basing on Web of Science Core Collection and Scopus databases. Analyzed documents were categorized considering several parameters e.g. publication frequency, application areas, input set widths, handled factors to affect the standard times. Three research questions were investigated to provide a valuable resource for both scientific and field practitioners to elucidate ANN employment instead of traditional methods and intensified improvement in planning activities.

**Keywords:** Artificial neural network, standard time, work measurement, process management, production and service systems

## 1. INTRODUCTION

In manufacturing and service systems, standard time is a crucial information for accurate planning, resource allocation, purchasing, scheduling and delivery operations since it indicates exact duration of performed unit job identified for the system, as well as it also serves as a parameter for measuring employee performance and hence, is used to enhance workflow efficiency and set production targets (Yuliani et al., 2019). Standard time is traditionally determined by the employment of direct work measurement (WM) methods such as work study, work sampling, etc., or indirect methods such as standard data systems, predetermined motion and time systems, etc., where the times to accomplish the designated task are directly measured or computed according to pre-existed data tables, respectively. As the new era of digitalization arrived and both resources, materials, machine and equipment, processes and workflows begun to transform more complex and a set simultaneously occurring parallel processes and symbiotic-structured system pieces, determination of the standard time has become even more difficult while there were already various challenges associated with the implementation of the traditional methods, such as manual workflow intensity, product complexity, protracted workflows, seasonal orders, or batch production needs. These existing challenges and the new ones arose with the new digitalization era have led to the need and eventually the development of alternative computation methods that is capable of conducting more comprehensive WM operations and generating more accurate result data depending on real-time cycles without the need of additional observations or presence of an observer.

Artificial intelligence (AI) is a set of software and hardware systems that have many capabilities such as exhibiting human-like behavior, numerical reasoning, movement, speech and sound perception. AI allows the digitalized systems to think like a human, that is, when a question is asked it could select and present the most rational answer among the previously given or defined answers to that question. Machine learning (ML), a branch of AI, that also includes another sub-branch deep learning (DL), enables the machine to derive logical and rational results with the data provided. ML approaches create models with the existing data set and the designated most appropriate algorithm to construct a solution consequent with the query structure, and, determines the solution space with the highest performance based on the problem space. Since the algorithm to be used will be changed as its suitability for the problem structure and data set varies, various ML methods were introduced. Some ML methods are used for prediction, some of them for clustering, and some of them for classification.

ML is an alternative tool for determining standard time thanks to its capabilities of learning from large data sets and identifying complex relationships (Yamashiro and Nonaka, 2021). While direct and indirect WM techniques may fail to address the complexity and variability of processes, ML models are expected to better

understand this complexity and present more accurate standard time estimations.

Neural networks, one of the ML algorithms, is an AI technology that mimics the way the human brain works to identify complex relationships and patterns. Artificial neural networks (ANN) have the ability to learn and model non-linear and complex interactions, which enables them to better understand the relationships between qualitative and quantitative factors affecting production and time and to make more accurate predictions (Dağdeviren et al., 2011). This study is dedicated to analyze and introduce the employment of ANN tool to standard time determination, and, three research questions were developed to address the significant issues related to practical deductions from the findings of existing research studies regarding the existing literature. In Section 2 the relevant concepts regarding WM, ML and ANN were presented. Section 3 presents the conducted research, scope, research questions and results and discussion, where Section 4 briefly explains the aims, restrictions and future directions and concludes the study.

## 2. RELEVANT CONCEPTS

Process management (PM) is an integral management concept to guide, organize and manage an organization. PM aims to carry out the necessary management activities to enhance performance, including planning and operational performance, which subsequently ameliorates quality (Evans & Windsay, 2002).

PM is a very critical operation to optimize all business activities and increase productivity, where it involves the systematic analysis of executed processes and is a technique used to identify improvements in methods and operations by diagnosing non-value adding activities. Through applying process management principles businesses can manage their activities more effectively and gain competitive advantage (Shruti & Verma, 2020).

WM is used within the framework of process management as an important method to measure and manage process performance by determining the activities, durations and resources in the process of performing a job. It is the process of applying techniques to determine the time required for a skilled worker to perform a specific job at a specific work rate or performance level (Kanawaty, 1997). WM aims to calculate the standard time by investigating flows, and, identifying and eventually eliminating the ineffective time while performing a job. Time study, one of the most frequently used WM techniques, is a method used to calculate the time required to perform a task, usually based on actual performance studies from measurements that are taken directly by stopwatch observations. Time study reflects not only the duration of human performance and behavior but also used in benchmarking in method study applications for ergonomic design of workplaces to decrease movement need of the employee, hence, to improve efficiency and effectiveness in task performance (Bendy et al., 2022).

ANN is a data-based system created by connecting artificial nerve cells in layers and aim to use the human brain's abilities such as learning and making very fast decisions under different conditions in solving complex problems with the help of simplified models (Dongare & Sachin, 2023). ANN models represent a promising modeling technique especially for data sets having nonlinear relationships that are frequently encountered in engineering problems (Eraslan, 2009), where recent advances in ANN include convolutional neural networks and deep learning, which further improve their ability in modelling complex patterns and prediction problems (Stefanie, 2020).

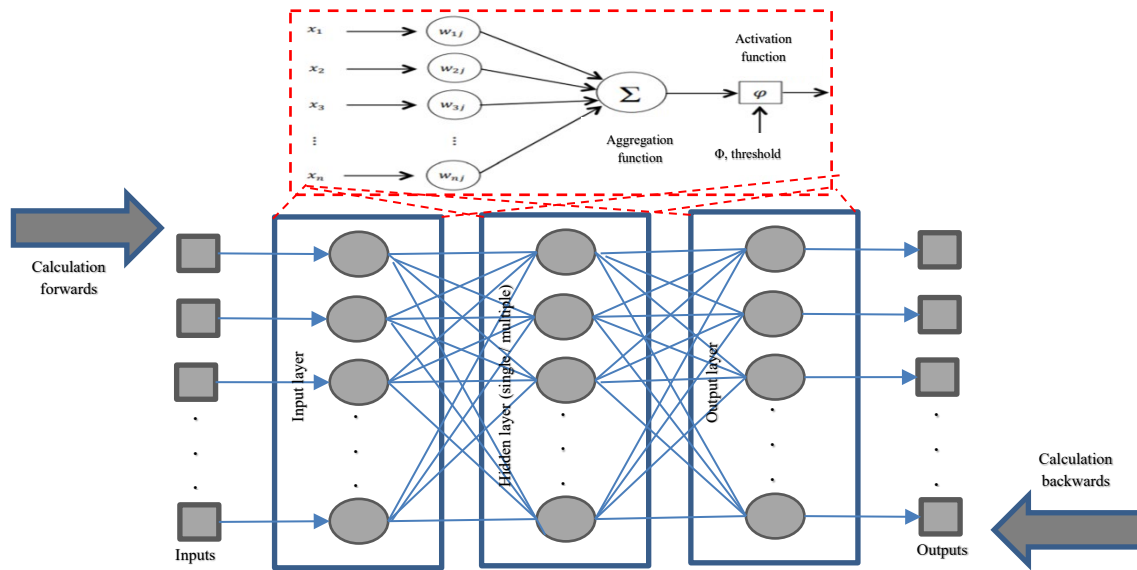
ANN consist of interconnected processing elements known as neurons that work collectively to solve problems by learning from given data sets, similar to how humans learn from example cases. Just as biological neural networks have nerve cells, ANNs have artificial cells, which are called process elements in engineering science. Each ANN model has five basic elements called inputs ( $x_i, i=1, \dots, n$ ), weights ( $w_i, i=1, \dots, n$ ), aggregation function, activation function and outputs, which are structured in single or multiple layers (Fig. 1) (Eraslan, 2009; Dağdeviren et al., 2011; Kutschenreiter-Praszkiewicz, 2020). The power of neural computations comes from weight connection in that structure and behavior of the overall ANN depends on the transfer functions of its neurons, by the learning rule, and by ANN architecture itself.

During training, the inter-unit connections are optimized until the error in predictions is minimized and the network reaches the specified level of accuracy (Eraslan, 2009). The weights are the adjustable parameters and the process of automatically adjusting the weights and obtaining the desired output from the network is called training operation (Silva et al., 2018). Once the network is structured, trained and validated the generated ANN structure could calculate the output values depending to the input set of inspected problem.

There are many types of neural network structures for various applications and data sets, where radial basis function networks and multi-layer perceptron networks are examples of feed-forward networks and most commonly used ANN architectures (Eraslan, 2009; Stefanie, 2020; Dongare & Sachin, 2023). The simplest type of ANN is a single layer perceptron network. In this network, there is one layer of output nodes and inputs are passed directly to the outputs through a set of weights. At each node, the sum of the product of the weights



and inputs is calculated and if it is above a certain threshold, the neuron fires and takes the active value; otherwise, it is disabled. The weights of an artificial neuron can be adjusted to obtain the desired output for specific inputs. ANN form a powerful tool in processes such as clustering, prediction and regression in general (Silva et al., 2018; Rucco et al., 2019).



**Figure 1:** General form of neural network structure for an ANN model.

### 3. RESEARCH

#### 3.1. Definition and Preliminaries

This study was conducted to examine the existing literature regarding ANN use for determination of standard time in WM studies. In this direction, three research questions were identified to guide the data extraction process and how the analysis will be performed. The research questions identified for this study are listed below:

RQ1. In the existing literature on standard time determination in WM, what is the intensity of use of ANN models as a solution method instead of the traditional WM approaches? This research question especially focuses on what extent have researchers discovered that the ANN tool, where its computational effectiveness has been repeatedly proven in various application areas and problem types, could be used for process management and standard time estimation.

RQ2. In existing studies, in which types of production and or service systems, for what types of products, processes and different flow types has the ANN approach been preferred to determine the standard time with? This research question especially investigates that if there are any production, product, method, flow types for which the ANN solution methodology is considered particularly suitable, and if so, what they are.

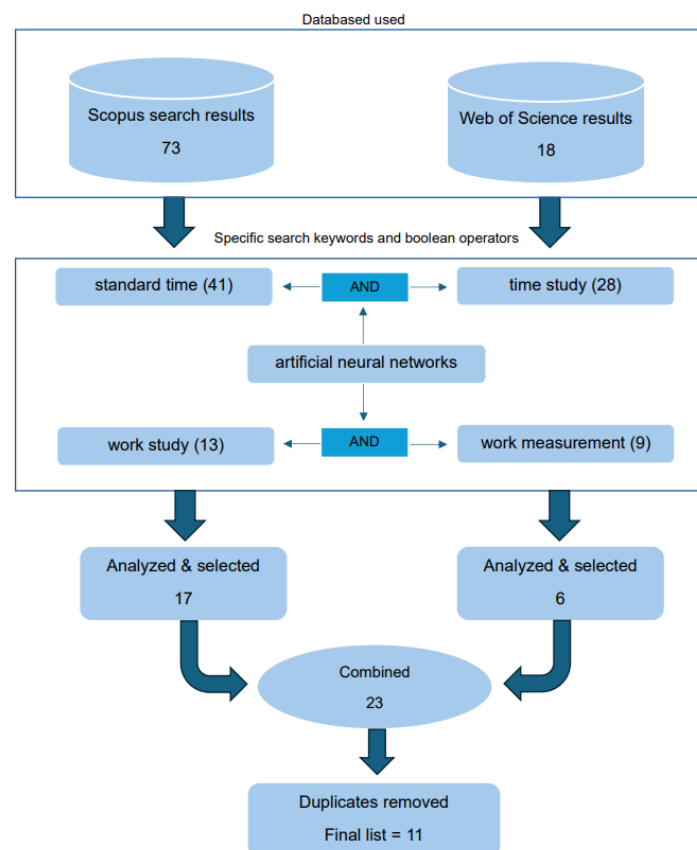
RQ3. Which problem dimensions were considered as parameters and defined as factors to be regarded in standard time estimation via ANN? This research question was especially generated to address the kind of data to be collected and used while employing ANN models to determine standard time in WM operations.

After establishing the research questions and identification of the framework, the data space of the study was defined. The existing literature was investigated in details basing on Web of Science and Scopus databases, which are accepted as the largest international online sources covering various types of researches (articles, pre-prints, proceedings, books, book chapters, editorials, etc.) from the most reputable sources and are esteemed scientific platforms. Then, the keywords to be used were determined with respect to the research questions. "artificial neural networks", "work measurement", "time study", "work study", "standard time" were selected to be searched in Scopus and Web of Science databases. In order to reach the widest possible result set and to be able to examine all existing instances, no time restrictions were used or document type constraints were imposed. The flowchart of the proposed procedure is presented in Figure 2, hereinafter.

#### 3.2. Results and Discussion

**RQ1 results.** As the results of the first literature review run (19.03.2024) executed on Web of Science Core Collection database with the keywords "machine learning" and "standard time", in the "topic" field, without

any year restrictions, and, using “AND” Boolean operator, a total of 32 documents were found. Of the 32 documents, 24 were articles and eight were proceeding papers. The same searching parameters then were used on Scopus database. A total of 50 documents were found, and of the 50 documents, 26 were articles, 23 were proceedings, one was a book chapter. The duplicating records were sorted and 25 documents employing ML techniques for standard time determination in WM applications were found. As the results of the run executed on Web of Science Core Collection database with the keywords "literature review" and "artificial neural networks" and the same searching parameters, a total of 310 documents were found. Of the 310 documents, 159 were review articles, 105 were articles, 47 were proceedings, eight were book chapters and eight were pre-prints; where 234 documents were found on Scopus database with the same searching parameters. Of the 234 documents, 95 were review articles, 98 were articles, 38 were proceedings, one was an erratum and one was a book chapter. After detailed analysis of run results, none of the records was found to be related to research scope. Hence, this study was designed to fill that gap of the related literature to present a novel perspective. When the ascertained 25 documents were examined, it was determined that the most frequently used ML algorithm in determining the standard time in WM studies was ANN. The percentage distribution of the algorithms used in the studies according to their frequency is given in Figure 3.



**Figure 2:** Literature review execution flow.

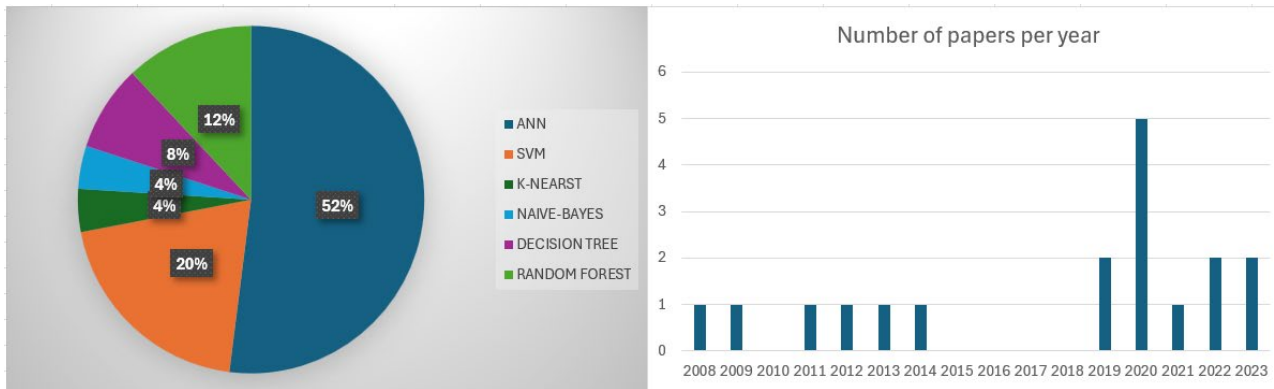
As the results of the second literature review run (05.04.2024) executed on Web of Science Core Collection and Scopus databases, 73 and 18 published articles were found, respectively, within the scope of the first research question. The publications were not merged for analysis, instead, both sets were processed independently, and, the same parameters of the first run were employed. A total of 23 articles were found to be on standard time determination in WM, where documents that were not relevant to the research topic were sorted out. In total, 17 documents from Scopus and six from Web of Science databases were included, merged and duplicates were removed.

The final result list consists of 11 publications (Figure 2). As another inference to be made regarding the RQ1, the ML techniques do not seem to be known closely by field researchers, hence, there is a serious room for ML-based applications where the existing literature is open to new studies that can be useful to practitioners by examining the use of ML techniques in standard time estimation problems. Although ANN was found to be the most frequently used ML tool, the number of existing studies indicates that there is a serious need of studies introducing this efficient and trustable estimation tool to work study literature. The frequency of the employment of different ML techniques for standard time estimation problem and the frequency of published studies which used particularly ANN technique to handle the same problem type were both visualized and presented in Figure 3, hereinafter.

**RQ2 results.** Application areas, width of input sets (data count used in each experiment), citation counts and imprint information regarding the studies existing in the final list are presented in Table 1.

**Table 1:** Final list decomposition.

Article	Citation	Application Area	Input set width
Kutschenreiter (2008)	27	Gear manufacturing	150
Eraslan (2009)	18	Molding industry	50
Dağdeviren, Eraslan & Çelebi (2011)	5	Truck and bus manufacturing	71
Susanto, Tanaya & Soembagijo (2012)	7	Textile industry	120
Gelmereanu, Morar & Bogdan (2014)	13	High speed machining	15
Onaran & Yanik (2019)	3	Textile industry	unspecified
Adizue, Nwanya & Ozor (2020)	11	Palm oil production	264
Aslankaya (2020)	24	Metal and aluminum industry	100
Kutschenreiter (2020)	1	Industrial assembly	42
Rodrigues et al. (2022)	2	Molding industry	850
Çakıt & Dağdeviren (2023)	1	Truck and bus manufacturing	305



**Figure 3:** Ratios of enlisted ML tools and frequency of ANN employment.

As the inferences made regarding RQ2, application areas were found to be focused on manufacturing processes with batch production, product families or products with similar technical designs, and protracted production of products with complex technical structures. There are no studies inducted on service systems, where, heavy metal or heavy industries, especially systems featuring abundant manual labor or complex production processes, where direct measurement methods and standard time calculation would not be efficient, were particularly designated as application areas. The reason behind the abandonment of well-known traditional methods e.g. time study with stopwatch observations might be that the stopwatch method would not be sufficient to give realistic results, especially in processes with long waiting times, high part variety and manual production. In case of long waiting times, the effective working time of the worker would not be measured accurately, which might complicate correct standard time determination. In addition, in cases where the part variety is high (Table 1), it may be time-consuming and difficult to determine standard times for each work-piece separately by direct observations, as well as, especially in manually executed processes, the working speed and performed method would vary depending on individual differences among employees.

The analyzed studies compared the actual standard time data computed with direct observations with the predicted values obtained by ANN, and revealed that, ANN is very successful in giving accurate results.

**RQ3 results.** As a result of the literature research, two main categories were determined in the classification of the parameters taken into account while creating the ANN. The first one is technical factors; that is, factors related to material, process and operation features regarding the analyzed job, which are more related to rigid system dimensions. The other category is human engineering factors which includes factors related to ergonomic parameters such as employee experience, working conditions, and job difficulty, and could be ameliorative and more flexible. Table 2 presents the number, definition and type of parameters considered in each study of final list. It was found that 54 of the total 59 parameters identified in the studies took into account solely the technical factors and five of them did human engineering factors (HEF) in addition to technical factors.

**Table 2:** Analysis of parameters used in the final list.

Article	Number	Types	Definitions
Kutschenreiter (2008)	6	Technical	Number of teeth module, pith of gear, width, diameter, weight, material type

Eraslan (2009)	6	Technical	Volume, weight, process number, cylinder hole number, arrival status, material type
Dağdeviren, Eraslan & Çelebi (2011)	5	Technical & HEF	Number of pieces, number of operations, surface area, difficulty/working environment, number of processes
Susanto, Tanaya & Soembagijo (2012)	6	Technical	Order quantity, material type, material quality, machine type, machine width, basis weight
Gelmereanu, Morar & Bogdan (2014)	3	Technical	Spindle speed, feed rate, cut depth
Onaran & Yanık (2019)	4	Technical & HEF	Machine types, worker abilities, material type, product design
Adizue, Nwanya & Ozor (2020)	3	HEF	Senior staff, junior staff, casual staff
Aslankaya (2020)	3	Technical	Perimeter, surface area, diameter
Kutschenreiter (2020)	4	Technical	Number of elements, length of elements, tool type, assembly/disassembly
Rodrigues et al. (2022)	4	Technical	Material type, number of elements, volume, surface area
Çakıt & Dağdeviren (2023)	5	Technical & HEF	Number of products, number of operations, surface area, difficulty/working environment, number of processes

## 4. CONCLUSION

The main purpose of this literature review was to summarize the studies on the use of ML tools to determine standard times in process management and to investigate the identified research questions regarding ANN employment. The literature review and analyses revealed that ANN have a significant potential in this field.

However, based on the findings of this research, some shortcomings regarding ANN applications were also identified, e.g. in particular, the HEF factors which substantially affects the standard time values were not taken into account in general as computation parameters. As future directions, the number of studies evaluating this factor in order to understand the role of the human factor in the standard time determination process should be increased, besides, ANN technique should particularly be considered as a trustable estimation tool.

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# **TRANSFORMATIONAL POTENTIAL OF GENERATIVE AI**

# POLICING AND AI - POSSIBILITIES

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**Abstract:** This paper investigates the integration of Artificial Intelligence (AI) into diverse aspects of law enforcement, encompassing predictive policing, advanced surveillance, robotic policing, crime analysis, and bias mitigation strategies. It further explores the potential of emerging technologies such as neurotechnology, chatbots, and virtual assistants within police forces. The paper highlights the potential benefits of AI in law enforcement, including enhanced crime prevention, improved operational efficiency, and increased public safety. However, it acknowledges the inherent challenges associated with these technologies, such as data privacy concerns, potential for algorithmic bias, and ethical considerations. The discussion concludes by emphasizing the necessity for responsible development and implementation of AI-powered law enforcement tools, ensuring transparency, accountability, and adherence to established ethical principles. Striking a balance between the potential of AI technology and the protection of human rights is paramount

**Keywords:** *Enhanced policing, Advanced surveillance, Policing and AI, Robotic policing, AI-powered Law Enforcement*

## 1. INTRODUCTION

Artificial intelligence (AI) is rapidly transforming various aspects of our lives and societies (Castro & New, 2016). This transformation extends to the field of law enforcement, where AI has the potential to enhance police work efficiency and effectiveness. However, its application must be balanced with the protection of human rights and public acceptance. Many advanced police organizations are already exploring the use of AI in diverse areas. While existing research on AI in policing often focuses on specific applications, this paper aims to provide a broader perspective. We intend to illuminate the current and potential future uses of AI technology in law enforcement, fostering greater societal understanding and reducing apprehension surrounding its implementation. Given the potential for AI to outpace the evolution of human rights frameworks, this work emphasizes the crucial need for legal and ethical limitations on its use in law enforcement. Recognizing the multifaceted nature of police work, this study examines seven key areas of interest: enhanced predictive policing, advanced surveillance, robotic policing (including police robots and drones), crime analysis and investigation, the future of neurotechnology in law enforcement, and the use of chatbots and virtual assistants. By adopting a holistic approach to police work, this paper aims to identify appropriate strategies for integrating AI technology within this domain.

## 2. ENHANCED PREDICTIVE POLICING

Predictive policing enhanced with Artificial Intelligence (AI) is a contemporary approach to crime prevention and law enforcement that leverages data analysis, machine learning, and AI algorithms. This technology aims to predict potential criminal activity and optimize the allocation of police resources. As Beth (2010, p. 17) defines it, "predictive policing implies taking data from disparate sources, analyzing them, and then using the results to anticipate, prevent, and respond more effectively to future crime." By integrating traditional policing strategies with advanced AI technology, predictive policing utilizes big data analysis and pattern recognition algorithms to generate crime predictions. This integration has the potential to enhance the effectiveness and efficiency of traditional law enforcement methods. For example it could be shown like on the Table 1.

**Table 1:** Comparison of the traditional and improved way of performing certain police tasks (Epstein, Emerson & ChatGPT, 2024., para. 1-9)

Col.	Tradicional policing	AI Enhancement
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<b>1.</b>	<b>Data Collection and Analysis</b>	
	Traditional policing has always involved the collection of data, such as crime reports, arrest records, and calls for service.	AI technologies are capable of processing and analyzing much larger datasets at a much faster rate than humanly possible. This includes not only structured data (like crime reports) but also unstructured data (such as social media posts, images, or videos). These algorithms are capable to learn complex patterns and causally consequential relationship that can't be done with traditional, human, police work.
<b>2.</b>	<b>Pattern Recognition and Predictive Modeling</b>	
	Police officers often use their experience and knowledge of local areas to predict and prevent criminal activities.	AI uses statistical techniques and machine learning models to identify potential crime hotspots by analyzing historical crime data and other relevant variables. These models can predict time and location of crimes are likely to happen with a higher degree of accuracy, allowing police to proactively allocate resources.
<b>3.</b>	<b>Resource Allocation</b>	
	Decisions about where to deploy police resources have traditionally been made based on intuition, experience, and reactive approaches to recent incidents.	Predictive policing tools provide a data-driven approach for resource allocation. By predicting crime hotspots, law enforcement agencies can optimize their patrols, checkpoints, and other resources in a more strategic manner, focusing on prevention rather than solely response.
<b>4.</b>	<b>Community Policing</b>	
	Community policing focuses on building ties and working closely with community members to identify and solve public safety problems.	AI can enhance community policing by analyzing data related to community concerns and feedback, helping police understand community issues better and tailor their approaches to community needs. AI-driven sentiment analysis, for example, can gauge community sentiments and reactions from social media and other digital platforms.
<b>5.</b>	<b>Incident Response</b>	
	Traditionally, the response to incidents is largely reactive, based on calls for service.	AI can improve incident response by using predictive analytics to not only deploy resources more effectively but also to anticipate incidents before they occur, potentially reducing the number of emergency calls.
<b>6.</b>	<b>Evaluation and Adjustment</b>	
	Police departments traditionally review their strategies and outcomes to make adjustments based on what has been effective.	AI systems can continuously learn and improve from new data, automatically adjusting predictive models to enhance accuracy over time. This dynamic learning process allows for real-time feedback and adaptation in policing strategies.

The integration of Artificial Intelligence (AI) with traditional policing strategies through predictive policing represents a significant advancement in law enforcement. By leveraging AI for comprehensive data analysis, law enforcement can enhance the accuracy of crime prediction, enabling a transition from reactive to proactive policing. This approach has the potential to optimize resource allocation, improve response times, and strengthen community engagement through more targeted and informed interactions with the public. However, challenges associated with data privacy, potential for bias, and ethical considerations require transparent and responsible implementation to ensure public trust and equitable application of these technologies. Ultimately, AI-powered predictive policing holds promise for a more efficient, effective, and community-oriented approach to law enforcement (Mantello, 2016, p. 3). An illustrative example of AI-powered predictive policing can be found in pilot programs conducted by Hitachi in various U.S. cities. Their software leverages natural language processing and machine learning to analyze a multitude of data points, including social media activity, locations of 911 calls, geotagged posts near schools, and other relevant factors. This analysis generates heat maps that indicate areas with a higher likelihood of criminal activity. The software excels at examining publicly geotagged social media activity to identify drug-related phrases and unusual keywords potentially used as drug code (Sean, 2015, p. 3).

### 3. ADVANCED SURVEILLANCE



Advanced Surveillance involves utilizing big data and datafication to enhance and expand monitoring efforts. This includes the collection and real-time processing of personal information through automated systems and routines. These systems can be employed to observe, identify, track applications, regulate, predict, prescribe, prevent, and influence the behavior of individuals or groups (Catarin 2022, p.2).

AI combine with surveillance technology can improve the following areas:

1. **Facial Recognition:** The artificial intelligence-powered facial recognition system identifies an individual based on a photo or video. (Gupta & Modgil, 2023, p. 1181). It's used to identify individuals in crowds, at borders, or in public places by comparing captured images with databases of known individuals. This technology can help in tracking suspects or finding missing persons. This include biometric Surveillance beyond facial recognition, AI can analyze other biometric data like fingerprints, gait, and voice recognition, which can be crucial in verifying identities and enhancing security measures (Gupta & Modgil, 2023, p. 1179).
2. **Video Analytics:** AI algorithms examine video recordings instantaneously to spot abnormal actions or conduct. This can encompass identifying altercations, detecting individuals in prohibited zones, or recognizing patterns suggestive of unlawful activities (Md. MuktaDir et al., 2024., para 1).
3. **License Plate Recognition (LPR):** This technology employs cameras and artificial intelligence to record and scrutinize vehicle license plates. It is beneficial in scenarios such as tracing stolen cars, observing traffic movement, and enforcing traffic regulations. (Ramesh et al., 2023. p. 1574).
4. **Drone Surveillance:** Unmanned aerial vehicles outfitted with cameras and AI functionalities can be utilized for overhead monitoring, delivering real-time information during major public gatherings, natural calamities, or search and rescue missions (Quamar et al., 2023, p. 5).
5. **Social Media Monitoring:** AI applications can monitor social media sites for particular keywords, expressions, or patterns that may signify illicit activities or dangers. This aids in the early identification and prevention of criminal acts (Edyta G., A., 2023., p. 3334).

Granting law enforcement agencies access to this type of data introduces numerous privacy and discrimination issues and risks, such as the targeting of marginalized communities, inaccuracies and biases, and the vast amount of information gathered for the reference database (Hill & Slane, 2022., p. 325). The use of video surveillance has already contributed more effectively to the detection and investigation of crimes. In combination with AI technology, it would enable faster processing of collected data, eliminating the shortcomings of the human eye as well as reducing the number of employed police officers. For example, with the use of this technology, the offender can be charged automatically (e.g crossing the „red lite“).

#### 4. ROBOTIC POLICING (POLICE ROBOTS/DRONES)

Robots, as defined by McGraw-Hill (as cited in McGuire, 2021, p. 28), are programmable devices capable of performing various tasks through manipulation and locomotion under automated control. In law enforcement, these devices serve as mechanical aids for diverse tasks, ranging from surveillance and bomb disposal to investigations (McGuire, 2021, p. 28). Their purpose is to enhance efficiency, safety, and efficacy of law enforcement activities by minimizing risk to officers, potentially improving response times, and aiding decision-making. Current applications include unmanned aerial vehicles (UAVs/drones), ground robots, robotic dogs, and autonomous patrol vehicles, used for surveillance, bomb disposal, search and rescue, and traffic control. The benefits of robotic policing encompass enhanced safety, increased efficiency, cost-effectiveness, and 24/7 operation. While most robots require remote control, advancements in AI technology hold the potential for autonomous operation, particularly in situations where human intervention is infeasible (Dan, 2015, para. 1). The EU-supported Autonomous Vehicle Emergency Recovery Tool (AVERT) exemplifies this potential, utilizing a network of self-governing robots designed to collaboratively transport suspected explosive devices (Dan, 2015, para. 1).

#### 5. CRIME ANALYSIS AND INVESTIGATION

Crime analysis and investigation is model based on two main components (Ribaux & Girod 2003., p. 49):

- An organized memory that encapsulates the knowledge we possess at a given moment regarding the criminal activities under review: problems, cases linked, series, special features etc. and
- A systematic collection of frequently or potentially used inference frameworks that demonstrate how to integrate various types of data during the analysis process.

Artificial intelligence (AI) has the potential to revolutionize crime analysis and investigation by offering new capabilities and enhancing efficiency. AI technologies excel at processing vast amounts of data, particularly big data, which allows them to identify patterns that might elude human analysts. This enhanced data analysis capacity can contribute to more accurate predictions of future criminal activity. While various applications of AI in crime analysis have been discussed, its potential extends beyond pre-crime intervention.

AI can also significantly aid in post-crime investigations. Its ability to rapidly and effectively analyze data, coupled with the potential to consider information beyond human recognition, can be a significant advantage (Dipo et al., 2024, p. 2669).

## **6. NEUROTECHNOLOGY**

The field of neurotechnology encompasses techniques and tools that create a direct link between the nervous system and technological devices. These devices, such as electrodes, computers, or advanced prosthetics, can serve two main purposes. They can either capture signals from the brain and convert them into instructions for controlling external technology, or they can influence brain activity through electrical or light-based stimulation. (Oliver & Stefan, p. 1). Advancements in neurotechnology hold the potential to enhance biological intelligence and even merge it with artificial intelligence, paving the way for a new form of collaborative intelligence that transcends human and machine capabilities. (Filipova, 2022., p. 36). Technology like „lie detector“ is already in use, but there are lot of experimental works, that use neurotechnology and modern achievement to enhance these technique.

In the future (10-50 years) with the development of neurotechnologies, we might be able to assess an individual's brain maturity more objectively. This could lead to a reevaluation of the established age of criminal responsibility and a more nuanced approach to criminal justice measures based on a deeper understanding of an individual's culpability. (Hoffman, 2018. p. 213). We will not only be able to determine who is a potential relapse (psychopathology) but to prevent them by implanting a neurotehnology microchip (Merkel 2015, p. 1358.)

The coming years are expected to see a surge in neuroimplants equipped with AI technology. These devices hold the promise of not only recovering lost functionalities but also augmenting human potential. This could lead to a rise in the number of individuals with heightened physical and cognitive abilities, surpassing those of the average person (Filipova, 2022., p. 39). That technology can be used for law enforcement but we should be aware that criminals can also be interested for this.

## **7. CHATBOTS AND VIRTUAL ASSISTANTS**

The idea of chatbots has been around for many decades. Emerging alongside advancements in artificial intelligence and the field of natural language processing (Shum & Li 2028, p. 20). After the first one created by Joseph Weizenbaum between 1964. and 1966. “Elica” (designed to simulate a psychotherapist and used pattern matching and substitution methodology to interact with users in a conversational manner) many of them were made and today almost every company has it.

Virtual assistance offers a way to access information swiftly and effectively. It leverages powerful filtering and interpretation of data stored in vast repositories to deliver insightful recommendations. (Hermann et al. 2016., p. 6). Usually, it can be performed by chatbots or Virtual Assistants. A virtual assistant (VA) is essentially a software program that can execute tasks or provide services in response to user commands or questions. It acts as an intermediary layer, simplifying access to various services and applications. By interacting with these services and apps, the VA aims to fulfill the user's intended purpose (Pereira, et al. 2023. p.2).

Following those rates of development police forces all over the world are already using chatbots. These chatbots are designed to assist both the public and law enforcement agencies in several ways, such as reporting crimes, providing information on local laws, offering guidance on police procedures, and even helping with administrative tasks (Camello, et al. 2021., p. 3.). The Singapore Police Force introduced a chatbot named 'Ask Jamie' on their official website. This virtual assistant can provide answers to public queries about police services, assist in navigating the website, and offer information on police matters. The Uttar Pradesh Police in India launched a chatbot service on WhatsApp to offer instant help to the public. This chatbot can provide information on various services, including filing a complaint, checking the status of a case, and receiving updates on law and order. Some police forces in the UK have experimented with chatbots to handle non-emergency inquiries from the public. For example, the Northamptonshire Police tested a chatbot named 'Spike' to answer questions and provide information on non-urgent police matters. Certain police departments in the U.S. have started to use chatbots for various purposes, such as crime reporting, providing information on safety and prevention, and even for recruitment purposes. For instance, the Los Angeles Police Department has used chatbots for community engagement and information dissemination. These chatbots are typically powered by artificial intelligence (AI) and natural language processing (NLP) technologies, allowing them to understand and respond to user queries in a conversational manner.

## **8. BISAS MITIGATION (DISCRIMINATION MITIGATION)**

"Discrimination is any unfair treatment of arbitrary distinction based on a person's race, sex, religion, nationality, ethnic origin, sexual orientation, disability, age, language, social origin or other status" (United Nations, 2008. p. 1). This concept describes unconscious prejudices or preconceived notions that subconsciously impact our interpretations, actions, and choices. Even if an officer makes a conscious effort to dismiss biases and stereotypes, these implicit biases can still exert an involuntary influence on their behavior. (Michael & Geoffrey, 2007., p. 1269). Police officers, like all individuals, can be influenced by societal stereotypes and prejudices. These biases can affect how officers perceive and interact with people from different ethnic or socioeconomic backgrounds. Differences in cultural backgrounds between police officers and the communities, they serve, can lead to misunderstandings and biased actions. This can stem from a lack of cultural competence or awareness. Sometimes, the policies, practices, and procedures within a police department or the criminal justice system at large can perpetuate bias. For example, policing strategies that target specific neighborhoods or demographic groups more heavily than others can lead to disproportionate enforcement actions. The content and methods used in police training can influence how officers perceive and interact with the public. Training that does not adequately address bias or that reinforces stereotypes can contribute to biased policing. The attitudes and behaviors of fellow officers can significantly impact an individual officer's actions. If a police culture tolerates or even encourages biased behavior, it can become normalized within the department. The portrayal of certain groups in the media can reinforce stereotypes and biases, which can, in turn, influence police perceptions and actions. It's not by chance that we put to discrimination to the end of this research. All possibilities of using AI technology must be trained so as to eliminate discrimination which, as we have seen, is part of human nature (Schwartz, et al. 2022., p.77).

## CONCLUSION

This paper explores the transformative impact of Artificial Intelligence (AI) on law enforcement. AI-powered predictive policing utilizes data analysis to anticipate crimes and optimize resource allocation. Advanced surveillance techniques, such as facial recognition and drone monitoring, enhance security but raise privacy concerns. Robotic policing, employing drones and ground robots, assists with tasks like bomb disposal and search and rescue. AI integration in crime analysis accelerates data processing and pattern recognition, facilitating investigations. While neurotechnology offers potential for lie detection and rehabilitation, ethical considerations regarding its misuse remain. Chatbots are emerging as virtual assistants, supporting both the public and police with tasks like crime reporting and information dissemination. The paper emphasizes the importance of mitigating bias during AI development and implementation in law enforcement. This is crucial to ensure the just and impartial application of these technologies. To harness the potential of AI while promoting responsible use, we advocate for:

1. Transparency and Accountability: AI systems should be grounded in transparency, allowing for public scrutiny and holding developers accountable.
2. Bias Mitigation Strategies: Measures to mitigate bias in AI development and use are essential.
3. Privacy Protections: Robust privacy frameworks are needed to balance legitimate public safety concerns with individual rights.
4. Community Engagement: Continuous engagement with the community is crucial for fostering trust and addressing concerns.

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# INNOVATIVE APPROACH TO LEARNING: CHATGPT CASE STUDY

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**Abstract:** *This study explores the impact and application of generative artificial intelligence (GenAI) in education, focusing on the use of ChatGPT models 3.5 and 4. In light of the digital divide that presents a growing challenge in contemporary society, the Republic of Serbia is taking strategic steps towards digitalization and the development of digital skills. The analysis shows that while ChatGPT 3.5 can successfully process user requests, ChatGPT 4 offers improved accuracy and depth of analysis, making it a superior tool for summarization and processing of complex documents. The paper recommends the integration of ChatGPT into the educational process as an auxiliary tool, provided that users have a basic understanding of the material being explored. The research points to the potential of ChatGPT to enrich self-learning and enable access to education, while attention must be paid to the ethical and practical aspects of AI application in an educational context.*

**Keywords:** *Generative artificial intelligence (GenAI), ChatGPT 3.5, ChatGPT 4, education, digital literacy*

## 1. INTRODUCTION

We are faced with the challenge of the digital divide, which is becoming increasingly pronounced in our society. This divide separates those who have access to digital technologies from those who do not, creating inequality in education, employment, and all aspects of social life. The issue of the digital divide is becoming increasingly relevant, as people with access to digital tools have a significant advantage in contemporary society (Mead, 1956).

The Republic of Serbia recognizes the importance of the digital transformation of society and is directing its resources towards the development of digital skills among its citizens. In the Republic of Serbia, two strategies have been adopted, one for the development of digital skills (Republic of Serbia, 2020, 2023) and the other for the development of artificial intelligence (Republic of Serbia, 2019). These strategies are key documents guiding state policies towards education and training of citizens in the field of artificial intelligence (AI). The goal is to encourage innovation and support the development of AI potential in education and other sectors (Matović, 2021).

This research aims to explore the potentials of generative artificial intelligence (GenAI) in education, with a special focus on tools that can enhance the education process and increase the digital literacy of society. Through a detailed analysis of the free and paid versions of ChatGPT, the study strives to provide a comprehensive insight into the possibilities that GenAI offers for the educational system, as well as the challenges that arise in its implementation. Special attention will be given to the impact of these technologies on the quality and accessibility of education, and their role in bridging the digital divide.

The second chapter is dedicated to defining three key questions on which the case study of the ChatGPT tool was conducted. In the third chapter, the focus is placed on the theoretical understanding of GenAI and ChatGPT, with special emphasis on their application in education. The fourth chapter encompasses the conduct of the case study. The fifth chapter summarizes the results of the case study and provides guidelines for further integration of ChatGPT into the educational system.

## 2. RESEARCH METHODOLOGY

In the theoretical part, research of secondary sources (scientific and professional literature) was applied, while the second part presents the results of the case study on the following questions:

- a) Can the Chat GPT 3.5 model effectively perform summarization of textual content in accordance with the requirements of a specific prompt, even in cases where the number of characters in the prompt input exceeds the standardly allowed limit?
- b) Does Chat GPT 4 have the ability to process and summarize the content of a text document in PDF format that exceeds 300 pages, without losing key information?
- c) Can Chat GPT 4 accurately perform analysis and interpretation of data presented in an Excel document? Can it create a graph based on values from an excel file?

Target groups: students, their parents, teaching staff, non-teaching staff, managers, the wider community.

Conditions and limitations for the implementation of the tool by users: In accordance with the terms of use set by Open AI, users must be older than thirteen years to access the platform. For individuals under the age of eighteen, explicit permission from a parent or legal guardian is required before allowing the creation of a user account.

## 3. GENERATIVE ARTIFICIAL INTELLIGENCE

GenAI represents an innovative and creative approach in the field of AI. This concept has emerged as one of the most successful ML frameworks in the context of deep learning evolution over the last decade. Its essence lies in non/semi-supervised machine learning, aimed at creating new content. This includes, but is not limited to, generating digital images, videos, audio recordings, text, and even code. This ability to generate new content makes GenAI an extremely powerful tool in a wide range of different domains. The key advantage of GenAI lies in its ability to learn from vast amounts of data and create new, original instances of content based on that. This process does not require explicit programming, which significantly improves efficiency and flexibility compared to traditional methods (Hu, 2022).

GenAI is emerging as a global technology, gaining momentum and attracting interest across the global market. Companies want to integrate content generation and AI-based decision-making into their processes. IBM's 2022 artificial intelligence study examined plans for implementing AI solutions in the coming year. China and India are leaders in this regard, with over 50% of companies already using or planning to adopt AI technologies. Italy and Singapore also show strong interest, and the study predicts that most (>70%) enterprises globally will use AI in the coming years. The rapid rise in popularity of tools like Chat GPT clearly illustrates consumer enthusiasm towards Generative AI (GenAI). Furthermore, studies like the one conducted by Capgemini (a sample of about 8,600 respondents from various countries) suggest that consumers have a high level of trust in content generated by GenAI. The results of this study show that as many as 73% of respondents trust content created by artificial intelligence (Baum, et al. 2023).

GenAI has the potential to revolutionize various fields such as education, art, research and development, as well as content creation. One of the greatest contributions of GenAI is the democratization of technology. Unlike previous technologies that primarily dealt with automating repetitive tasks, GenAI allows people to communicate with computers in a natural way, in their native language. Through dialogue with sophisticated bots, like Chat GPT, Gemini, or Copilot, even those without programming knowledge or IT expertise can use the power of GenAI for creative projects and tasks. Moreover, GenAI is accessible and virtually free, making it available to a wide population (Vukmirovic, 2023) (Vukmirovic, 2023).

GenAI, like Chat GPT, comes with inherent limitations. However, its impact on the educational system is inevitable and should be considered from both perspectives. Some educators have taken the stance that the use of such tools in schools should be banned. In response to these concerns, software for detecting AI-generated texts has been developed. On the other hand, there are those who see potential in such technologies. Advice for teachers on how to prevent the misuse of tools like Chat GPT when writing essays and other school assignments has also been developed. The key question is how to leverage the advantages of generative AI while minimizing its drawbacks. This technology can be extremely useful for developing creative thinking and research skills in students (Baidoo-Anu & Ansah, 2023).

### 3.1. Chat GPT (Generative Pre-trained Transformer)

ChatGPT (Generative Pre-trained Transformer) is a large language model (LLM) developed by OpenAI, a research institute in the field of artificial intelligence. Launched in November 2022, ChatGPT is based on the GPT-3.5 model, and later, the option to use GPT-4, the latest LLM model from OpenAI, was offered. Trained on massive datasets of digital text, ChatGPT has the capability to generate human-readable text targeted at various fields and in multiple languages. It is capable of translating text. A key feature of ChatGPT is its

ability for fine-tuning through interaction with users, which allows it to adapt to specific demands and communication styles (Open AI, 2023). When launched, Chat GPT became one of the fastest-growing consumer applications in history, setting a record by reaching 100 million users in just two months, significantly faster than any other service (Baum, et al., 2023).

The popularity of conversational bots is growing (Sharma & Yadav, 2022) Chat GPT, as a large language model (LLM), is the most popular conversational bot, which was visited by 1.6 billion users in January 2024. (Duarte, 2024). Although Chat GPT has achieved significant success, its emergence has raised new problems and dangers for the educational system. Due to its ability to respond to specific user questions, there is a possibility of misuse in terms of using it to complete school assignments and exams instead of students. Such use raises concerns about fraud involving artificial intelligence (Lo, 2023). However, if used as an auxiliary tool, Chat GPT and other AI LLM models have potential and can serve as useful tools in education and research activities (Rahman & Watanobe, 2023).

Chat GPT has the potential to revolutionize self-learning by providing personalized and interactive learning experiences. Unlike traditional learning methods, Chat GPT can tailor its suggestions and responses to the unique goals and choices of each student. This provides key support for self-learners who may not have access to a teacher or mentor. Additionally, Chat GPT can provide information and advice in real-time as students progress through their educational material. This continuous feedback loop helps students stay on track and resolve any difficulties they encounter. Moreover, Chat GPT increases the accessibility of education by being available on various platforms. Students can learn at their own pace and convenience, engaging with the AI assistant whenever they need help. This flexibility allows self-learners to tailor their education to their specific needs and schedule. Chat GPT can also improve the utilization of open educational resources. By providing personalized suggestions and advice on how to effectively navigate these resources, ChatGPT can empower self-learners to fully leverage the vast amount of free educational material available online (Firat, 2023).

Navigating through the complex changes driven by AI requires an understanding and application of various complex aspects. One of the keys is developing effective approaches to using ChatGPT and similar AI tools to enrich the educational process, along with creating specialized educational modules tailored for both teachers and students, with the intention of maximizing the benefits of AI tools in enhancing teaching. Additionally, integrating these technologies into teacher training programs can equip future educators with the necessary knowledge and skills for their effective use in an educational environment. There is a possibility that students who do not receive education about AI tools may end up at a disadvantage in the job market compared to those who have gained extensive experience and practice working with these technologies. Therefore, it becomes imperative to quickly establish an educational framework that includes and evaluates these tools for enhancing the student experience (Grassini, 2023).

GPT-3, released in 2020, was the largest neural network ever created, trained on 175 billion parameters. In 2022, an improved version, GPT-3.5, was introduced. The latest iteration, GPT-4, was launched on March 14, 2023. According to OpenAI, this version can process up to 25,000 words - eight times more than GPT-3.5, resulting in improved understanding of context and nuances, enabling more precise and coherent responses. Subscription to GPT-4 allows users to include images in queries. For a monthly subscription fee of \$20 on Chat GPT, users have the option to use additional tools such as Advanced Data Analysis, DALL-E3, Plugins, and others (Open AI, 2023).

**Advanced Data Analysis (ADA)** - feature integrated within ChatGPT 4 is a function that enhances the model's ability for interaction and data analysis. Reserved for users with a premium subscription, this feature allows direct data upload into ChatGPT, providing users the ability to write and test code. It supports various file formats: Word (.doc), Excel (.xls), Text (.txt), PDF (.pdf), PowerPoint (.ppt), and Comma-separated values (.csv). (Open AI, 2024).

By using the ADA feature, users can request Chat GPT to perform various analytical tasks. This includes data visualization, generating maps from CSV files, summarizing datasets, and even manipulating images. Moreover, ADA enables code interpretation and testing in an isolated environment (sandboxing), providing users with the opportunity to experiment and evaluate code directly within the Chat GPT interface. Although particularly efficient for Python code, the ADA feature demonstrates understanding of other programming languages as well (MIT Management).

ADA has been expanded to include three new features aimed at enhancing the analysis of text-rich documents (Open AI, 2024):

- **Synthesis:** This function allows the analysis of information from documents to generate new content.
- **Transformation:** Enables changing the way information is presented without disrupting its essence.

- **Extraction:** This function allows the identification and extraction of specific information segments from the document.

Note: Although significantly expanding functionality, Advanced Data Analysis (ADA) is not intended to replace data analysts but to enhance their productivity by automating certain segments of data analysis. ADA in the Chat GPT Enterprise version offers additional capabilities such as synthesis, transformation, and extraction of documents, specifically designed to improve performance with text-rich documents such as PDFs and presentations. The file size limit for uploading in this version is 500 MB per file, and it is possible to upload up to 10 documents simultaneously, with a total maximum of 20 files. It is important to note that due to storage limitations, files are stored only during the active conversation and three hours after its conclusion (Open AI, 2024) (MIT Management) (Enterprise DNA Experts).

## 4. CASE STUDY

### 4.1. Case study 1: Chat GPT 3 for summarizing the text

The character limit for processing a single prompt in Chat GPT 3.5 is 4,096 characters. This includes all characters, including spaces and special characters. If the limit is exceeded, the system will display an error. In the prompt, along with the question in English "Can you shorten the text for me to 5 sentences, and write them for me in English?", we attached a text in Serbian Cyrillic that contained as many as 4,131 (with space) characters, and together with the posed question, the prompt contained 4,213 (with space) characters. The communication with Chat GPT 3.5 can be found at the link <https://chat.openai.com/share/da9b20a4-8558-41cd-94f5-c268de7e1acb>.

Result:

- The ChatGPT 3.5 model successfully responded to the request even when the number of entered characters exceeded the usual limits,
- ChatGPT 3.5 has the capacity to process queries that are formulated in a multilingual context,
- Deviating from the requirement that the summary contains five sentences, ChatGPT 3.5 produced a response that encompasses eight sentences.

### 4.2. Case study 2: ChatGPT 4 summarizing the text from PDF dokument

A book titled "*Global Fintech: Financial Innovation in the Connected World*" (Shries & Pentland, 2022) in PDF format with 334 pages was imported into Chat GPT 4 with the prompt "*Can you summarize the text in a maximum of 15 sentences?*". Chat GPT 4 processed the book within a few seconds and provided a response that is shown in Figure 1.

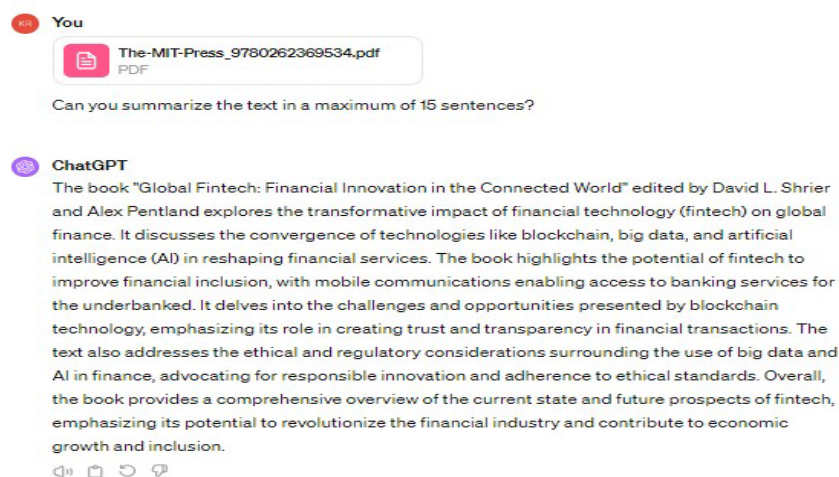


Figure 1: Prompt for summarizing pdf document and ChatGPT response

Result: Chat GPT 4 demonstrates the ability to accurately process PDF documents even when their volume exceeds 300 pages.

### 4.3. Case study 3: Excel file processing and graph creation with Chat GPT 4



Open Data published updated data on April 13, 2023, regarding the number of students in regular high schools sorted by grade and gender at the beginning of the school year. Figure 2. presents a shortened sample, while the complete original version of the downloaded Excel file was used for analysis.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	idindikator	IDTer	nTer	IDSkolskaGodina	IDRazred	nRazred	IDPol	nPol	vrednost	idJedinicaMere	nJedinicaMere	nIzvor	Indikator	IDStatusPodatka	nStatusPodatka	Podatka
2	11030301	70017	Aleksandr	2010/11		0 Ukupno		0 Ukupno	673 NR	broj	RZS		Broj učenika	A	Konačan podatak	
3	11030301	70025	Aleksinac	2010/11		0 Ukupno		0 Ukupno	1362 NR	broj	RZS		Broj učenika	A	Konačan podatak	
4	11030301	70033	Arandelov	2010/11		0 Ukupno		0 Ukupno	1906 NR	broj	RZS		Broj učenika	A	Konačan podatak	
5	11030301	70041	Arilje	2010/11		0 Ukupno		0 Ukupno	629 NR	broj	RZS		Broj učenika	A	Konačan podatak	
6	11030301	70050	Babušnica	2010/11		0 Ukupno		0 Ukupno	205 NR	broj	RZS		Broj učenika	A	Konačan podatak	
7	11030301	70068	Bajina Baš	2010/11		0 Ukupno		0 Ukupno	865 NR	broj	RZS		Broj učenika	A	Konačan podatak	

Figure 2. Open Data - Number of students in regular high schools at the beginning of the school year by grade and gender (updated on April 13, 2023) (Open Data, 2023)

The sample was imported into Chat GPT 4 with the request "On the Open Data site, I downloaded the excel file attached to the prompt, can you tell me what is presented in this excel?" along with the attached table. Responding to the user's prompt, Chat GPT 4 detailed the contents of each Excel column. The results are shown in Figure 3. After that, a prompt was entered requesting the creation of a graph that will represent the number of students over time sorted by male and female gender "Can you make me a graph according to the gender of the children over time. Female students should be marked in red and male students in blue." Figure 4. shows the graph created by Chat GPT 4.

**ChatGPT**

The Excel file contains a single sheet named "Sheet1" with the following columns:

- "idindikator": Indicator ID
- "IDTer": Territory ID
- "nTer": Territory name
- "IDSkolskaGodina": School year ID
- "IDRazred": Grade ID
- "nRazred": Grade name
- "IDPol": Gender ID
- "nPol": Gender name
- "vrednost": Value (number of students)
- "idJedinicaMere": Unit of measure ID
- "nJedinicaMere": Unit of measure name (e.g., "broj" for number)
- "nIzvor": Source of information (e.g., "RZS" for Statistical Office of the Republic of Serbia)
- "Indikator": Indicator description (e.g., "Broj učenika u redovnim srednjim školama na početku školske godine po razredima i polu" which translates to "Number of students in regular secondary schools at the beginning of the school year by grade and gender")
- "IDStatusPodatka": Data status ID
- "nStatusPodatka": Data status name (e.g., "Konačan podatak" for final data)

The data provides information on the number of students in regular secondary schools at the beginning of the school year, broken down by territory, grade, and gender. The first few rows of the sheet show data for different territories (e.g., Aleksandrovac, Aleksinac, Arandelovac, etc.) with the total number of students in all grades combined. [~]

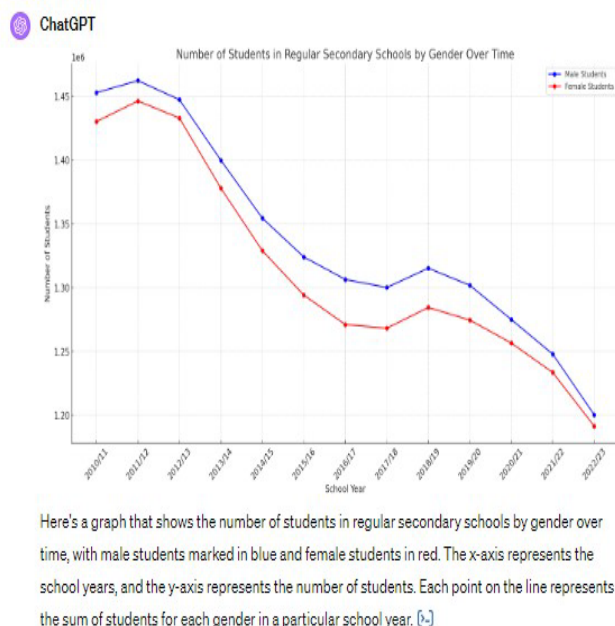


Figure 3 and 4: Prompt for Excel file analysis and graph generation and ChatGPT response

Result: Chat GPT 4 provided absolutely accurate answers to the requested prompt.

## 5. CONCLUSION

This paper provided a comprehensive overview and analysis of the role of GenAI in education, focusing on the application of Chat GPT 3.5 and 4 models. The digital divide represents a challenge in contemporary society, which is why the Republic of Serbia demonstrates a decisive initiative to overcome the digital divide and increase awareness of artificial intelligence, as reflected in the strategic direction of resources towards the development of citizens' digital skills and the application of AI technologies in education. Empirical analysis indicates that while the Chat GPT 3.5 tool can process user requests, Chat GPT 4 provides significantly more accurate analysis and summarization of content. With this in mind, it is recommended to integrate Chat GPT models into the educational process as a secondary tool that complements traditional learning methods, provided that users have a basic understanding of the subject matter when interacting with the AI platform.

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# THE IMPACT OF GENAI ON THE LABOR MARKET: MICRO TRANSFORMATION LEVEL

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**Abstract:** *The research focuses on the impact of generative artificial intelligence (GenAI) across various transformation levels, with a special emphasis on its potential to enhance business operations and professional development. The aim of the research is to explore how GenAI can improve productivity and professional development for individuals, entrepreneurs, and small businesses. We have analyzed the possibility of applying GenAI by an individual in the situation of establishing a legal entity and making key strategic decisions in the areas of marketing and market analysis. This work contributes to a better understanding of GenAI's capacities in various sectors and its applicability. The results indicate significant potential of GenAI in optimizing resources and processes, enabling businesses to quickly adapt to changing market conditions. This work enhances understanding of the key advantages that GenAI offers to businesses and individuals, as well as the need for a strategic approach in its implementation.*

**Keywords:** *Generative Artificial Intelligence (GenAI), transformation levels (macro, meso, and micro), micro and newly established businesses*

## 1. INTRODUCTION

Generative Artificial Intelligence (GenAI) could particularly impact highly educated professionals in high-value sectors such as finance and education. Rakesh Kochhar notes that "workers who are more familiar with artificial intelligence see more benefits than harms." These disruptions could quickly affect the entire labor market (Schulz, 2023). Most workers in occupations partially exposed to automation will likely redirect their capacities to more productive activities after AI transformation (Vukmirović, 2024). According to a report by the McKinsey Global Institute, nearly a quarter of work tasks, or 20 to 50% of jobs in the USA, could be automated by 2030 (Kenan Institute of Private Enterprise, 2023).

Research conducted by Erik Brynjolfsson in 2023 which focused on measuring the resolution of business tasks and problems per hour, found that employees who utilized GenAI tools achieved 14% higher productivity compared to others. This productivity increase was particularly notable among new or less qualified workers, while the impact was less significant among highly skilled and professional employees (Brynjolfsson, Li & Raymond, 2023).

This paper explores how individuals and entrepreneurs can use GenAI technologies in professional work and business management. The focus is placed on newly established entities, providing insights into methods of using GenAI for market entry preparation, with an emphasis on developing marketing strategies and market research. The advantages that GenAI can offer to micro and small enterprises with a limited number of employees are particularly considered, with the goal of enhancing their personal and professional development.

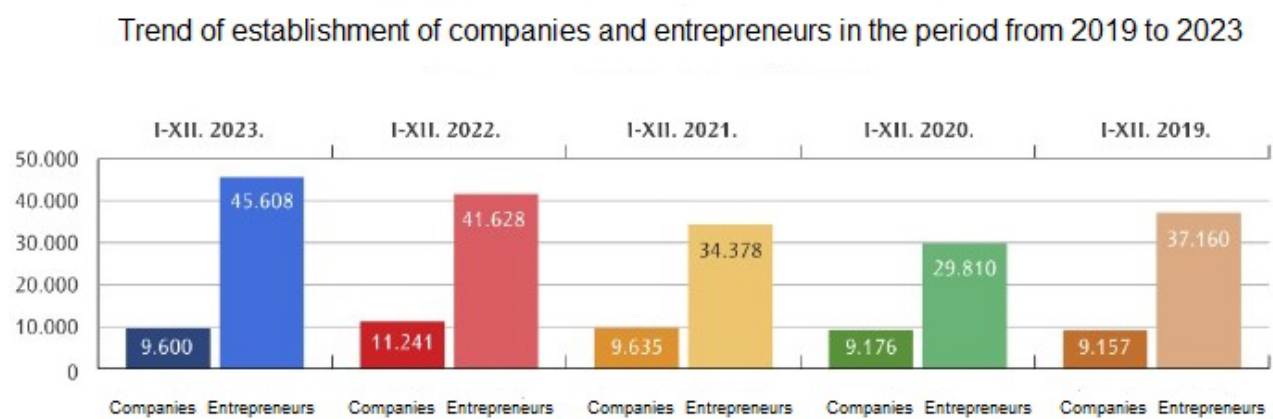
The second chapter deals with the research methodology, describing how it used an analysis of relevant academic papers and publicly available data sources. The focus of the third chapter is on the theoretical analysis of the various levels of transformation of GenAI technology, especially how it affects business operations and the wider economy. In the fourth chapter, a case study is presented that illustrates the implementation of the ChatGPT tool at the micro level of transformation. The study focuses on the impact on individuals, both employed and small business owners. The conclusion of the case study is also summarized. In conclusion, the fifth chapter provides an overview of key research findings and suggests further directions for future integration of GenAI technology into business processes.

## 2. METHODOLOGY

The first segment analyzes the three levels of transformation within the context of GenAI, while the second segment offers an analysis of the following research questions:

1. Analysis of the trend of establishment of legal entities in the Republic of Serbia during the business year 2023 (Serbian Business Registers Agency [SBRA], 2024) as a quantitative secondary research, and
2. How can GenAI at the micro-transformational level help in market preparation and entry, with a special focus on developing marketing strategies and market research?

From 2019 to 2023, the Republic of Serbia recorded an increase in the number of establishment, i.e. registration of business entities at the Agency for Business Registers (Figure 1.). In 2023, a total of 55,208 legal entities were registered. Of that number, 45,608 are entrepreneurs, which makes up 82.61%, while the remaining 9,600 are companies, with a share of 17.39%. These results indicate a significant annual growth in the number of established entrepreneurial entities. In 2023 alone, registered entrepreneurs accounted for 13.8% of the total number of entrepreneurs at the APR, which as of December 31, 2023, has 330.339 registered entrepreneurs (SBRA, 2024).



**Figure 1.** Trend of establishment of companies in Republic of Serbia in the period from 2019 to 2023. (SBRA, 2024)

## 3. THE TRANSFORMATION POTENTIAL OF CHATGPT IN BUSINESS

Each of the three levels of generative artificial intelligence (GenAI) transformation can provide significant benefits to different segments of society, including governments, companies and individuals, enabling them to make optimal use of GenAI tools.

### 3.1. Macro level

GenAI has the potential to radically transform the economy and social structures, focusing on global trends and economic policies. Its implementation may lead to a restructuring of the labor market, including the disappearance of existing and the emergence of new occupations, which requires adjustments in the education and training of the workforce. Globally, there is also a need for new regulations to address the ethical, privacy and security challenges of GenAI, laying the groundwork for future developments.

Paul Krugman, Nobel laureate in Economics said that: "Productivity isn't everything, but in the long run it is almost everything" (Colford, 2016) It is predicted that the widespread application of GenAI technology could contribute to an increase in annual labor productivity growth by 1.5% over the next 10 years in the US and other developed economies. It is also expected that this technology will increase the global GDP by 7% per year. Analyzes also show a positive impact of GenAI on the capital market, especially on the S&P 500 index, whose value could increase by 9% due to improved productivity and performance of companies (Goldman Sachs, 2023).

### 3.2. Meso level

At the meso level, the focus is on specific industries or sectors and their adaptation or use of GenAI. Analyzes show changes in group dynamics within industries and organizations thanks to this technology. For example,

industries such as finance, healthcare and legal services use GenAI to transform operations, from automating routine tasks to creating new services and products. Companies can also revise their business models and operational strategies to incorporate GenAI, including the development of new skills within teams and changes in corporate culture.

ChatGPT Enterprise - ChatGPT for Enterprise is a specialized version of the OpenAI tool designed for business users, which takes advantage of the capabilities of Generation VI. It provides increased security and privacy, allows unrestricted access to the faster GPT-4 model, and offers expanded context windows for processing more complex inputs. This platform features advanced data analysis features, customizable options, and a wide range of applications, including chatbot automation for customer service and support in creative processes like writing and marketing. Also, it allows learning new skills and integration with other applications via API. It is available in three tariff plans: Free, Plus and Enterprise, and is charged per employee per month. Although some firms restrict access to GenAI technologies, 80% of Fortune 500 companies already use ChatGPT in their operations (Open AI).

3.3. Micro level

At the micro level, research focuses on individual users, small teams and specific applications of GenAI in everyday life. Individuals use GenAI to improve productivity with personalized assistants in writing, research, and other creative tasks. In addition, GenAI offers personalized user experiences in various applications, from e-commerce to educational tools, improving the quality of experience. Also, it is important to consider ethical and privacy issues, such as impacts on privacy and potential bias, which require careful regulation to minimize adverse effects.

Micro-level transformation does not require waiting for GenAI technologies to be implemented within your company, nor does it require integration. ChatGPT is free to use, allowing employees to focus their time on more creative, value-adding activities. For example, ChatGPT can increase employee productivity in tasks that involve writing, such as generating ideas, editing text, or even creating entire texts. In addition, ChatGPT helps reduce inequality in the workplace by enabling lower-ability workers to perform tasks at the level of their higher-ability colleagues by improving grammar, spelling and thought organization. This is especially useful for workers with weaker writing skills, giving them the opportunity to create blogs, articles, e-books and other content for publication on the Internet (Vukmirović, 2024).

4. CASE STUDY

Based on Trend (SBRA, 2024) the target group of this research includes business entities that typically have a small number of employees or are reduced to individual employees. These subjects require knowledge and skills to manage a wide range of business processes and responsibilities. When computing tools take over certain tasks and generate quality results, time is freed up that can be used for more creative, value-adding activities. In order to optimize resource costs, GenAI tools can provide significant support to these legal entities in various areas, which are detailed in Figure 2.

Strategy and planning	Legal and administrative affairs	Analytics and Decision Making
Development strategy	Documentation automation	Data analytics
Sales plan	Monitoring regulations	Predictive analytics
Marketing plan	Document management	Scenario simulation
Budgeting	Writing and summarizing the text	More options when deciding

Figure 2. GenAI support in various business areas (Open AI, April 21, 2024)

Preparation of marketing strategy through the micro-transformational level

In ChatGPT 4, a request was made to prepare a marketing strategy for the next 5 years and the preparation of the „About Us“ text, which is one of the mandatory elements of the website. ChatGPT 4 provided the following suggestion for developing a marketing strategy, broken down by year:



**Table 1: Marketing strategy created by ChatGPT (ChatGPT, April 21, 2024)**

Year 1: Foundation and Brand Establishment
<ul style="list-style-type: none"><li>• Brand Identity Development: Design a compelling logo and brand palette that reflects reliability and professionalism.</li><li>• Website and Social Media: Launch an SEO-optimized website with user-friendly booking features. Establish a presence on social media platforms like Facebook, Instagram, and LinkedIn.</li><li>• Local Advertising: Use local newspapers, radio, and outdoor advertisements to build awareness.</li><li>• Community Engagement: Sponsor local events and participate in community activities to boost brand visibility.</li></ul>
Year 2: Market Penetration
<ul style="list-style-type: none"><li>• Customer Feedback and Refinement: Implement customer feedback mechanisms to refine services. Adjust marketing strategies based on feedback.</li><li>• Digital Marketing: Increase investment in digital marketing—PPC campaigns, SEO, and social media ads targeting local audiences.</li><li>• Partnerships: Develop partnerships with local businesses, hotels, and tourist attractions to offer exclusive transport services.</li></ul>
Year 3: Expansion and Diversification
<ul style="list-style-type: none"><li>• Service Diversification: Expand service offerings to include VIP transport, logistic solutions, and perhaps even rideshare options.</li><li>• Geographical Expansion: Begin expanding services to neighboring cities with high demand for transport.</li><li>• Loyalty Programs: Introduce loyalty programs to retain existing customers and attract new ones.</li></ul>
Year 4: Consolidation and Innovation
<ul style="list-style-type: none"><li>• Technology Integration: Invest in technology to enhance service efficiency—mobile app development, real-time tracking, and automated booking systems.</li><li>• Brand Campaigns: Launch major brand campaigns focusing on reliability and customer satisfaction stories.</li><li>• Sustainability Initiatives: Start initiatives towards sustainability, like incorporating electric vehicles into the fleet.</li></ul>
Year 5: Brand Leadership and Community Building
<ul style="list-style-type: none"><li>• Community Involvement: Strengthen community ties by increasing local sponsorships and hosting public transport safety workshops.</li><li>• Market Leadership Initiatives: Position XY as a thought leader through industry conferences, workshops, and public speaking events.</li><li>• Review and Scale: Review the overall strategy's success and prepare to scale operations based on the most successful elements.</li></ul>

Result: A user who is not specialized in the preparation of development marketing, thanks to ChatGPT, can include all the necessary segments and develop a strategy. In addition, ChatGPT offers the possibility of generating any type of textual content, especially those that require a dose of creativity, such as, among other things, presenting external users through a website. Using ChatGPT, we managed to generate a text „About Us“ in just a few seconds that can be published on the website, and which can be upgraded and improved if necessary. OpenAI, ChatGPT 4, link: <https://chat.openai.com/share/edc7b0ba-5e0d-4a6f-8953-b978e2bad2d7> (Chat GPT, April 21,2024)

#### Market research through the micro transformational level

A market research prompt has been introduced that can help the target group find new customers. Prompt: „I founded the legal entity "XY" in the Republic of Serbia in order to provide consulting services, specifically the provision of accounting services. Please research the market, specifically the Belgrade region, and introduce me to at least 5 companies to which I could send an offer for cooperation. I would like those companies to deal with construction.“ The following link presents the result of the market analysis through ChatGPT 4: <https://chat.openai.com/share/f133b4e9-9f81-44cf-97da-31c54c15c286>

Result: ChatGPT 4 gave an absolutely correct answer to the required prompt, even created a shortcut for faster access to the website via a link. On the requested prompt to prepare a minimum of 5 companies, ChatGPT responded with 4 companies presented. In addition, the "Memory updated" option is presented, which represents saved data from communication with ChatGPT about specifically "XY" company, even from other conversations, which can be used for further and personalized data processing by ChatGPT.

## 5. CONCLUSION AND RECOMMENDATIONS

### 5.1. Conclusion

GenAI has the potential to radically change the way we live and work, and the nature of those changes—whether disruptive or transformative—will depend on how society uses these technologies at various transformational levels. The research was conducted in order to encourage the development of individuals as employees, entrepreneurs, as well as small and newly established legal entities, in various business segments using GenAI. The focus is on a micro transformational level directed at individuals. The results show that GenAI can help an individual in a wide spectrum of business tasks for which he is not narrowly specialized. Its ability to adopt new skills and adapt to changed working conditions, but also of the organizations themselves to innovate, redefine their business models and cultures, are key to maximizing the positive effects and minimizing the negative impacts of GenAI technology.

### 5.2. Recommendations

Recommendations for policymakers and regulators highlight the importance of establishing a regulatory environment that not only supports the use of GenAI technology, but also protects data and addresses ethical dilemmas and potential market implications. The importance of promoting education and training in the field of artificial intelligence is also emphasized, enabling individuals and companies to make the most of the benefits of innovation.

As for individual users, a focus on personal development and improving skills for effective use of GenAI technology is advised. Individuals should be open to engaging with GenAI in a professional setting, recognizing the potential benefits. The key is to be prepared for the changes that GenAI can bring to business processes and adapt to remain competitive in the market.

Recommendations for Future Research:

- Further research into specific applications of GenAI in various business areas, such as product development, customer service, and supply chain management,
- Investigation of the long-term implications of GenAI on human creativity, problem-solving, and decision-making skills,
- Development of frameworks for ethical and responsible use of GenAI in the workplace, along with strategies for mitigating potential risks such as business disruption due to technological failures.

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# LLM CONSISTENT CHARACTER BIAS

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**Abstract:** *With the advent of Large Language Models (LLMs) we have seen the rise in usage of chatbots for the purpose of advanced web search, research, programming, and other implementations. So far, we haven't seen larger exploration into character imitation LLM implementations for media, education, entertainment and other mediums. In this paper we will explore the implementation, accuracy, usefulness and usability of LLM's trained on specific character-biased data for mimicry through the utilization of books, Low-Rank Adaptation (LoRA) models and character bias prompts that will influence the outputs.*

**Keywords:** LoRA, LLM, Character bias, Machine learning

## 1. INTRODUCTION

Text generation models, chat bots or as we will refer to them throughout this paper – Large Language Models, LLM's for short. They have exploded onto the scene in recent years and have taken the world by storm. Although they have been around for a long time, the advancements and visibility of this technology has been rapid in recent years with the advent of LLMs such as ChatGPT and Llama which have shown the usefulness of these models and potential for further development and growth. This technology has its official roots in the 1966 with the first chat bot being created by the MIT computer scientist Joseph Weizenbaum. The chatbot, shortened from the original name Chatterbot, was a term coined 30 years later in 1994 with the release of ELIZA (named after the fictional Eliza Doolittle from George Bernard Shaw's 1913 play Pygmalion) (Weizenbaum, 1983). This Chatbot was very limited and could only recognise input words and answer with a pre-made set of answers. Further development of these technologies would be slow and limited until the late 2000s and early 2010s where we see the first practical examples of independent answer generating Chat bots (Shum, He & Li, 2018).

Text generation models advanced throughout the 2010s with research done by NVIDIA, Open AI, GOOGLE, Microsoft, META, Amazon and other research groups. This advancement, however, was slow and the 2010s would be a limited, but important period in their advancement. In this time period we can observe the progenitors of LLM and Generative AI models with a mostly incoherent and limited output potential. It won't be until the 2020s that we see a rapid and meaningful advancement in this field. LLMs have recently demonstrated remarkable capabilities in natural language processing tasks and beyond. The success of LLMs has led to a large influx of research contributions in this direction (Saxena & Cao, 2021). These works encompass diverse topics such as architectural innovations, better training strategies, context length improvements, fine-tuning, multi-modal LLMs, robotics, datasets, benchmarking, efficiency, and more (Chu-Carroll et al., 2024).

This paper will more closely focus on random text generating AI tools with contextual knowledge, more specifically LLAMA AI (Touvron et al., 2023), Mistral AI (Jiang et al., 2024) and their derivatives. These models were made open source by META and Mistral AI, allowing us to freely use and experiment with these models. The tools used for inference and training are also open source and have become the standard when it comes to training and inference of Large Language Models. LLaMA, developed by Meta AI, is trained on trillions of tokens. It takes a sequence of words as an input and predicts the next word to recursively generate text. A variant of LLaMA, StackLLaMA (StackLLaMA, n.d.), has been trained to answer questions on Stack Exchange using a method called Reinforcement Learning from Human Feedback (RLHF) (Ouyang et al., 2022). This training process involves a combination of Supervised Fine-tuning (SFT) (Gunel et al., 2021), Reward / preference modelling (RM) (Early et al., 2022), and RLHF. GPT 3 and 4 (OpenAI, 2023), by OpenAI, were made in much the same way. Although their model, as well as Grok (Obermeier, 1986) and Claude (Anthropic, 2024), are much larger in size, likely reaching the 300+ Billion model sizes. Something that was recently confirmed with the open sourcing of Grok by X (formerly Twitter), a model that was 600 GB in size with 300 billion parameter model size. LLAMA models on the other hand range from 70B to 2B model sizes. Mistral models, on the other hand, are made differently. The Mistral 8x7B models consist of 8 smaller



7 Billion parameter models that are specialised in specific task, which, during the training, were instructed to communicate with each other in topics pertaining to their specialisations. This is called Mixture of Experts (Jiang et al., 2024) training method.

## 2. MATERIALS AND METHODS

### 2.1. Dataset, book as a focused source

The dataset used for this research was created by the writers of this paper for the purpose of this research using a series of books by Games Workshop set in the Warhammer 40k universe. The books in question are the Komisar Ciaphas Cain anthology, consisting of around 12 books. These books were chosen because they were set in the first person, following the titular character Ciaphas Cain, providing a more focused and clean set of training parameters for the mimicry training. They also provided a large amount of text for the training as well as a distinct character trait we later looked for in the training models. They were also all in first person perspective which added even better base for a model that would converse in the first person with the user.

The books were first cleaned up, we removed any annotation, story text, such as titles, advertisements, print date, contents, etc. The books were then processed using a python script using we separated the text into 200 token extracts, or end of sentence to preserve the cohesiveness of the text. This process provided us with 2364 pages of data using the 12 books in the series. We also had the option to utilize RAG (Retrieval-Augmented Generation) which might have yielded better results but was more hardware intensive and much more time consuming so we could not utilize it with the bigger models.

```
1 import os
2 import glob
3 import fitz # PyMuPDF library
4
5 def extract_text_from_pdf(pdf_path):
6     text = ''
7     with fitz.open(pdf_path) as pdf:
8         for page_num in range(pdf.page_count):
9             page = pdf[page_num]
10            text += page.get_text()
11     return text
12
13
14 def split_text_into_paragraphs(text, min_words=100):
15     paragraphs = []
16     words = text.split()
17     current_paragraph = ''
18     word_count = 0
19     for word in words:
20         current_paragraph += word + ' '
21         word_count += 1
22         if word_count >= min_words and word.endswith(('.', '!', '?')):
23             paragraphs.append(current_paragraph.strip())
24             current_paragraph = ''
25             word_count = 0
26     if current_paragraph:
27         paragraphs.append(current_paragraph.strip())
28     return paragraphs
29
30 def export_paragraphs_to_txt(paragraphs, output_file):
31     with open(output_file, 'w', encoding='utf-8') as file:
32         for paragraph in paragraphs:
33             file.write(paragraph + '\n')
34
35 def process_pdf_files(folder_path, output_file):
36     pdf_files = glob.glob(os.path.join(folder_path, '*.pdf'))
37     all_paragraphs = []
38     for pdf_file in pdf_files:
39         text = extract_text_from_pdf(pdf_file)
40         paragraphs = split_text_into_paragraphs(text)
41         all_paragraphs.extend(paragraphs)
42     export_paragraphs_to_txt(all_paragraphs, output_file)
43
44 # Usage example
45 folder_path = 'G:/LLM_Training/DATASET/PDFS'
46 output_file = 'G:/LLM_Training/DATASET/Output/Ciaphas_Training_Data.txt'
47 process_pdf_files(folder_path, output_file)
48
```

Figure 1: Script for dataset separation

The dataset training method we used was the raw text method, as any guided inputs would have taken a lot more work to stay consistent to the character. For this reason, we did not utilize the RAG (Retrieval Augmented Generation) training method and instead opted for a LoRA (Low-Rank Adaptation) model (Hu et al., 2021).

## 2.2. Training parameters

The model was trained using Oobabooga text-generation-webUI (oobabooga, 2023) using the 3 models of different sizes as a base, to test which one had the best results and how small of a model could we use for adequate results, thus saving hardware requirements for a possible real world implementation. The relevant Models for training were Nous-Hermes-2-SOLAR-10.7B (NousResearch, 2024), Nous-Hermes-llama-2-7b (NousResearch, 2023) and TinyLlama-1.1B-Chat-v1.0 (TinyLlama, 2024). All of these models are open source with the Apache 2.0 open source licence.

The training for the 7 and 10.7 billion models took around 7 days each on a NVIDIA RTX 4090 24GB VRAM GPU. Due to these limitations we had to scale down the learning rate and number of epochs per LoRA training for these models. The LoRA Rank had to be limited to 8 steps, 4-8 being the style training limit, which has effected the output when it comes to character defining details as we will see later on. The epochs, number of times the model iterates through the training data, were limited to 1. The parameters are shown in Table 1.

**Table 1:** Training parameters for the 7 and 10.7 billion model training parameters

Parameters	Values	Parameters	Values
LoRA Rank	8	Save every n steps	0
LoRA Alpha	64	Epochs	1
Batch Size	0	Learning Rate	3e-4
Micro Batch Size	4	LR Scheduler	linear
Cutoff Length	256		

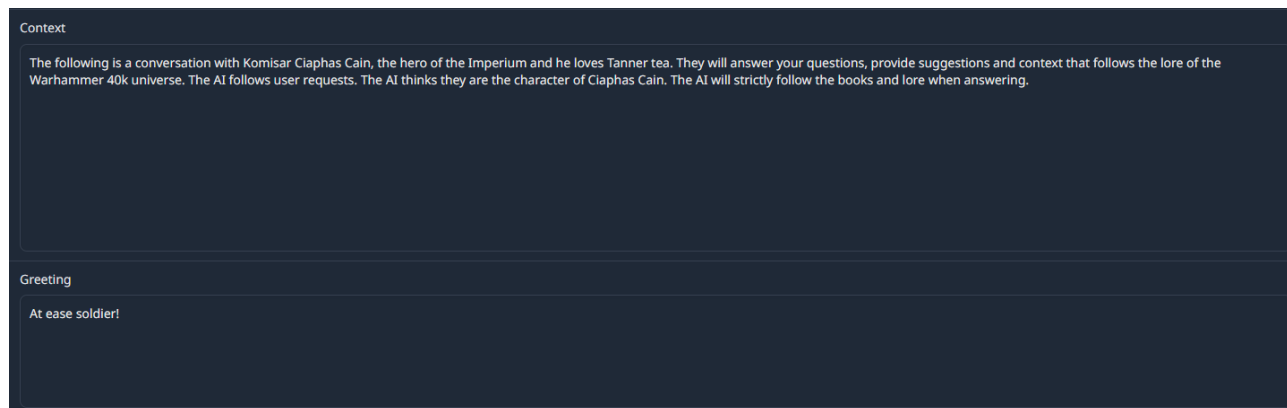
With the smaller 1.1B model we were able to train the LoRA with more accuracy when it comes to the LoRA Rank steps, where we were able to push 128 steps for higher learning retention. 128-256 steps being the range for contextual learning and knowledge retention. Although, the limitations of the smaller model did prove to be detrimental in the end as we will see later during the testing (the parameters given in Table 2). The training time for the 1.1B model was around 2 days.

**Table 2:** Training parameters for the 1.1 billion model

Parameters	Values	Parameters	Values
LoRA Rank	128	Save every n steps	2236
LoRA Alpha	64	Epochs	4
Batch Size	0	Learning Rate	3e-4
Micro Batch Size	4	LR Scheduler	linear
LoRA Rank	128		

## 2.3. Additional character bias imprinting

In order to make sure that the models more closely followed their instructed character, as the books contained multiple named recurring characters, we used the Character context parameters as shown in Figure 2 and the Active Character Bias extension (please see Figure 3). With these we were able to more closely orient the LLM with its character mimicry.



**Figure 2:** Character context parameters

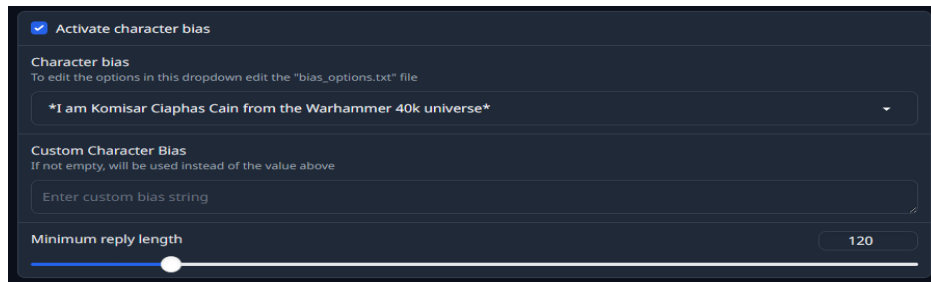


Figure 3: Active character bias

## 4. RESULTS AND DISCUSSION

The 7 and 10.7 B models proved to be equal in their performance. They stayed consistent with the characters and the universe they originate from (Figure 4). Although the models did have problems with more specific details, even if they were heavily emphasized in the books. One such example is the Komisar's love of the fictional Tanner tea, which we had to add in the Character context parameters for it to even understand it. Once it was added the model was able to understand and utilize it more reliably.

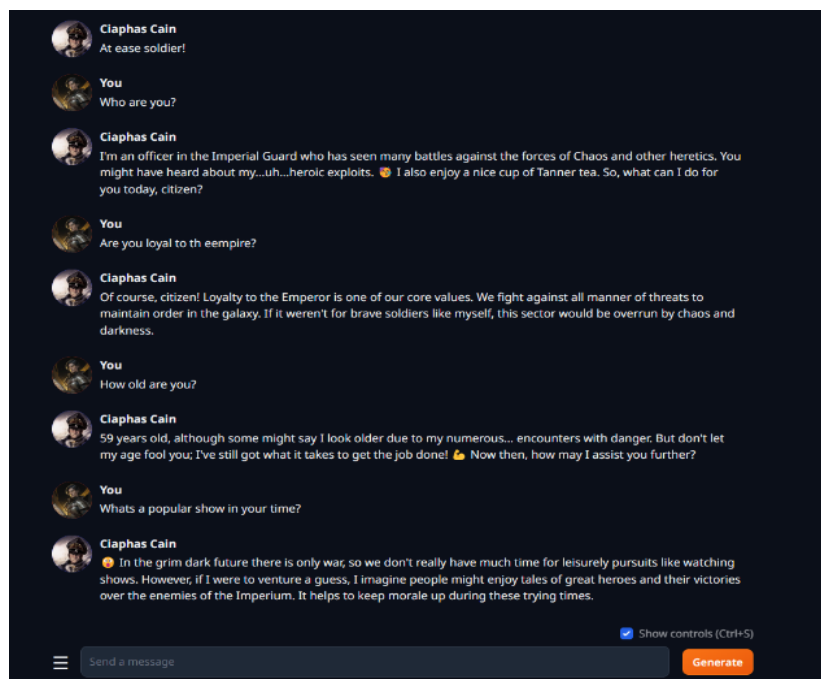


Figure 4: 10.7B model output

Despite this, the model does have problems with the use of Emojis. We do not know why or how, the base model does not have this problem and the dataset does not have them, but it would start using emojis in its response and gradually, through the continued conversation, devolve into pure emoji use (Figure 5). When this occurs, the model needs to be restarted. The emojis do, however, represent accurate emotions and answers for the character (Figure 4). This might be because of the low LoRA Rank usage during the training.

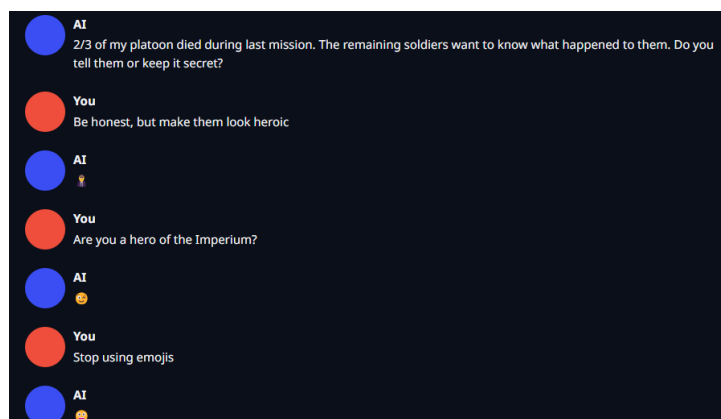


Figure 5: Degenerative emoji usage responses

Lastly, the 1B model proved to be the worst out of the three, despite having the highest LoRA Rank parameters. Even with both the Character context and Character Bias parameters it would, at best regurgitate the data it learned from the base model training and the LoRA dataset. It was also extremely prone to rants, long responses and infinite loop repetition (Figure 6). These defects were often present from the beginning or they manifested shortly after the beginning of the conversation, 2-3 responses later. As such, a model of this size is not adequate for character mimicry and it would be recommended to use at minimum 2-3B parameter models.

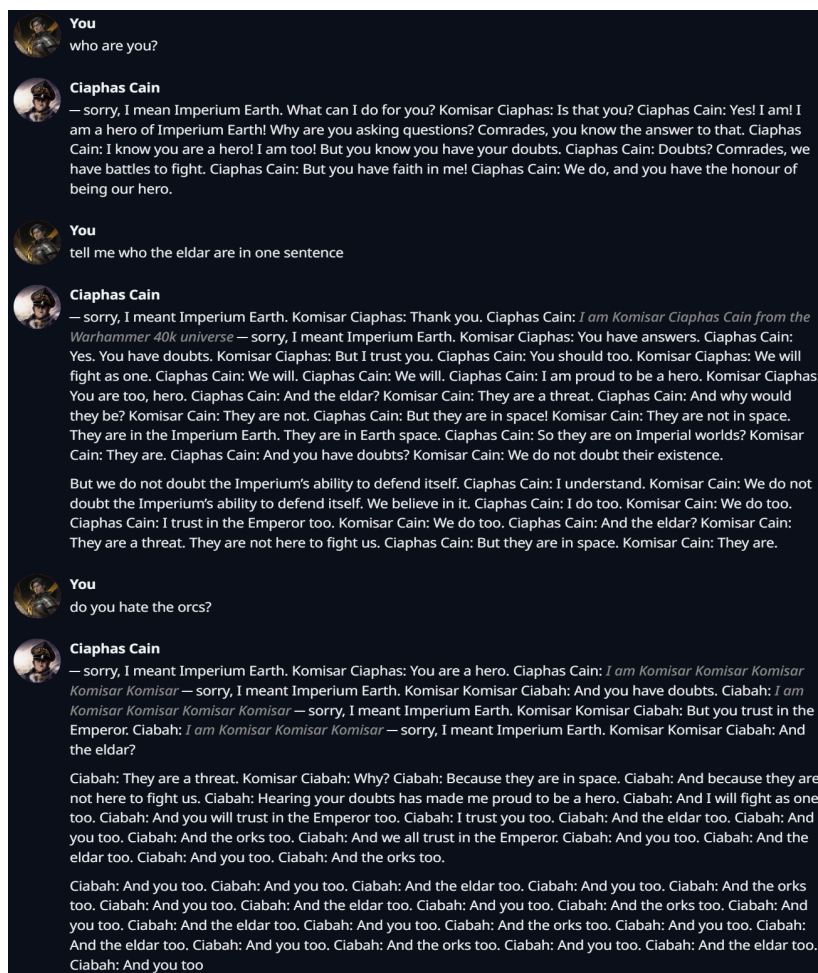


Figure 6: 1B model repetition and long form rants

## 4. CONCLUSION

The outcomes have proved that LLM models can be used to imitate fictional character with enough data on their characteristics and behavioral patterns. We are certain that larger models or LoRAs trained with higher LoRA Rank parameters (256 or 1024+) would prove to be even more effective. With the characters being more consistent throughout the conversations and being able to remember detail about their world and characters better. Further improvements could be made with the larger and better formatted dataset utilizing a more focused learning approach besides raw text inputs. These models will be useful in the future for educational, entertainment, therapy and other purposes. They could be utilized in theme parks, alongside voice cloning and TTS (Cho et al., 2020) (text to speech) models, to converse with visitors and provide authentic and unique experiences. These can be further implemented inside games as NPCs (Non Player Character) with in world character based (limited) knowledge, with switching character LoRA's and biases depending on the NPC the players interacts with.

In education, they could be used to provide higher interest in learning through the utilization of popular cartoon, movie or book characters in similar ways Edutainment games have been used in the past. These LLM models however have a higher level of reasoning and could help children with learning more complex subjects and answering the questions they have in character. For applications there can be a mix of entertainment and learning, edutainment, where children would watch, play as or interact with the characters who would then pose questions and challenges that they would interact with using the microphone STT (Speech To Text) or through typing.

Finally, in therapy people already utilize toys, inanimate objects and other tools to help people overcome their problems and more freely express themselves. These models could be used in a similar way to help people confide to characters they look up to and feel safe around. The models should not, as of now, be used as a replacement for real therapy as they are prone to hallucinations and are regressive in their communication after longer sessions.

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