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SERVICE MANAGEMENT IN MANUFACTURING: EVIDENCE FROM SERBIA

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Abstract: *In nowadays economy, the service sector has increasingly significant role in every country or region. Following the trends and competing in globalized market, services are not only offered by service companies today, but also by manufacturers. Those services are referred as product-related services and the phenomenon is well-known as the servitization. With the Serbian dataset from the European Manufacturing Survey (EMS), presented paper analyzes the importance and the influence of product-related services on company's performance. Furthermore, using a regression model, it provides the insights and guidelines about the services that have the highest positive effect on company's turnover. It is shown that different types of product-related services have diverse impact on financial success of companies, depending on the way how they are invoiced, directly or indirectly. The results could be useful for companies to improve their customer value and gives the fundamentals for future research.*

Keywords*: Servitization, Manufacturing, EMS, Serbia, Product-related services*

1. INTRODUCTION

The structure of economic output (i.e. product, service) has significantly changed over the last 35 years in whole Europe(Dachs et al., 2014).Almost all developed countries have large service sectors. According to Central Intelligence Agency (2018), in the United Kingdom, for example, the share of services in GDP in 2015 was 79.6% and in 2017 it rose to 80.4%. Also, in 2017 France had the share of service sector in GDP 78.9%, Belgium 77.5% and Denmark 75.2%. Moreover, labor force engaged in service sector in European Union in 2012 was 70.1% (Eurostat, 2018) and in 2014 was 73.1% (Central Intelligence Agency, 2018). However, it is important to note that services are not only provided by service companies. Manufacturing firms also provide a wide range of different types of services (product-related services) in order to give better offer to the customers on the competitive market (Kinkel et al., 2011).

As service sector seems to play an increasingly significant role for all countries on today's global market, services in the Republic of Serbia might be a topic of great interest for success of both types of companies, service and manufacturing. Since there is a lack of the literature and empirical research which addresses this problem in developing countries, the possible effect of services on company's success could be missed. On the other hand, if the manufacturing companies in Serbia decide to offer product-related services, the way of charging for the provided service could be under question for them.

Although the significant contribution of product-related services to financial performance of manufacturing companiesis proven in general(Vandermerwe & Rada, 1988), it is not sufficient acknowledged how specific types of services could influence the company's sales (Kinkel et al., 2011). According to this, it is important for companies to have information and guidelines not only for use of specific product-related services, but for making the strategic approach which includes the appropriate way of charging customers for provided services.

This paper aimed to give insights into the importance and the effects of different types of product-related services on company's turnover in developing countries such as Serbia. Moreover, it contributed to existing literature providing the empirical results on the relevance and differences between two ways of invoicing the given product-related service, separately or calculated in product's price.

2. LITERATURE REVIEW

2.1. Servitization

Servitization as a term was firstly defined and discussed by Vandermerwe and Rada (1988). Servitization refers to the "fuller market packages or bundles of customer-focused combinations of goods, services,

support, self-service and knowledge" (Vandermerwe & Rada, 1988, p.1). Up to now, a variety of definitions has been formed to describe the phenomenon of manufacturers turning into service providers (Cvetković et al., 2017). Baines et al. (2009) defining the manufacturing servitization as a migration process wherein product companies embrace a service orientation and/or develop more and better services, with the aim to offer total client solutions. According to Tellus Institute (1999) this term is defined as "servicing" which represents the emergence of product-based services which blur the distinction between manufacturing and traditional service sector activities. Since there are different terms for the output of servitization depending on different academic disciplines, in the context of this article, the term servitization is used in the sense of product-related services to explicitly cover the whole range of definitions. Product-related services can be defined as services in the manufacturing industry which are offered to customers together with the main products as an integrated solution (Dachs et al., 2014). Product-related services can serve as a differentiating characteristic which distinguishes firms within the same market. The distinctive strategy pattern is the ability of these firms to offer their customers unique problem solutions, integrating professional services and innovative products (Kinkel et al., 2011).

Nowadays, attention and interest for servitization has grown in academia (Dachs et al., 2014; Lightfoot, Baines, & Smart, 2013; Szász, Demeter, Boer, & Cheng, 2017). Most of the research has been conducted in the fields of manufacturing (Baines et al., 2009), service management (Pawar, Beltagui, & Riedel, 2009) and marketing (Gebauer, Ren, Valtakoski, & Reynoso, 2012). More and more manufacturing companies are utilizing the trend of servitization by changing their perspective on value creation and creating product-related services (Shimomura, Nemoto, Ishii, & Nakamura, 2017). The shift towards product-related services can bring to a company a better competitive position (Rondini, Pezzotta, Pirola, Rossi, & Pina, 2016), strengthen global competition (Oliva & Kallenberg, 2003)(Davies, Brady, & Hobday, 2006), and provide better financial results (e.g. revenue stream and profit margin) (Santamaría, Jesús Nieto, & Miles, 2012). It is important to mention that some other authors have also proposed environmental rationales as important (Frambach, R.T., Wels-Lips, I., Gundlach, 1997; Goedkoop, Van-Halen, Riele, & Rommens, 1991; Wise & Baumgartner, 1999).

It is shown that product-related services significantly contribute to the sales of manufacturing firms (Kinkel et al., 2011). The profit rationale behind servitization is often considered in the literature as a financial driver (Baines et al., 2009). For example, researcher explored the financial consequences of servitization using a large international database, and found that the proportion of manufacturing firms reporting to provide services is at least 30% (Neely, 2009).

Several classifications and types of product-related services have been considered in the servitization literature. For example, Kinkel et al. (2011) make distinction between 'traditional' and 'advanced' services while Cusumano et al. (2014) consider product-related services as complement or substitute for purchasing the product. Looking at these services from a different perspective Mathieu (2001) differs services which support the supplier's product or which supports the client's action. On the other hand some authors make distinction between product-related services depending on their orientation towards product or process (Szász et al., 2017). Typical examples of the services provided include installation and training, after-sales services (i.e. product repair and maintenance, customer support and recycling of goods at the end of their lifetime), software development, remote support and modernization (Santamaría et al., 2012).

2.2. Research questions

Based on literature review, it is important to define two different methods for charging the users for product-related services. One method is to directly invoice the service, so user pays for it separately from the product. The second method of indirectly invoicing the service means that company includes the price for particular service in the price of the product. According to this, the following research questions were proposed in attempt to identify the different effects of product-related services on manufacturing's firm performance in transitional economy such as Serbia:

- RQ1: Do product-related services increase revenue, when directly invoiced?
- RQ2: Do product-related services increase revenue, when indirectly invoiced (included in the product price)?

Summation of our research questions is given in Figure 1. Proposed model analyses the effect of product-related services such as installation, maintenance and repair, training, design, consulting, and project planning, software and development, remote support for clients, revamping or modernization, end of life services. The research is based on the hypothesis that observed services have positive impact on the revenue of manufacturing companies.

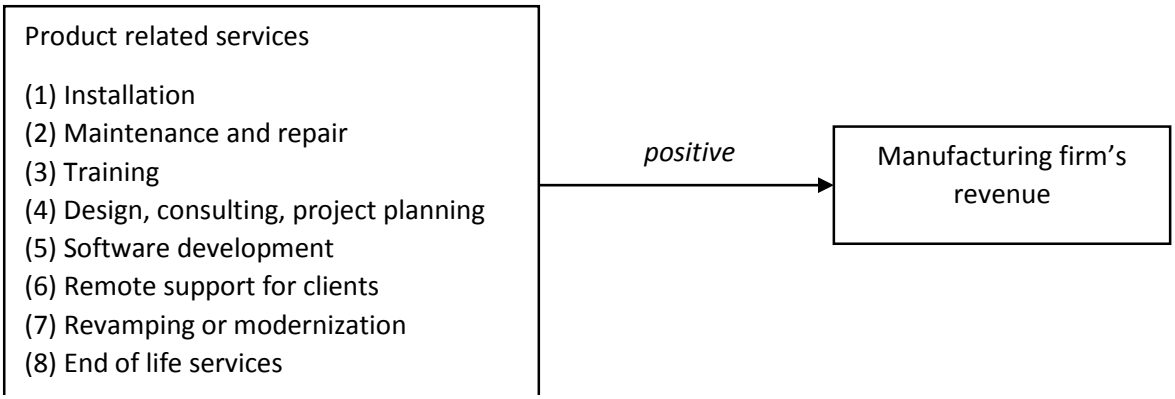

Figure 1: Proposed model

3. METHODOLOGY

Our analysis used the Serbian dataset from the European Manufacturing Survey (EMS) conducted in 2015. EMS is a survey on the manufacturing strategies, the application of innovative organizational and technological concepts in production, and questions of personnel deployment and qualifications in European manufacturing industry (Bikfalvi, Jäger, & Lay, 2014; Lalić, Tasić, Marjanović, Delić, & Cvetković, 2016). For the purposes of this study, the survey was conducted among manufacturing firms (NACE Rev 2 codes from 10 to 33) having at least 20 employees. Total population in Serbia that meets the above criteria was 2043. The initial population was obtained from the Serbian Business Registers Agency. To obtain a representative sample, 828 companies were contacted evenly distributed across all NACE sectors and in all the districts in Serbia. Data collection was done through a pre-test phase and the two mass distribution phases. Total number of companies who participated in the study is 280, representing a response rate of 33.8%. About 38.2% of the firms in the sample are small firms between 20 and 49 employees, another 50.4% of the firms have between 50 and 249 employees, and 11.4% of the firms have more than 250 employees. The largest industry in the sample is the manufacture of food products (NACE 10), followed by manufacture of fabricated metal products, except machinery and equipment (NACE 25) and the manufacture of rubber and plastic products (NACE 22). Tables 1 and 2 give an overview of the sample.

Table 1:EMS database – distribution of firms by size

Firm size	**n**	**%**
20 to 49 employees	107	38.2
50 to 249 employees	141	50.4
250 and more employees	32	11.4

Table 2: Classification on manufacturing sectors according to share on total sample

NACE Rev. 2	**Manufacturing industry**	**Share on total sample (%)**
10	Manufacture of food products	18.2
25	Manufacture of fabricated metal products, except machinery and equipment	13.6
22	Manufacture of rubber and plastic products	8.3
28	Manufacture of machinery and equipment n.e.c.	6.0
14	Manufacture of wearing apparel	6.0
27	Manufacture of electrical equipment	5.3
23	Manufacture of other non-metallic mineral products	5.3
18	Printing and reproduction of recorded media	4.6
31	Manufacture of furniture	4.3
29	Manufacture of motor vehicles, trailers and semi-trailers	4.0
16	Manufacture of wood and of products of wood and cork, except furniture	3.6
20	Manufacture of chemicals and chemical products	3.3
17	Manufacture of paper and paper products	3.3
13	Manufacture of textiles	3.3
	Others	10.9

4. RESULTS

For research questions testing, regression analysis was conducted by IBM SPSS. Each research question was tested with separate model. Model 1 relates to research question 1 – *Do product-related services increase revenue, when directly invoiced?* and refers to the situation when company directly charge user for observed service. Model 2 relates to research question 2 – *Do product-related services increase revenue, when indirectly invoiced?*and refers to including the observed service in the product price by the manufacturing company.

Table 3 presents two different regression models.

4.1. Modeltesting

Model 1
The overall model was significant, Adjusted R^2 = .453, F = 13.785, p < .001. Three predictors had a significant coefficient – maintenance and repair (B = .352, p < .001), design, consulting, project planning(B = .257, p < .01), and end of life services(B = .186, p < .01). Three predictors had a limited significant coefficient – software development (B = .179, p < .1), remote support for clients (B = -.140, p < .1), and revamping or modernization (B = .164, p < .1). However, installation (B = -.127, p > .05) and training (B = .047, p > .05) were not significantly different from 0. This confirms support for research question 1.

Model 2
The overall model was significant, Adjusted R^2 = .242, F = 4.937, p < .001.Two predictors had a significant coefficient – design, consulting, project planning(B = .275, p < .01) and maintenance and repair (B = .239, p < .05).However, all other predictors were not significantly different from 0, installation (B = .128,p > .05),end of life services (B = .032,p > .05), software development (B = .031,p > .05),remote support for clients(B = -.104,p > .05), revamping or modernization (B = .064, p > .05)and training (B = -.019, p > .05).This confirms support for research question 2.

Table 3: Results of regression models for two research questions

Product-related services	**RQ1**	**RQ2**
Installation	-.127	.128
Maintenance and repair	**.352*****	**.239***
Training	.047	-.019
Design, consulting, project planning	**.257****	**.275****
Software development	**.179**$^{+}$	.031
Remote support for clients	**-.140**$^{+}$	-.104
Revamping or modernization	**.164**$^{+}$	-.064
End of life services	**.186****	.032
R	0.673	0.491
R^2	0.453	0.242
F	13.785	4.937
Sig	0.000	0.000

Note: ***p<0.001; **p<0.01; *p<0.05; $^{+}$p<0.1;

5. DISCUSSION

This research has addressed the problem of servitization from the financial perspective. The results given in Table 3 contribute to the existing literature which is predominantly focused on the measuring the share of product-related services altogether, by the way they are accounted either directly or indirectly, in the total turnover of the companies. As Kinkel et al. (2011) stated, it is important not only to measure and monitor the offer of product-related services in general but also different types of services.

Since the aim of the research is to explore the effects of specific product-related services on manufacturing's firm performance, especially financial performance, two research questions analyzing the possible methods of invoicing these services to clients were proposed: directly (paid separately from the product) and indirectly (included in the product price). The product-related service types whose importance was analyzed from the financial perspective are: installation, maintenance and repair, training, design, consulting, project planning, software development, remote support for clients, revamping or modernization and end of life services. Observing given results, it can be discussed that answering the both research questions gives important findings for the manufacturing companies in transition economy such as Serbia because there is a significant difference between the influence of specific product-related service on share of turnover of services in

manufacturing companies which participated in the survey when it comes to the chosen method of invoicing product-related service.

If product-related services are directly invoiced, maintenance and repair have the higher positive impact on the company's turnover with the highest statistical significance. In addition, if companies include design, consulting, project planning in their offer and directly invoice this product-related service, they will increase turnover. The same could be applied on the end of life services. With a limited significance, software development and revamping or modernization have also a positive influence on turnover of the companies in this situation. However, when it comes to remote support for clients, it has a negative influence on turnover which means that turnover will decrease when offering this product-related service and directly invoice. It means that companies should be aware of this negative influence and to think it through before including remote support for clients in their offer and to calculate what are the possible benefits for them (e.g.if they want to achieve competitive advantage at the market giving to the users the remote support for their products even it decreases the share of turnover).

Second research question analyzes the situation when companies include the price for observed types of product-related services in the price of the product. Analyzing the results generated by this research question it could be discussed that they differ from the results from the first research question. Just two types of product-related services have the statistically significant influence on the share of turnover, both positive. Information acquired from different companies are positively associated with the share of turnover in the situation of design, consulting and project planning and maintenance and repair. Due to positive correlation between these types of product-related services and the share of turnover, design, consulting and project planning and maintenance and repair should be taken into consideration by the companies because we showed that it has the greatest effect on increasing share of turnover when included in the price of the product.

In this study, we have empirically shown that product-related services have the influence on the overall turnover. This study gives important guidelines and information for the Serbian manufacturing companies regarding servitization. We found that only two types of product-related services positively influence the share of turnover in the situation of indirectly charging users for this service. The assessment, which focused on servitization, is consistent with the literature on servitization. Kinkel et al. (2011)found that product-related services have positive impact on firm's performance. Specifically, indirect turnover from services is higher than direct service turnover in general. In addition, Dachs et al. (2014) confirmed in the results of their large-scale survey from 10 European countries that servitization in manufacturing sector is worthwhile. Therefore, plant managers or technical directors should plan which type of product-related services will design and how they will charge – directly or indirectly, included in the product price.

6. CONSLUSION

This research paper examined the influence of product-related services on firm's performance. The findings show that product-related services have positive impact on the company's turnover. Moreover, this paper provides some implications and possible effects for companies which intend to offer different product-related services to customers and charge for them separately or altogether with the product. Some of the observed types of product-related services show the highest positive impact on the turnover of companies when directly invoiced (i.e. maintenance and repair; design, consulting, project planning; end of life services) and indirectly invoiced (i.e. maintenance and repair; design, consulting, project planning). Although, some of the product-related services influence the firm's turnover in both situations, we found that maintenance and repair have the highest positive impact when directly invoiced, as well as design, consulting, project planning when indirectly invoiced. Given results contribute to existing literature and provide important recommendations for companies which want to include services in their product offerings with evidence from the Republic of Serbia.

Limitations to this study are in the areas of sampling. The sample was drawn from a single developing country (i.e. Serbia), probably lacking the diversity that can be expected from a comparable sample chosen from across different economies, both developed and developing. Further research should test the model and relationships in the manufacturing companies within developed economies. Furthermore, it would be of interest to know more precisely what factors drive (or hamper) innovation in new product-related services.

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THE MANAGING OF THE TEMPERATURE MAPPING PROCESS OF THE WAREHOUSE

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Abstract: *The managing of the temperature mapping process of the warehouse is a measurement performed to obtain information about the temperature distribution on the surface or in the space, in the function of time. Temperature mapping represents collecting and presentation of temperature data from the locations which are defined in the space. The method for determination of the degree on which the system is controlled is industrially accepted. The purpose of temperature mapping is to document and control the distribution of temperature within the warehouse space. Based on the measurement data values, the system automatically regulates the observed parameters within the given limits. The role of man is to oversee the entire process, and at the same time to react when there are disturbances of processes that are not being resolved by the automated system.*

Keywords: *temperature mapping, measurement, pharmaceutical industry, improving quality.*

1. INTRODUCTION

In the pharmaceutical industry, it is very important to provide appropriate equipment and procedures for checking of the ambient conditions in which medicines are stored. In point 3.2.1. (Temperature and ambient conditions control) guidelines for good practice in distribution, a short description is given of how a temperature mapping study needs to be done, and it is described temperature mapping in warehouse and talking about the obligation of temperature mapping. "The ambient conditions that are controlled include temperature, light, relative humidity and room cleanliness. Initial temperature mapping is carried out in the areafor the storage of medicines, before the beginning of use of the warehouse itself, under representative conditions. The temperature monitoring equipment is distributed in accordance with the results of temperature mapping, ensuring that the temperature monitoring devices are positioned in zones where extreme fluctuations are present. Temperature mapping is repeated in accordance with the results of the risk assessment or when significant changes of space or temperature control equipment are made. For small rooms, areas of several square meters, which are at room temperature, an assessment of the potential risks (eg heaters) is carried out and the temperature monitors are installed accordingly. "(Guidelines of good distribution practice, Official Gazette of the Republic of Serbia, No. 30/10 and 107/12, 2016).

As far as temperature mapping in the warehouses in the Republic of Serbia is concerned, mentioned guidelines of good practice in distribution GDP (GoodDistributionPractice) are applied. "GDP is the part of quality assurance that ensures that the quality of drugs is maintained at all stages of the supply chain from the place of production to the pharmacy or other person authorized to issue medicines" (GDP Guidelines 2013/C 343/01). Also, the recommendations of the World Health Organization are applicable, as well as any official recommendations in order to demonstrate compliance with legal regulations, management, clients and inspections.

Considering GDP does not go into details, and the temperature mapping process is not strictly indicated, it is necessary to prescribe proposals and guidelines that will explain and clarify in detail the process of temperature mapping in warehouses. Therefore, this work gives a proposal, guidelines and explanation of the entire temperature mapping process in warehouse of pharmaceutical products, raw materials and packaging.

2. DESCRIPTION OF MEASUREMENT AND RESULTS

To begin the process of temperature mapping of the warehouse, it is necessary to have an approved protocol, which is detailed, clear and comprehensive. The protocol should be approved by the responsible person within the organization, that it has the revision mark, the description and the reason for the change. If the protocol is prepared by an external house, it is necessary that the authorized person signs the consent

(application). If the new system is in question (as is the case in this work), according to the guidelines of good manufacture practice it is necessary to have the following:

- DQ (DesignQualification) –Design Qualification proves that the given design correspondto the needs of users and GMP requirements.
- RA (RiskAnalysis) - Defines the extent of testing which should be performed on the equipment and system.
- IQ (InstallationQualification) -Installation qualification proves that the device is installed in accordance with the manufacturer's design and specifications.
- OQ (OperationalQualification) –Operational qualification proves that the whole system really works in the prescribed way. During the OQ, the initial temperature mapping of the warehouse needs to be done.
- PQ (PerformanceQualification) – Performance qualification proves that the system functions in the prescribed manner at the expected level of filled. During the PQ it is necessary to do winter and summer temperature mapping of the warehouse.

After confirmation of the correctness and functionality of system, it can start with the “filling”process of the warehouse. In the continuation of this work, the description of the measurement, the results, as well as all the necessary information for the successful execution of the temperature mapping of the warehouse will be presented.
The legal regulations prescribes temperature mapping of the warehouse, and the basic purpose of the temperature mapping study is to identify the temperature deviations that effecton the selected area during the execution of study, so that appropriate corrective actions can be taken.

The methodology for execution of temperature mapping study involves certain steps and the traceability. The listed steps are recommendations and they should be completed before the protocol is approved.

1. **Choose the type of equipment with which testing will be done**. Data loggers are the best solution for conducting a temperature mapping study. Data loggers are electronic devices that record data over a certain time interval, on their internal memory, or directly sent to the computer. During the choosing, make sure that the device has enough memory for the planned duration of the study and for the selected recording interval. An important feature is the time response of the sensor in the data logger, as well as the battery life. All data loggers have to be calibrated (every 12 months) in accredited laboratories according to ISO IEC 17025: 2017, to possess calibration certificates, and to have a error of no more than ± 0.5 °C at each point of calibration. Calibration points on data loggers should cover the allowed temperature range of thewarehouse. It is necessary that data loggers be calibrated in 3 points. There should be one calibration point below the permitted range, one calibration point in the center of the permitted range, and one calibration point above the allowed range. To ensure consistency, only one type of data logger per study should be used. Write a working manual for using data loggers before using them, and train staff who will use the equipment. TESTO 174H is the type of data logger used to create this work.
   In case more than 9 sensors are used during the duration of the study, and if 90% of the sensors used for the temperature uniformity mapping test were successfully readout, mapping can be considered successful. In the case of that the measured data after mapping is not available with less than 10% of the usedsensors, it is necessary to give a comment regarding the position of the observed sensors as well as the data from the sensors located in the immediate vicinity of them. In the case of that the measured data after mapping is not available with more than 10% of the used sensors, and if it is not possible to get data from the sensors located in the immediate vicinity of them, proceed according to the operational procedures, initiate a deviation and carry out an investigation.

2. **Determine the team that will perform the temperature mapping test in the warehouse.** All members of the validation team should be identified and personally enrolled into the protocol (name, surname, position in the company, signature, initials and date). All team members must be trained for the purposes of conducting a temperature mapping study.

3. **Collect sufficient information about warehouse.** The information listed in followingtext is quite satisfactory for testing purposes. The width of the tested warehouse is 52.34 m, length 47.3 m and height 14 m. The maximum height of the pallet storage is 11.95 m, and the total warehouse capacity is 6782 pallets. HVAC (Heating, Ventilation, and Air Conditioning)system supplies fresh and recirculated air, and with frequency regulator, regulates fan speed to maintain airflow max 48400 m3/h on the intake and 45400m3/h on the exhaust fan. The required temperature range is from 15 °C to 25 °C.Set point temperature value is 21 °C. In addition to basic warehouse information, it is necessary to attach warehouse drawings that locate racks, pallets, passages and locations of components for heating and cooling.

4. **Establish (determine) the acceptance criteria.** The protocol should define the necessaryacceptance criteria, such as the allowed temperature range, the duration of the mapping, the trends from the SCADA (SupervisoryControlAndDataAcquisition) system, mandatory attachments, and the like. Trial and informative testing, as well as testing for some kind of optimization, can be performed without prior definition of any acceptance criteria, therewith that it is necessary to document such a type of study. If the study is designed so that to include door opening, that should be stated in the acceptance criterion, and the door opening parameters (frequency and duration) should be defined. The establishment of the acceptance criteria for the results of the qualification tests is carried out in accordance with the regulations, where the order of priority is as follows:
   - Pharmaceutical requirements - GMP regulation/ requirements for medical resources,
   - Pharmaceutical requirements - GDP regulation,
   - Requirements and recommendations from the specifications of the materialswhich is stored,
   - Recommendations from the warehouse domain.

5. **Determine locations where testing will be carried out**. It is best to make a risk analysis, and based on that document,determine the locations and the number of data loggers that is sufficient for testing purposes. Data loggers should be arranged to the network by width and length, so the area is reasonably covered, and data loggers should be setted at every [3 - 30] meter. The selected sensor network should take into account the look of the area to be mapped, the degree to which the air on the insertion and/or the exhaust air can effecton the raffs and products as well as the positions where the pallets are placed. Data logger's positions should match with the pallet locations on which the products are located. Depending on the size of the warehouse differs the number of locations on which it is necessary to carry out measurements depending on the height and surface (volume) of the warehouse.The number of levels in which measurement is made varies:
   - In the case that storage is done at a height of up to 3m, all measurements must be carried out at least in one level, and that in the middle, between the lowest and the highest storage point.
   - In the case that storage is done at a height of up to 6 m, all measurements must be carried out at a minimum of two levels. The first level near the lowest level of storage, and the second level near the highest storage point.
   - In the case that storage is done at a height above 6m, all measurements must be carried out at a minimum of three levels. The first level near the lowest level of storage, the second level in the middle (between the lowest and highest storage points), and the third level near the highest storage point.
   - The distance between measuring instruments and walls (side walls, ceiling, floor), for measuring instruments intended to be located near the walls, should be 10% of the total observed length (width) of the warehouse, respectively should not be below 0.3m, and not more than 6m.
   - In case the temperature mapping is done in one level, it is necessary that the distance between the two adjacent measuring instruments is not greater than 5m.
   - In case the temperature mapping is done in 2 levels, the measuring instruments must be set minimum in each corner and one in the center of the warehouse so that the distance between the two adjacent measuring instruments in the horizontal plane is between 3m and 15m.
   - In case the temperature mapping is done in 3 levels, it is necessary that the distance between the two adjacent measuring instruments does not exceed 30m.

   Add a unique tag to each location of the data logger. Provide a connection between logger data and location, so that the data logger can be traced all the way to the certificate. For the study shown in this work, 35 data loggers were used, setted according to the scheme shown in Figure 1.

6. **Setting up and installation of data loggers**. It is necessary to set up data loggers in the appropriate software (CFR 21-11). Set the same parameters for all data loggers, taking into account that the start time of the study, the duration of the study, and the recording interval are the same for all data loggers. There is no time limit for the duration of the study. It is typical for warehouses that the study does not last for less than 60 hours. Testing was performed, where in the first scenario data loggers were set to sample every 15 minutes, for one week, which provided 6 720 samples. The second scenario is that the data loggers were sampled every minute, for one week, which provided 100 800 samples. The first scenario provided the same general results as the second scenario, and much less time spent analyzing the registered data. The key is the time of response of the data logger. Most temperature data loggers need more than 20 seconds to react to temperature changes, and in rooms of more than 2000 m^2, most temperature changes will occur very slowly over several minutes, making frequent sampling scattered and unnecessary. Data loggers are set in a time interval of 5 minutes and the duration of the study is 72 hours.

7. **Set data loggers according to a pre-made scheme**, take care that theywill not be damaged or be moved by someone during the lasting of the study. Keep in mind the time required to stabilize the data logger. Enable the air conditioning system to work at least 24 hours before the start of the study.

   Be sure to set up one data logger in the outside environment. When installing the sensor for measuring external conditions, make sure that the sensor is located in a place that is not exposed to direct heat sources (sun, motors, heat exchangers, light sources, light reflecting effect), and other external factors (snow, rain, air conditioning system condensate). It is necessary to place the sensor at a height of 1.5 meters to 2 meters from the ground, and enable the air to streaming. Duration of testing, as well as the time interval between the samples, should coincide with the data loggers placed in the warehouse itself. Enable enough time for stabilization of the sensors.

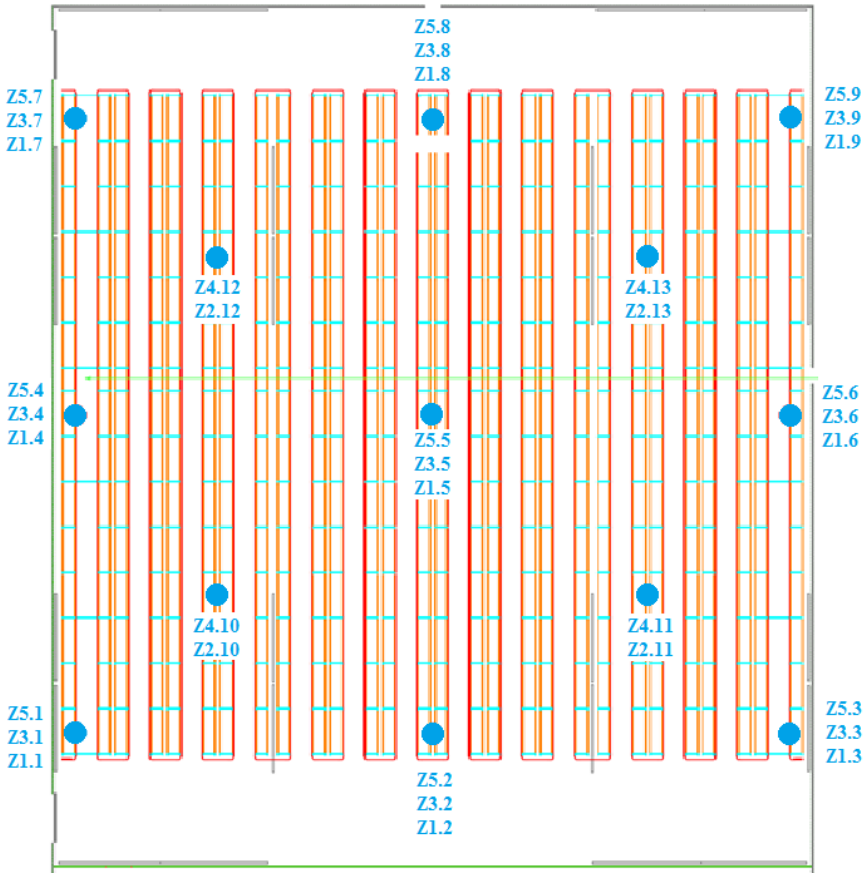

Figure 1: Data loggers positions

Note: *Data loggers are marked in the ZX.Y format where X is the height, and that 1 for data loggers which are set at a height of 1.2 meters from the floor, 2 for data loggerss which are set at a height of 3 meters from the floor, 3 for data loggers placed in the central part of the warehouses at a height of 5.5 meters from the floor, 4 for data loggers which are set at an altitude of 8 meters from the floor, and 5 for data loggers placed near the highest storage point, at an altitude of 11.5 meters from the floor. While Y represents the position of the data logger.*

8. **Download and read data loggers.** Download data loggers, read them, and save data for analysis.

9. **The report.** Data analysis procedures should be described and made to show the uniformity of the temperature at a given location over time (time uniformity) and at specific time in the area of interest (spatial uniformity). It is necessary to create a diagram which showing all locations where the temperature readings are taken , and where a link is made between the position and the data logger designation. Tabulate the minimum and maximums for each location, the mean value for each data logger, as well at the standard deviation. The time interval between readings, occupancy rate of warehouse and duration of the study is important to present in the report.
   After the data analysis has been done, it is necessary to give conclusions and recommendations on the further use of the warehouse. Depending on the economic aspect, after an initial qualification, a certain number of internal sensors must be placed in the warehouse, which will perform continuous monitoring.

The results of the initial mapping of temperature in the warehouse will be presented hereinafter, as well as what is needed to complete the complete testing successfully.

2.1. Initial Temperature Mapping

Initial temperature mapping is carried out after completion of the works, under representative conditions, the warehouse should be empty. External conditions need to be monitored, but not relevant at this time. Initial temperature mapping is used to determine the starting points for monitoring and is considered as part of the operational qualification.

In the study performed during the initial mapping, 35 data loggers were used, which are set according to the scheme given onFigure 1. Occupancy rate of warehouse was 0%. The setpoint of the HVAC temperature was 21 ° C. Mapping of temperature during initial mapping was carried out in the period from 12.06.2017. 15:00 to 15.06.2017. 15:00, ie. 72 hours. The distance between two consecutive measurements was set to 5 minutes. The statistical data for each data logger are shown in Table 1. Based on the analysis of the results, the examination of the critical "warm" and "cold" points, the mean values, the distribution of the temperature in the warehouse and other relevant parameters, the recommended locations for setting internal sensors are: Z1.1; Z1.3; Z1.9; Z2.11; Z2.13; Z3.7, Z3.9, Z4.11; Z4.13; Z5.2; Z5.3; Z5.4; Z5.5; iZ5.7. At these positions, it is necessary to set internal sensors, which will continuously monitor the temperature.

Since the warehouse is intended for storage from 15 ° C to 25 ° C, and the temperature during the study ranged within the allowed range, from 18.3 ° C to 21.3 ° C, and bearing in mind all the indicated results of temperature mapping, the conclusion is that all pallet positions in the warehouse can be used. Monitoring sensors should be placed at recommended locations so it can start with continuous monitoring. It is necessary to perform summer and winter mapping of the warehouse, when appropriate external conditions are created. The final recommendations of the locations for continuous monitoring will be given after the completion of summer and winter temperature mapping in the warehouse. The diagram shows the temperature changes during initial mapping, Figure2. Table 1 shows the measured minimum and maximum values, mean values, as well as the standard deviation of data loggers used during the temperature mapping study. The minimum values are indicated by the blue color, while the maximum values are indicated in red color.

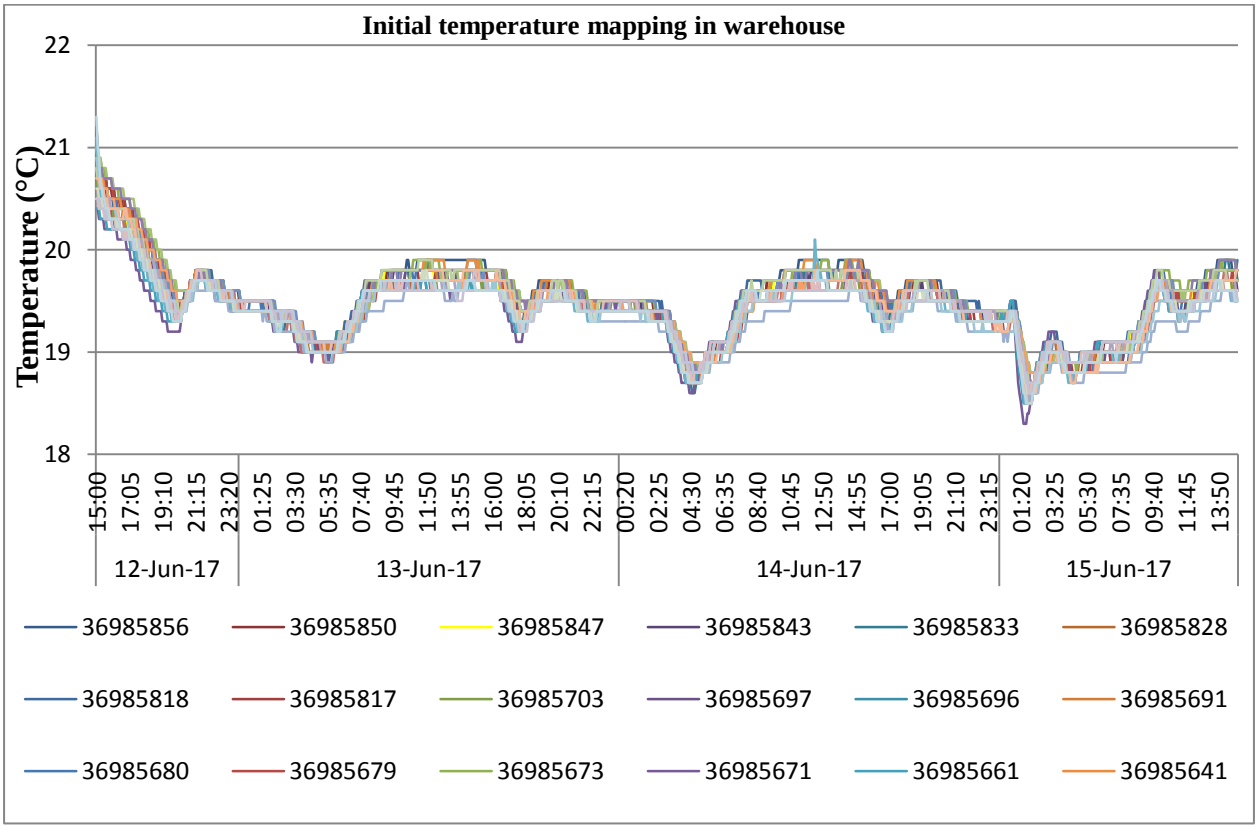

Figure2: Chart of the data from temperature data loggers

Table 1: Results of initial mapping in the warehouse

Results of initial mapping in the warehouse					
Position	**S / N**	**MIN**	**MAX**	**AVG**	**STDV**
Z1.1	36985459	18.7	20.5	19.434	0.279
Z1.2	36985445	18.6	20.5	19.445	0.291
Z1.3	36985594	18.5	20.5	19.325	0.324
Z1.4	36985696	18.7	20.5	19.453	0.277
Z1.5	36985828	18.6	20.5	19.408	0.306
Z1.6	36985691	18.6	20.6	19.478	0.328
Z1.7	36985427	18.6	20.5	19.427	0.279
Z1.8	36985847	18.7	20.6	19.491	0.309
Z1.9	36985843	18.6	20.6	19.466	0.336
Z2.10	36985578	18.6	20.5	19.412	0.295
Z2.11	36985485	18.6	20.9	19.390	0.338
Z2.12	36985817	18.7	20.9	19.478	0.356
Z2.13	36985608	18.5	21.1	19.392	0.326
Z3.1	36985604	18.8	20.8	19.475	0.326
Z3.2	36985661	18.5	20.4	19.420	0.290
Z3.3	36985624	18.5	20.6	19.403	0.342
Z3.4	36985494	18.7	20.7	19.467	0.316
Z3.5	36985818	18.7	20.8	19.550	0.326
Z3.6	36985460	18.5	20.7	19.436	0.359
Z3.7	36985638	18.7	20.8	19.521	0.325
Z3.8	36985440	18.6	20.6	19.420	0.321
Z3.9	36985641	18.6	20.9	19.514	0.379
Z4.10	36985616	18.7	20.9	19.534	0.362
Z4.11	36985697	18.6	21.2	19.463	0.358
Z4.12	36985703	18.7	20.7	19.465	0.299
Z4.13	36985411	18.5	21.3	19.412	0.334
Z5.1	36985622	18.8	21.0	19.516	0.368
Z5.2	36985671	18.3	20.4	19.416	0.301
Z5.3	36985833	18.5	20.7	19.448	0.356
Z5.4	36985679	18.7	20.9	19.451	0.357
Z5.5	36985850	18.7	20.8	19.543	0.339
Z5.6	36985680	18.6	20.9	19.484	0.377
Z5.7	36985673	18.8	21.0	19.553	0.368
Z5.8	36985563	18.7	20.8	19.526	0.334
Z5.9	36985856	18.6	20.9	19.530	0.394

The HVAC system is managed according to the mean value of all 14 internal sensors. Internal sensors take a temperature sample every 15 minutes and they are stored via the SCADA system. Prescribe the way in which the temperature is monitored in the warehouse if there is a power failure or a failure of some of the sensor.In case of short-term deviations from the defined limits occur while reading the results, it is necessary to calculate the Medium Kinetic Temperature (MKT) to prove that the deviations have no effect on the stability of the product or the material in the observed warehouse. MKT - a mathematically determined temperature value that simulates the temperature variation over a certain period of time - during storage and transport. MKT is not used as an alternative to adequate temperature control during storage and transport of the drug, and is not the arithmetic mean of all recorded temperature values. According to USP (UnitedStatesPharmacopeia) –Temperature deviations (bouncing) up to 40 ° C are permitted provided that the mean kinetic temperature does not exceed 25 ° C. If the calculated MKT for each location is within the defined limits, the alleged deviations do not have an impact on the product being stored.

3. CONCLUSION

After the successful completion of the initial temperature mapping in the warehouse, the operational qualification is completed. It is necessary to issue a complete report on the completion of qualification tests (when summer and winter mapping is done), and give recommendations for using the warehouse. After the summer and winter mapping is done, it is necessary to prescribe the frequency of re-mapping. It depends exclusively from the way of how critical parameters are monitored. Re-mapping of empty warehouse does not need to be done. Make an analysis of whether it is necessary to carried out mapping both in summer and in winter. If a temperature mapping is performed well (as done in this work) and probes for monitoring are set up on a sufficient number of locations (for a storage of this size, 14 data loggers are more than enough), re-mapping should be done only after bigger changes on the system. Table 2 shows a unique example of a

spreadsheet of all relevant information about temperature mapping in warehouses. It is recommended that each protocol / report has this type of table, due to easy and quick insight into the temperature mapping process.

Table 2: Temperature Mapping Table

	Temperature Mapping Table	**Results**
1	Type of mapping (initial, summer, winter, other)	Initial
2	Dimension (m) / capacity (number of pallet)	52.34 x 47.3 x 14 / 6782
3	Temperature range (°C)	15 - 25
4	Percentage of Warehouse load(%)	0
5	Number of internal sensors	14
6	Number of used data loggers	35
7	Starttime – End time	12.06.2017. 15:00 – 15.06.2017. 15:00
8	Sensor accuracy ±0.5°C?	YES
9	Sample rate (min)	5
10	Min- max / avg min -avg max	18.3 – 21.3 / 19.32 – 19.55
11	Outside data logger min - max / avg	12.3 – 32.3 / 23.41
12	Deviations?	NO
13	If there is deviation, calculated MKT	N / A (Not applicable)
14	Certificates attached?	YES
15	Raw data, Diagrams, statistic are attached?	YES
16	Recommended locations for monitoring	Z1.1; Z1.3; Z1.9; Z2.11; Z2.13; Z4.11; Z4.13; Z5.2; Z5.3; Z5.4; Z5.5; Z5.6; Z5.7; i Z5.9.
17	Next temperature mapping	Summer

For the competent authorities (inspections) it is important to have a summarized presentation of relevant data. By inspecting of this type of table, they will receive the necessary information, and if it necessary, they can also request attachments (diagrams, raw data, certificates, etc.). In this work only the initial temperature mapping is shown, due to the scope of the work itself. The summer and winter mapping of the warehouse impliesa series of procedures and rules which should be applied in the given conditions and require special research.

For the pharmaceutical industry, the satisfaction of the GMP and GDP requirements is unavoidable, since the legal obligation is the application of the principles and the requirements of good manufacturing practice within which the requirements of good distribution practice are mentioned, which is of great importance for increasing competitiveness. Adopting and practicing recommendations by large companies and world organizations can only contribute to improving quality and increasing competitiveness.

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VIRTUAL TEAMS: CONSTRAINS AND CHALLENGES

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Abstract: *This paper provides a theoretical perspective of teams' efficiency which work in virtual environments. Working in virtual teams has become every day appearance, because companies sometimes need certain skills, which are not available within them. By the usage of information technologies, boundaries such as distance and time are now easily bypassed. Although technology has made it easier to work on mutual tasks working in virtual environment can be very challenging for team members. Literature has addressed multiple issues related to phenomenon of increased number of globally dispersed teams, which differ in culture, language, habits and values. Therefore, building up a team which will be consistent of members, who will differ in so many areas, can be very challenging for project managers, since there are many various aspects which need to be thoroughly reconsidered before setting it up. The main objective of this paper is to provide insight into most common challenges for virtual teams and challenges they need to overcome in order to work effectively.*

Keywords*: virtual teams, project management, information technologies, communication, globalization*

1. INTRODUCTION

A wide range of disciplines and literatures have addressed the notion of virtual teams. Under the influence of rapid technological development, barriers such as space and time are easily crossed since it enables people to work on mutual goals and projects. With newly developed technological solutions, new formations of teams' organizations were created. Those are related to teams which work together on mutual task, but are dispersed worldwide.

On hand of technology, although being physically parted, team members can collaborate, communicate and interact with one another in virtual, Internet mediated environment in order to fulfill delegated duties in time. So far literature has addressed many different standpoints on virtual teams, and has shown both good and bad aspects of individuals being part of these teams. Project managers should carefully reconsider pros and cons of hiring external members as addition to their current team, who will not be present all the time during projects' realization. Therefore, managers have to thoroughly exam all the possible outcomes of this form of team building, especially if they lack international experience in doing business. Barriers such as, values, tradition, time management, perception of goals and trust are only some of possible constrains which can occur during projects' duration.

The first part of the paper will review authors' attitudes towards members' engagement in virtual teams and the most common ways of its description, while the third and fourth segment will deal with the issues faced by virtual teams and constrain they need to overcome in order to establish good communication. Numerous authors, who have dealt with these, have identified certain problems which are likely to occur within teams which operate in virtual environment. Although these formations provide multiple benefits and high flexibility, they also create numerous challenges, which will be addressed in the following sections of the paper.

2. DEFINING VIRTUAL TEAMS

Globally dispersed virtual teams were almost unheard of a decade ago, but today they present a critical element for integration of information, decision making process, and implementation of actions around the globe (Canney, Davison, & Ward 1999). In today's doing business, global virtual teams are increasingly making and implementing important decisions (Maznevski & Chudoba, 2000).According to Cascio (2000) virtual work place, where employees operate away from each other and from managers is a reality for many of them and is likely that this trend will keep growing in the future. On hand of technology they are now able to work on different issues and challenges that company is facing on international scales (Ives & Jarvenpaa, 1991). Powell et al. (2004) suggest that the usage of technology by virtual teams as a key medium represents a foundation of modern business. With electronic and communication technology developing quickly, distributed work had become more efficient, easier and faster (Hertel et al., 2005). These types of formations are an essential organizational mechanism because they allow organizations to stretch limited resources across geographic and other barriers (Munkvold and Zigurus, 2007).

Their reliance on integrated communication links, such as: wires, phones, computers, modems, networks, servers, and databases in order to support almost all interaction makes these teams distinctive (Suchan and Hayzack, 2001). There were many authors who gave their definitions on virtual teams. For instance, Lipnack and Stamps (1997) define them as "a group of people who interact through interdependent tasks guided by common purpose and work across space, time, and organizational boundaries with links strengthened by webs of communication technologies."

Cohen and Gibson (2003) stress three core criteria of virtual teams. Firstly, it is a team interdependent in task management, which equally participates in responsibilities for project results, and collectively managing relationships across organizational boundaries. Secondly, team members are globally dispersed, and thirdly, participants rely on technology supported communications rather than face-to-face interactions.

Balotsky and Christensen (2004) describe virtual teams as geographically dispersed participants who communicate with each other on hand of various technologies and information. Fisher and Fisher (1997) pointed out several advantages of virtual team members: specific technical knowledge, constant desire to improve personal skills, strong problem solving and decision making capabilities and good team working approach.

Although virtual teams are increasingly used, and in some cases stand for the only alternative, there are still authors who argue certain standpoints against usage of virtual formations. For example, study introduced by Lee – Kelly et al. (2004), included the total of eight globally distributed teams and concluded that virtual teams differ a lot from traditionally organized teams and that managers have to face multiple issues when guiding them, whilst the teams who operate regularly, do not have to face these issues and can overcome them easier.

3. KEY ISSUES CONCERNING WORK IN VIRTUAL TEAMS

There are many advantages from which organization can benefit by adoption of virtual teams, but there are also many challenges (Precup et al., 2005). Usage of virtual teams comes with significant challenges for companies wishing to introduce them. Although the majority of these challenges are present in traditionally organized teams, they may become even more dramatic in this set up (Solomon, 1995).

Communication amongst team members can traditionally be characterized as one of the possible issues amongst team members, which in case of virtual teams can be even bigger issue due to physical absence, cultural differences, language and accent difficulties. Some additional issues concerning working as a part of virtual team are related to mistrust between project participants, conflicts, communication break – downs and power struggles (Rosen et al, 2007). When building a virtual team, these problems must be identified in time in order for team to operate effectively (Hunsaker and Hunsaker, 2008). Diversity in culture and nationality are common in transnationally organized groups (Staples and Zhao, 2006). According to Mazevski et al. (1997), culture can be defined as a set of deeply rooted values, shared by the group of people within which certain individual lives. Through the prism of cultural values, certain individual interprets necessary information needed in order to make decisions (Hofstede, 1984). These differences in perspective of information comprehension can be seen as multicultural teams' strength, but due to hidden influences, these teams often meet issues connected to cooperative decision making process.

One of the most important issues related to working in virtual teams is the matter of trust which is considered to be the key for building strong bonds for successful interactions. In regular teams, which operate face-to-face, trust is developed on basis of social and emotional attachments (Furst et al., 2004) while on the other hand, virtually organized teams develop it in a different way. Jarvenpaa et al. (1998) concluded that the lack of social presence and face – to – face interactions can have detrimental consequences to trust building amongst team members. In addition to that, several other authors (Warketin, 1999; Heghtower and Sayeed, 1996) questioned effectiveness of artificial communication as a substitute for regular face – to – face meetings and its influence on team members' creativity and decision making process, which some studies proven to be correct, since face – to – face group performed better than groups who operated via technology (Smith and Vanecek, 1990). Within virtual teams, members communicate with one another in a way that sometimes it can be hard to explain an idea to some of the participants or to advocate the reason behind certain decision. According to Alavi and Tiwana (2002) failure to share and remember certain information in virtual team environments may lead to misunderstandings or misinterpretation of a distant team member's behavior. For instance, being late in responding to e-mail because of an equipment issues, trip, or a local holiday may be related to disinterest, laziness, or disagreement. Electronic communication has multiple pros and cons that are described as "process gains and losses" (Nunamaker et al., 1991). PMBOK (2004) emphasizes the importance of communication planning and it involves determining the communication and information needs as follows: (1) Who needs what information? (2) When will they need it? (3) How it will be

given to them and by whom? According to Bjørn and Ngwenyama (2009) the lack of regular meetings for social or work related activities inhibits the development of a shared meaning context and makes the risk of communication breakdowns bigger.

4. ADAPTIVE STRUCTURATION THEORY IN VIRTUAL TEAMS

DeSanctis et al. (2000) stated that more geographically dispersed administrative teams were more likely to use advanced communication technologies than more geographically closer teams. The more team members' view advanced technologies as capable of reducing coordination related issues and improving the teams work, they are more likely to adopt it.

Adaptive structuration theory (AST) describes a method which is related to the relationship between advanced information technologies usage, social structures, and human interaction. In the heart of this theory is the usage of technology and its application by the employees in sense of reaching maximum performance. It is grounded on structuration theory introduced by Giddens (1984), which takes into account the structure of relationships and their dynamics in order to depict a full understanding of social interactions required.

According to this theory, adaptation of advanced technology structures by organizational actors is a fundamental element in organizational change (DeSanctis & Poole, 1994). Adaptive structuration theory emphasizes that team member make their decisions about engagement in virtual formations on the grounds of an abundance of factors including groups' structure, duties, and the frequency of interaction (Kirkman & Mathieu, 2005). AST, in the context of a group support system, depicts a process within which a group decision support system (GDSS) offers a collection of features to a group, but essentially it is the process through which the team goes as it uses those them for its own purpose that matters (Han et al., 2011).Technological adaptation happens when people learn how to use the technology and the tools available in order to find ways of reaching their communication goals despite technological boundaries like restricted bandwidth and lack of turn yielding cues, while on the other hand work adaptation occurs when people adapt technology to their own way of usage (Qureshi and Vogel, 2001). A key problem in the domain of social adaptation is the form of communication and norms of behavior which evolve within the virtual social environment and which of these is most suitable to the creation of technology supported learning systems (Alavi et al., 1997).

This theory is focused on social structures, rules and resources given by technologies and institutions as the foundation for human activity. These structures serve as starting point for planning and finishing tasks. The way people use technology helps them shape their decision making process.

5. CONCLUSION

Managing globally dispersed team members can be very challenging for project managers, since there are many constrains, which can have a disrupting role in efficient task completion. Information – communication technologies facilitate communication and information flows among virtual team members. However, being able to effectively communicate and delegate tasks, while in the same time lacking face to face communication can be very hard, especially if managers lack in cultural knowledge on their team members. For that reasons, scientists have been developed theories and methodologies for adaptation of advanced technologies in order to ensure maximum performances and effective communication among business entities. One of these theories is described in the paper, it is about Adaptive structuration theory (AST), which is oriented towards technology and social adaptation with aim to facilitate process of communication among dispersed team members. Based on the literature review, authors found this theory as a suitable mechanism for effective communication and decision-making process in virtual environment.

Further research will be focused on the element of *agility* in virtual teams. *"For virtual teams, what does agility mean*?" is the question that the authors' future research will answer.

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AN APPROACH TO EVALUATING GOODNESS OF HEURISTIC SOLUTIONS IN MANUFACTURING CELL FORMATION

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Abstract: *Manufacturing cell formation is the initial and most important step in designing cellular manufacturing system. Through this step the similar parts are grouped into part families, the related machines are grouped into machine cells, and then the part families are assigned to the appropriate machine cells where they should be produced. The focus of this paper is on performance measures suitable for evaluation and comparison cell formation solutions. The particular group of these measures that can be used for evaluating the goodness of heuristic solutions in binary form is discussed. Further, within the case study, the measures are used to compare solutions obtained by GRASP, GAVNS and CFOPT methods. The results show that solution obtained by CFOPT method has the best performance according to grouping efficacy, grouping efficiency, weighted grouping efficacy, grouping index and weighted modified grouping efficacy. Additional valuable advantage of CFOPT is its velocity i.e. minimal CPU time for finding solution.*

Keywords*: cell formation problem, quantitative measures, measures of grouping efficiency, comparative analysis, methods.*

1. INTRODUCTION

Cellular manufacturing can be viewed as a promising operations management practice, a good lean manufacturing approach, an enabler of just-in-time (JIT) manufacturing, a prerequisite for computer integrated manufacturing (CIM) and a strategy for organizing work in order to shorten market response times and minimize inventories and costs (e.g. Hyer & Wemmerlov, 2001; Shah & Ward, 2003; Abdulmalek & Rajgopal, 2007; Ilić, 2014). Cellular manufacturing have been applied in many manufacturing firms within the mechanical, electronics, automotive and other discrete-part manufacturing sectors (e.g. Hyer & Wemmerlov, 2001; Diaz et al., 2012). The first foremost and complex issue in designing cellular manufacturing system is the problem of cell formation. The cell formation problem (CFP) considers grouping the part types into part families and the machines into machine cells, and further assigning the part families to the appropriate machine cells where they should be produced (Paydar et al., 2011; Ilić & Cvetić, 2014; Danilović & Ilić, 2016). The formation of machine cells will foster continual performance improvements by closely locating machines and assigned operators required for processing the part families (Hyer & Wemmerlov, 2001). The main objective is to achieve the minimum of inter-cell and intra-cell movements of parts during the manufacturing process.

Numerous approaches have been developed for solving CFP. These are various clustering methods, similarity coefficient based approaches, mathematical programming, graph theory based approaches and different meta-heuristics such as genetic algorithms, simulated annealing, TABU search and neural networks algorithms (e.g. Ilić & Jovanović, 2008; Paydar & Saidi-Mehrabad, 2013; Danilović & Ilić, 2016; Aalaei & Davoudpour, 2017; Bychkov et al., 2017). The cells have been formed on the basis of different established objectives and constraints (Imran et al., 2017). During the process of solving the same problem, especially one large-scale, by several methods, usually more solutions can be found. The tough issues of how to evaluate the goodness of final solutions and how to conclude which method gives better solutions were always important. To give answers on these questions the different performance measures have been developed and used. In this paper, the CFP is formulated as a block diagonalization problem. The focus will be on using performance measures suitable for comparison solutions obtained by three methods GRASP heuristic (Diaz et al., 2012), the hybrid genetic-variable neighborhood search algorithm GAVNS (Paydar & Saidi-Mehrabad, 2013) and the CFOPT method (Danilović, 2017).

The following definitions and notations will be used in the paper.

Definitions:
Binary machine-part matrix: A matrix that shows which machines are used to produce each part by an entry which can takes value of [0,1].

Block: A sub-matrix of the binary machine-part matrix formed by the intersection of rows representing a machine cell and columns representing a part family (Sarker, 2001).
Block-diagonal space (sparsity): The total number of elements (both 1s and 0s) inside the diagonal blocks of the final machine-part matrix.
Void: A zero (0s) element appearing inside the diagonal block.
Exception: An operation (1s) appearing outside the diagonal blocks.

Notations:
m - the number of machines;
n - the number of parts;
C - the number of cells;
o - the total number of operations (1s) in machine-part matrix;
v - the total number of zeros (0s) in machine-part matrix, $v = m \cdot n - o$;
e_1 - the total number of operations (1s) inside the diagonal blocks;
e_v - the total number of voids;
B - block diagonal space ($B = e_1 + e_v$);
e_e - the total number of exceptions.

The reminder of the paper is organized as follows. In the next section, the measures of grouping efficiency for evaluating the goodness of cell formation solution are presented. Through a comparative case study, these measures are used for comparison solutions obtained by three algorithms GRASP, GAVNS and CFOPT in the third section. Further, discussion of study results and their limitations are presented. In the final section, conclusions and directions for future research are given.

2. MEASURES OF GROUPING EFFICIENCY

The different quantitative measures were developed and used for evaluating the results obtained from grouping the parts into part families and the machines into machine cells. Those related to grouping efficiency are often used for evaluating the goodness of the cell formation solution. These measures are suitable only for binary data arranged in form of machine-part matrix; i.e. the binary machine-part matrix that shows which machines are used to produce each part (Ilić and Cvetić, 2014). The mathematical properties of these measures are: non-negativity and range between [0,1]. Non-negativity means that all the elements of observed measure are positive. The other property is related to extremes: (1) the value of observed measure is 0 when all operations are outside the diagonal blocks; and (2) the value of measure is 1 in case of perfect block diagonal form i.e. all operations inside the diagonal blocks and all voids outside the diagonal blocks. Additionally, the measure should give the appropriate importance to the voids inside the diagonal blocks and exceptions.

Here, several well-known grouping efficiency measures are presented and further used to evaluate solutions obtained by three methods. These are:

- the grouping efficiency;
- the grouping efficacy;
- the weighted grouping efficacy;
- the grouping index; and
- the weighted modified grouping efficacy.

The grouping efficiency (E) is the first proposed quantitative measure for evaluating the goodness of the cell formation solution. The merit for development of this measure belongs to Chandrasekharan and Rajagopalan (1986). The grouping efficiency takes into account the voids inside the diagonal blocks and exceptional elements outside the diagonal blocks. It is defined as:

$$E = q \cdot \eta_1 + (1 - q) \cdot \eta_2, \tag{1}$$

$$\eta_1 = \frac{e_1}{e_1 + e_v},$$

$$\eta_2 = \frac{v - e_v}{(v - e_v) + (o - e_1)},$$

where,
η_1 - is the ratio of the number of operations inside the diagonal blocks to the total number of elements in the diagonal blocks;
η_2 - is the ratio of the number of voids outside the diagonal blocks to the total number of elements outside the diagonal blocks; and
q - is a weighting factor ($0 \le q \le 1$), which can give the same importance to the both functions (in that case $q = 0.5$).

Comments on *E*: The *E* measure is still used very often, although it has a low discriminating power (e.g. Yin and Yasuda, 2005; Keeling et al., 2007). Usually, the value of *E* is high, and even for solution with a large number of exceptional elements *E* can go from about 0.75 to 1. Further, the selection of right value for a weighting factor is difficult. For high-dimensional problems, the lower value of weighting factor has been recommended in order to give greater importance to the second ratio (Sarker, 2001).

The grouping efficacy (Γ) is another measure proposed by Kumar and Chandrasekharan in 1990. The Γ considers the voids inside the diagonal blocks and exceptional elements as equally important. This measure is defined as:

$$\Gamma = \frac{1-\psi}{1+\varphi}, \tag{2}$$

$$\psi = \frac{e_e}{o},$$

$$\varphi = \frac{e_v}{o},$$

where,
ψ - is the ratio of the number of exceptional elements outside the diagonal blocks to the total number of operations in the final machine-part matrix;
φ - is the ratio of the number of voids inside the diagonal blocks to the total number of operations in the final machine-part matrix.

Therefore, the Γ can be expressed as

$$\Gamma = \frac{o - e_e}{o + e_v}.$$

Comments on Γ: The Γ measure is one of the most used measures (Keeling et al., 2007; Bychkov and Batsyn, 2018; Pinheiro et al., 2018), which has overcome the lower discriminating power of *E*. The application of Γ is independent of the process of assigning weights to the voids and the exceptional elements. This measure is more sensitive to changes in the number of voids inside the diagonal blocks, than to changes in the number of exceptional elements (Nair and Narendran, 1996; Sarker, 2001).

The weighted grouping efficacy (*W*) is proposed by Ng in 1993. This measure uses a weighting factor (q, where $0 < q \le 1$) in order to associate weight q with each element inside the diagonal blocks and a weight $(1-q)$ with each exceptional element outside the diagonal blocks. The derived formula for *W* is:

$$W = \frac{q \cdot (o - e_e)}{q \cdot (o + e_v - e_e) + (1-q) \cdot e_e}. \tag{3}$$

Comments on *W*: The *W* measure is tested on ten large-scale problems (dimension mxn, 100x200) (Ng, 1993). This measure implies choosing the suitable value for weight.

The grouping index (*I*) is a measure introduced by Nair and Narendran (1996). The *I* considers the block-diagonal space (*B*) in order to ensure equal weights to the voids and exceptional elements and to provide good discriminating power for problems of all sizes. This measure incorporates a correction factor (*A*) along with the block-diagonal space and the weighting factor. It is defined as:

$$I = \frac{B - q \cdot e_v + (1-q) \cdot (e_e - A)}{B + q \cdot e_v + (1-q) \cdot (e_e - A)}, \tag{4}$$

where A is a correction factor with values $A = 0$ for $e_e \leq B$, and $A = e_e - B$ for $e_e > B$.

Comments on I: The I tends to overcome some of the limitations of the E and Γ measures. This measure gives importance to the block-diagonal space which reasonably should reflect the goodness of the diagonal blocks. The user needs to determine the value of weighting factor by taking into account the size of the matrix.

The weighted modified grouping efficacy (M) is suggested by Al-Bashir et al. in 2018. This new efficiency measure can be expressed as:

$$M = \frac{1}{2}\left(\frac{e_1 + e_e - e_v}{e_1 + 2 \cdot e_e}\right) + \frac{1}{2}\left(\frac{e_1 - e_e + e_v}{e_1 + 2 \cdot e_e}\right), \text{ or simply } M = \frac{e_1}{e_1 + 2 \cdot e_e}. \tag{5}$$

Comments on M: The M measure is derived as a critique of the modified grouping efficacy measure proposed by Rajesh et al. in 2016. The authors of M claim that this measure can be used to evaluate all types of structure data and to logically compare solutions that have the same sum of voids and exceptional elements (Al-Bashir et al., 2018).

It is obvious that all measures of grouping efficiency are based on some assumptions and concept, and that their different definitions lead to different conclusions (Sarker, 2001). The common assumption for these measures is the use of binary machine-part matrix. In case that the other data are important, such as parts production volume, processing times of operations, setup times, or similar, these measures cannot be used. Several authors tried to compare the grouping efficiency measures and concluded that, in general, each measure is unique and have different perspective (Sarker, 2001). Additionally, the process of comparing these measures is difficult for implementation.

3. COMPARATIVE CASE STUDY AND RESULTS

The case study is focused on the cell formation problem of 37 machines and 53 parts introduced by McCormick, Schweitzer and White, in 1972. This problem can be viewed as a large-scale problem. The solutions of the problem are firstly found by applying three recently developed methods, and then the measures of grouping efficiency are determined. The aim is to make contributions in answering question of how to evaluate the goodness of the cell formation solution and how to compare different solutions.

Therefore, the solutions of the problem are found by applying the following three methods: GRASP heuristic (Diaz et al., 2012), the hybrid genetic-variable neighborhood search algorithm GAVNS (Paydar and Saidi-Mehrabad, 2013) and the algorithm CFOPT (Danilović, 2017). The new algorithm CFOPT was coded in C# and implemented on a laptop computer with Intel Core 2 Duo CPU T6600, 2.2 GHz, and 6 GB of installed memory, running Microsoft Windows 7. The GRASP, GAVNS and CFOPT methods are suitable for comparison because all the three have the same objective function i.e. they strive to maximize the grouping efficacy Γ (Kumar and Chandrasekharan, 1990). The relevant computational results obtained by these methods are presented in table 1. The data related to the Γ measure and the CPU time shows that the CFOPT algorithm gives better CFP solution of instance by McCormick, Schweitzer and White (1972), than algorithms GRASP and GAVNS. Of course, the best results regarding CPU time obtained by GRASP and GAVNS are taken for requirements of this comparison.

The derived conclusion about algorithm which gives the better CFP solution is further considered (table 2). The solution found by CFOPT has the minimal number of voids inside the diagonal blocks (e_v) and the minimal number of exceptions outside the diagonal blocks (e_e). The GAVNS also scored the minimal number of exceptional elements. The other measures of grouping efficiency, besides Γ, are calculated and presented in table 2. These are: E, W, I and M. According to all these measures the solution obtained by CFOPT is better than solutions found by GRASP and GAVNS. That was expected results in accordance with determined values of voids and exceptions for this case. The calculation of E, W and I was done for different values of the weighting factor q, because of some earlier discussion related to the selection of right value for q. On the other side, the measure M is insensitive to the weighting factor since it is not weighted measure.

Table 1: Computational results obtained by GRASP, GAVNS and CFOPT

GRASP	
C	2
Γ	0.59854
CPU time	00:03:45.23
Machines	12111212112122212222212112112121222211
Parts	22222222222222222222222211111111111111112222212211222
GAVNS	
C	3
Γ	0.60573
CPU time	00:04:05.68
Machines	13113212112322212222212112113121232333
Parts	22222222222222222222222211111111111111112222212211222
CFOPT	
C	3
Γ	0.61315
CPU time	00:00:00.22
Machines	23223321221311131111121231223212133133
Parts	11111111111111111111111112222222222222221111121122111

Table 2: Performance measures of CFP solutions

Measures		**GRASP**	**GAVNS**	**CFOPT**
o		977	977	977
v		984	984	984
e_1		647	653	653
e_v		104	101	88
e_e		330	324	324
B		751	754	741
E	$q = 0.3$	0.76755	0.77191	0.77847
	$q = 0.5$	0.79440	0.79881	0.80783
	$q = 0.8$	0.83467	0.83915	0.85188
W	$q = 0.3$	0.42538	0.43245	0.43621
	$q = 0.5$	0.59852	0.60575	0.61315
	$q = 0.8$	0.77624	0.78204	0.79440
I	$q = 0.3$	0.93841	0.94007	0.94689
	$q = 0.5$	0.89256	0.89550	0.90707
	$q = 0.8$	0.81515	0.82036	0.83931
M		0.49503	0.50192	0.50192

This case study is limited to only one instance. It was shown how several measures of grouping efficiency can be used for comparative analysis of solutions obtained by three different methods.

4. DISCUSSION

Many different methods are available for solving the cell formation problems that are NP-hard by nature. The efficient implementation of these methods reasonably requires their coding in some programming language. When the complex cell formation problem is solved by different methods more solutions can be found. The next issue becomes how to appropriate assess and quantify the goodness of obtained solutions. Therefore, some researchers ventured into the challenge of defining, testing and using performance measures to evaluate the CFP solutions. The particular case, otherwise very common in research practice, is using input binary data in the form of machine-part matrix, and accordingly, the relevant measures of grouping efficiency.

These measures try to find the right balance between the importance of voids in the diagonal blocks and exceptional elements outside these blocks.

In this paper, several well-known measures of grouping efficiency are presented and further used to compare solutions found by three recently developed methods GRASP, GAVNS and CFOPT. These measures are: the grouping efficiency, the grouping efficacy, the weighted grouping efficacy, the grouping index and the weighted modified grouping efficacy. The definitions of these measures are accompanied with useful comments. The case study is carried out to examine the solutions obtained by GRASP, GAVNS and CFOPT with the help of grouping efficiency measures. The comparative advantage of CFOPT is confirmed by all these measures in this case. Moreover, regarding the required CPU time for reaching the solution, the algorithm CFOPT, which was coded in C#, was faster than GRASP and GAVNS. The results of the presented case study are interesting, although only one large-scale instance was considered. In future work, it will be valuable to repeat the same comparative procedures on a set of referent instances from literature in order to generalize the conclusions obtained through this case study. The conclusions can also be expanded for more relevant measures.

5. CONCLUSION

This paper presents the measures of grouping efficiency that can be used to evaluate the quality of cell formation solutions. These measures are based on some assumptions and mostly have different perspective. Therefore, the conclusions about the quality of CFP solutions should be based on using several measures, although the goodness of some solution can be anticipated through the number of voids and exceptional elements. The presented comparative case study was focused on one large-size cell formation problem. This study showed the advantages of using the CFOPT method for solving the cell formation problems over other two methods GRASP and GAVNS. The solution obtained by CFOPT method has the best performance according to grouping efficacy, grouping efficiency, weighted grouping efficacy, grouping index and weighted modified grouping efficacy. Also, the process of finding solution by CFOPT required a minimal CPU time. In future, the following directions can be interesting: (1) A comparative analysis between methods for solving the cell formation problems can be expanded by more performance measures; (2) The comparative analysis between methods GRASP, GAVNS and CFOPT can be conducted on a wider set of referent instances; (3) The CFOPT algorithm can be modified in direction to include various performance measures; and (4) The experimental analysis regarding the measures of grouping efficiency can be performed.

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APPLICATION OF TYPIZATION AND STANDARDIZATION IN ACOMPANY FOR THE PRODUCTION OF PANEL FURNITURE

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Abstract: *Modern business conditions impose conflicting goals to production companies, as well as companies which do production of corpus furniture made of wood-based panels. On the one hand, customers and the market require the production of products by order and quick delivery, and on the other hand, the companies strive to lower the production price of the products. In order to adequately respond to these requirements, production companies choose to apply the typization of the products as well as the standardization of the components of the products. Their application aims to provide a simple, highly productive and economical production of a wide range of products. In this paper, a model of typization and standardization of a production assortment was presented, using the example of a company for production of corpus furniture made of wood-based panels. In addition, the way of designing new products using standardized elements and organizational measures necessary for the process of typization and standardization are presented in this paper.*

Keywords*: furniture production, typization of product assortment, standardization of product's component elements, organizational measures, bar code.*

1. INTRODUCTION

A wide range of products and frequent changes in the assortment are requirements that are imposed on every company for furniture production. A saturated market and a large number of companies that have similar products are the main reasons behind the frequent changes in the assortment. According to the changing trends and demands of the market, companies are changing the design of their products to attract customers. Contrary to the requirements of the market, companies need to reduce production costs and simplify manufacturing process to produce a small number of different products which include a large number of common constituent elements. The answer to these opposing requirements, besides the use of automated machines that have a high degree of flexibility and high capacity, is also thetypization and standardization of the production assortment.

The aim of typization and standardization of structural elements of a product is to reduce the number of different products of the same type that have approximately same measures and then reduce the component elements from the same group to the same dimensions. This enables the reduction of the number of different structural elements. This enables significant salvage in production time, increase of productivity, increase of the percentage of material exploitation and standardization of tools. This provides better business results.

The process of designing new products is one of the key processes in every company. Only a products that satisfies the demand of the customers and at the same time is different from other products, will be accepted by them. The design of new products, which satisfy the requirements of the customers and the production process, is significantly easier if company has defined product assortment, implemented typization of products and applied standardization of the structural elements. In this case, designers have defined structural elements of the product, which facilitate the process of designing the new product.

The assignment of the designers is to design products which hare consisted of a large number of elements that are standardized components in other products from their production assortment. The new product should be designed with a different stacking of these standardized elements. Frequent changes in the decor of the component elements, different way of stacking component elements in a product and using different types of hardware, the company provides wide range of product assortment.

In this paper, the model of typization and standardization of the production assortment in the chosen company is shown, the model for creating new products that are standardized, and the influence of the typization and standardization of the product assortment.

The study presented in this paper was done by the method of field research in the selected company which is currently one of the largest companies for production of wood-based panel furniture in Serbia. This company which applies typization and standardization in their production become one of the leaders in this field in Serbia.

The paper consists of three chapters. After the introduction, the second chapter presents the significance of stylization and standardization of structural components in this production company. The third chapter of this paper explains the results of the research and the model for typization of products and standardization of component elements. The last chapter consists of the conclusions of the study.

2. TYPIZATION AND STANDARDIZATION

The production is a process of transforming sets of input elements into the set of output elements (products) through the production process, with the aim of creating useful values (Lečić-Cvetković, 2015).

Today, many countries have recognized design as a priority direction for the development of education and economy, seeing in it the quintessence of innovation and an opportunity to modernize European economy. However, it should be noted that modern furniture is not only fruit of the work of individual architects and artists. Creating an attractive, functional, ergonomic and safe piece of furniture requires an effort of many people working in interdisciplinary teams (Smardzewski, 2015).

The main goal and motive for introducing flexible production in the furniture industry is to organize the production process with smaller number of different components and to offer an unlimited number of products to the market, according to its requirements, using various combinations of a limited number of components elements (Šuletić, 2012).

The purpose of creating groups of details lies in the fact that through the mass production, reduce of preparatory and finishing time for piece, that increasing the flexibility of the production system (Vukićević, 2011).

The fast change in assortment in individual and serial production influenced the introduction of flexible automation. Flexible technology systems enable the processing of different types of products that belonging same family of products (Figurić, 1989).

Today, a wide and variable production program imposed by the customer and the market and achieve a flexible production. Flexible technological systems have a major role in the realization of such a concept. In these systems, inventories of materials and incomplete production are less (Grladinović, 1999).

Modular design enables simultaneous achievement of a great variety of products and a small variety of components. The basic idea is to develop basic components of products that can be assembled into a large number of different products. Customers can then seems that there are a number of different products, and the production has a limited number of components (Schroder, 1993).

From the aspect of the manufacturer is important that the desired design, composition and properties of the products can be realized in production, and that such production has an economic adequacy, allowing sufficient productivity and economy (Omerbegović-Bijelović, 2006). Every increase of the capacity of existing technical instrumentality leads to an increase in production volume, respectively to the increase of productivity (Glavonjić, 2010).

An important question for a large company with multiple product development projects is how standard or varied the sets of activities it uses to conceive, design, and commercialize products should be across the organization (Rupani, 2011).

Small differences between products from the same group, such as small differences in the dimensions of component elements of products, significantly slowdown the production process, reduce productivity, require larger storage space for basic materials and larger storage space for finished products. They require a large number of documents reduce production flexibility and range of product assortment.

These problems can be solved by reducing the number of different component elements from the same group of products to a smaller number of different component elements, which will be used in the product of the same type and other products can be the solution for this problem. Reduction of the number of different

component elements can be done by application of typization of products and standardization of component elements.

Product standardization is a process of setting generally uniform characteristics for a particular goods or service. Product standardization among the goods provided by different businesses operating in technology-based industries can be useful for consumers since it permits competition among the various suppliers (Product standardization, 2018).

Typization of products is a process of reducing the number of types of products in product assortment. The wide product assortment in furniture industry and a consequence of that imposes the need for reduction of the number of products to the most typical representatives. In addition, products with small differences must be omitted, and thus provide the opportunity for more rational production in larger quantities of the same types of products. The product typization entails the typization of technological procedures, production equipment, tools and devices, working documentation, etc. (Nešić, 1983).

The process of standardization has a similar purpose as the process of typization, i.e. to reduce assortment and increase the quantity of the same products. Unlike typization, which is mainly related to the whole product, standardization is related to the component elements of products, details, compositions and components (Nešić, 1983).

All products included in the product assortment belong to a particular group and type of product. Within one group, almost all products consist of the same common component elements. For example, wardrobes have elements: sides, floor, ceiling, backs, doors and shelves. Chairs are composed of: seats, legs and backrests. Between the elements of one type or group of products there are many small differences, which are primarily seen in the dimensions, which influence to the optimization of the production process.

Standardization aims to increase the number of identical parts of products that can be jointly and simultaneously produced, and later used at different times and in different products. In this way, a large number of different products can be produced from the same sets of component elements (Nešić, 1983).

As standards reduce the variety of practices, they harmonize operations, an effect which also contributes to cost reductions and greater economic efficiency (Clarke, 2005).

The creation of robust processes is a key driving force behind standardization, as it warrants quality consistency of products. Through standardization, production processes are stabilized and become more robust, thus ensuring constant output and constant quality (Clarke, 2005).

3. IMPLEMENTATION OFTYPIZATION AND STANDARDIZATION IN COMPANY FOR PRODUCTION OF PANEL FURNITURE

Company where the study was conduct has a wide range of product assortment. All products in this company are made of wood-based panels. Looking at the diversity of product assortment, it can be noticed that this company makes furniture for different usages. This company produces furniture for storage, including wardrobes, shelf and drawers. The company also produces kitchen furniture, and furniture for resting.

As for a variety of the offer of their product assortment, each of the mentioned types of furniture has a large number of collections that have some different characteristics. In order to recognize the significance of typization and standardization of component elements, for the purpose of this paper, furniture for storage and wardrobes were selected as representatives of this assortment. According to these products, the model of typization and standardization of products was shown as well as the effects of typization and standardization.

Figure 1 shows wardrobes from four collections that can be found in the offer of this company. Differences between these four wardrobes are in the external appearance, dimensions, constructive solutions and technological process, which is different for some segments.

a) b) c) d)

Figure 1: a) Colection1 b) Collection 2 c) Collection 3 d) Collection 4 (Company Data, 2018)

Wardrobes which were the examples of standardization of product assortment are shown in Figure 1. Wardrobes from other collections are different by the number of technological operations during their production, decors which were used and the way of combining the component elements.

Figure 2 shows the appearance of the wardrobe with dimensions of belonging to the first collection in Figure 1.

a) b) c) d)

Figure 2: a) Wardrobe *G1*44X189x56 b) Wardrobe *G2* 84X198X56 c) Wardrobe *G23* 84X198X56d) Wardrobe *G33* 126X198X56 (Company Data, 2018)

Figure 3 shows component elements that belonging of collection shown in Figure 2.From Figure 3, it can be seen that a total of sixteen different elements are included in these four wardrobes. The first group of elements make the sides, all wardrobe from this collection have the same side. The other group makes the elements of floor and ceiling. Three different elements belong to this group; their diversity is conditioned by the different width of the wardrobe. The third group consists of shelf elements. Different width of the wardrobes and different constructive role of the shelves condition four different elements in this group.

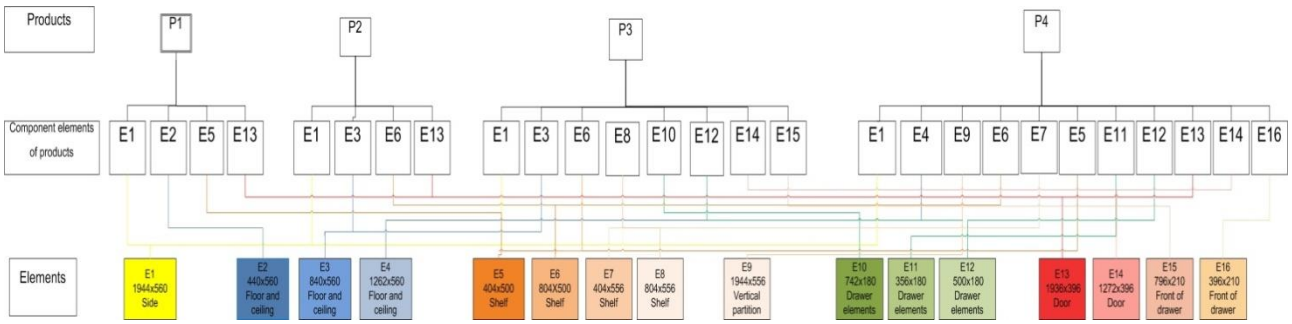

Figure 3: Component elements of wardrobes from Collection 1 (Kalem, 2018)

The fourth group of elements consists of vertical partition. Since only one wardrobe has a vertical partition, there is only one element in this group. The fifth group of elements consists of the drawer elements. As the depth and height of the drawers is the same for all wardrobes, but width is different, this group has three different elements. The sixth group of elements consists of elements of the fronts. This group contains two types of doors; the doors are different in height, while the width is the same. In addition, to two different door elements, this group also has two different elements for the drawer fronts. Due to the width difference, there is a need for different widths of the drawers, while the height for all the fronts of drawers is the same.

The model of typization and standardization of component elements in this company was a two-step process.

The first step was to determine the overall dimensions of a product from one collection. Based on the established dimensions a structural component of the product was created. After a structural component of the product was being made, the number of common components for the products was determined before the typization. After determining the number of common assembly elements, the product was typified.

Typization implies reducing the products to having approximate dimensions to one common dimension. When adopting new dimensions, attention was paid to the products that are in the same group to have dimensions which differ for no more than 10%. In the first step, a formula (1) was used for typization of products. After obtaining a new value, it is necessary to determine in what percentage the new dimension differs from other dimensions from that group. To check this, it is necessary to determine the mean deviation (2), and then the percentage difference in dimensions (3).

Example: Typization of products range

$$Xs=\frac{X1+X2+..+Xn}{n} \quad (1)$$

$$\Delta = \sqrt{\frac{(X1-Xs)^2+(X2-Xs)^2+..+(Xn-Xs)^2}{n}} \quad (2)$$

$$V1=\frac{\Delta}{Xs} * 100\ (\%) \quad (3)$$

After finishing the typization, oversized product dimensions are changed, which requires the adoption of new overall dimensions for all products that are included in the formula. As the change in the overall dimensions of the product causes a change in the dimensions of the component elements, it is also necessary to make a structural component of the elements after typization. After designing the structural component of the product after typization, the number of common components is determined. Adoption of these new dimensions of the products leads to an increase in the number of common component elements. The typization in this company made it possible for the overall dimensions of the products to be the same for all products.

After finishing the typization of products, which reduced products of various dimensions to the products of the same overall dimensions and increased the number of common component elements, it is necessary to do the standardization of component elements.

Different construction of the products and a different number of component elements that make up the product cause the typization of the products is not sufficient enough to increase the number of common component elements to a satisfactory percentage. For this reason, it is necessary to standardize the components of the product.

Based on these new dimensions, component elements are compared to the dimensions of component elements from the same group for several different products. The groups are formed according to the constructive role. With the wardrobes, which were the subject of the study, the first group is consisted of side elements; the second group of floor and ceiling elements, the third group of vertical partitions, a fourth group of drawer elements, the fifth group make up elements of the front and this group has two subgroups.

Based on the established differences in dimensions for the same constituent elements, the standardization of component elements is done.

On the example of the side dimensions of all wardrobes from one collection, a model of standardization will be presented.

Example: Standardization of products component elements

Step 1.

Sides of wardrobe have dimension:
Wardrobe 1: 189 x 54 cm;
Wardrobe 2: 195 x 57 cm;
Wardrobe 3: 194 x 56 cm;
Wardrobe 4: 198 x 55 cm.

Step 2.

The mean value for length and width of side panels is determined using formulae (4) and (5), respectively.

$$M_{len}=\frac{G1+G2+G3+G4}{4}=\frac{189+195+194\ 198}{4}=194{,}75\text{ cm}\approx 195\text{ cm} \quad (4)$$

$$M_{wid}=\frac{G1+G2+G3+G4}{4}=\frac{54+57+56+55}{4}=55{,}5\text{ cm}\approx 56\text{cm} \quad (5)$$

Since the plate elements are made of plates produced in standard dimensions and all elements always have the same thickness, standardization is not required for this measure.

After the elements are reduced to a common value, these elements are applied in the construction of products with the new adopted dimensions. When applying component elements with new values in the products, there is a change in the overall dimensions of the product.

From Figure 2 it can be seen that the dimensions of the wardrobes are standardized; all wardrobes have the same length and depth, while the width varies. In this collection, there are three different widths of wardrobe. The standardization of the component elements of a product from one collection made it possible that a small number of different components to be included in the composition of the products from this collection. For the products shown in Figure 2, the structural analysis of these products shows that the sixteen different elements shown in Figure 3 made up of four wardrobes from Figure 2.

Also, from Figure 2 it can be seen that the wardrobe has a significantly different appearance, which gives a wide range of products, and the production of component elements is simple, productive and economical. When the offer for a certain product, which is standardized, becomes enriched by a large number of decors of corpus and front elements, it provides the variety of product assortment and high flexibility.

When a new product is being designed belonging to the collection from Figure 2, the designer will use the component elements that are available for this collection, which are shown in Figure 3.

Since wood-based panel furniture belongs to the group of cheap furniture, companies want to be competitive with the prices of the product. They must ensure that the production is lean and productive utilization of a material in a high percentage, not less than 94%.With the fulfillment of these requirements, the costs of production become lower as well, allowing a lower selling price of the product. Standardization of component elements of a product has a great importance for shortening the time of production, increasing productivity, utilizing materials, and therefore the sales price of products.

Designers have a key role in product standardization in this company. When designing the products, they pay attention to the fact that the dimensions of the component elements are such that they correspond to the dimensions of the panels from which the component elements are cut. Increasing or reducing dimensions of the component elements, for only a few centimeters, can significantly contribute to increasing the utilization

of the panel from which the elements are cut. Since the difference of several centimeters in overall dimensions does not represent significant data to the customer, this measure significantly increases the utilization of materials.

Customers who want to buy furniture that fit their exact needs according to their dimensions do not buy furniture in companies engaged in serial production of furniture, but in companies for the project type of production. For this reason, product design is a key process for a wide range and optimal production process.

One of the important organizational measures taken by the company, which provides a wide range of product assortment and the flexibility of the assortment, is separate packaging of corpus elements from the front element. This measure ensures that the consumer can choose a certain decor of the corpus and certain decor of the front, and boxes with the ordered decors jointly arrive during delivery. The typization of product assortment and standardization of the component elements has enabled this way of packaging the products and their later delivery to the consumer.

When the component elements of a product are standardized, it is possible to replace an element without affecting other component elements or characteristics of the product. In this company, using standardization of component elements and subsequent separation of corpus elements from the front element, it is possible to always introduce new decors for corpus elements or front elements in the offer, which refreshes the products, the customer is introduced with the new product, and the production remains simple.

In case the elements of the corpus and the element of the front are packed in the same boxes to meet the requirements for the width of the assortment, it would be necessary to engage large funds. Packaging of corpus elements and front elements in the same box would require that each corpus décor in this collection (Oak, Nebraska, Dark Nebraska and White Décor) is packed with each of the front from this collection (White, Sand, Blue, Green and Pink). Combining all the corpus elements decors with front elements décor would require primarily large funds and then a large storage area where these products would be stored waiting for a demand for them.

A separate package of an element of the corpus from the front element requires significantly less money, because it is not necessary to create a large number of combinations of corpus and front decors, independently created and packed each decor in the planned amount for a certain period of time. This quantity is located in the product storage and no matter how the consumer will order a combination of front and corpus decor, these elements will be delivered, and on the other hand, the storage is much smaller and less money is spent.

Standardization of production assortment has enabled the production process to be productive and economical. Since edging and drilling of elements from a large board are basic operations, the standardization of the component elements saved and reduced preparatory time to a minimum using bar code technology. When the machine is set to process one element, regardless of which decor the element is made of, the machine does not need to be adjusted until the element is changed.

Typization of product assortments and standardization of components elements in this company, in addition to the mentioned possibilities, enabled simple production planning as well as quantity of products in the storage. Since the products of this company are standardized, whereby the corpus elements are packaged separately from the elements of the front part, production planning is based on the condition of one and other elements according to the decor for a particular product.

Based on the data about the condition of corpus elements and front elements of a certain decor of a particular product in the storage, and the data on the predicted demand for a particular decor in a certain period of time for a particular product, production planning is performed.

This way of planning based on data about the finished product in the storage, and information on the anticipated market demand for products enables numbers of benefits that are primarily related to financial assets of the company and prompt delivery of products to consumers. This makes it possible to have a sufficient amount of products in the storage of finished products at any moment and to deliver these products to the customer within three days, which is the shortest delivery time compared to competing companies.

4. CONCLUSION

The characteristics of the production of wood-based panel furniture, primarily the use of a smaller number of machines compared to furniture made of other materials, are relatively simple production process which usually consists of only three operations, cutting, edging and making connecting elements. The characteristics of the furniture itself and materials of which this furniture is produced indicate the fact that the production of this furniture is a suitable area for the application of the product typization and standardization of the component elements of the product.

Typization and standardization of product assortment is one of the key approaches in industrial production of corpus furniture made of wood-based panels. The benefits that typization of the product assortment and the standardization of the component elements of the product brought to the study of the company in which the research was carried out are numerous. Product typization and standardization of component elements has provided this company with a wide range of products and flexibility of assortments, which makes it easy to introduce new products into an assortment or to change the appearance of existing products.

Also, the production process has become highly productive and at the same time very flexible. The introduction of organizational measures, primarily a separate package of corpus elements from the element of the front, is another of the actions that brought a lot of advantages to this company with competing companies.

The subject of the future research it will be creation of the super bills of material (BOMs) for the production process from the study. Also, the results of this study will be compared with other similar studies.

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SAP APO APPLICATION IN THE PRODUCTION PROCESS FROM AUTOMOTIVE INDUSTRY

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***Abstract**: This paper presents the application of the SAP APO (Advanced Planner and Optimizer), as a part of the SAP ERP software, for management and planning of production processes in the automotive industry. SAP APO modules and application of PP/DS module, as a tool for production planning on strategic-tactical and operational levels, is presented. The aim of this paper is to present the practical application and support of SAP APO in production management and planning, tracking of customer orders and detailed scheduling on a real example of production process of wiper blades.*

***Keywords**: ERP, SAP APO, Production Process, Automotive Industry, Wiper Blade*

1. INTRODUCTION

ERP (Enterprise Resource Planning) is an integrated, consulate enterprise-wide information system that combines all necessary business functions like production planning, purchase, inventory control, sales, finance and human resource (Yazgan et al, 2009). According to these authors, the implementation of ERP software in a company is done for integration of customer orders, reduction of order preparation time and inventory level, standardization of production process and human resource information. This paper presents the application of the SAP APO as a part of the SAP ERP software, customized for the automotive industry. The main goal of using this software is to coordinate activities for planning and management of all processes within a supply chain with a constant focus on customer requirements.

Companies from the automotive industry have developed departments for the design, development, production, marketing, and sale of motor vehicles and their components. This industry presents one of the most important economic sectors of one country. All processes needed for the function of the company must be defined and planned in advance. Production management and production planning are some of these processes. Companies from the automotive industry use software solutions created according to their requirements, with an aim to provide a continuous production flow.

The paper is organized as follows. After the introduction, activities of the production process management and planning in the automotive industry are explained in the second chapter. In the third chapter are described SAP APO, its modules and the interoperability between ERP and APO systems. The practical application of SAP APO module PP/DS on example of production of wiper blades in the company from the automotive industry is presented in the fourth chapter. The fifth chapter presents the conclusion.

2. PRODUCTION PROCESS IN THE AUTOMOTIVE INDUSTRY

Production presents activities of transforming material elements and different types of energy into material products that satisfy social needs (Lečić-Cvetković & Atanasov, 2015). It considers transformation process of the inputs (materials, energy, and information) into outputs (products or services). In addition to its own size, the automotive industry generates more economic activity through various backward (to supplier industries) and forward linkages (to customers) (Heneric et al, 2005). Production in the automotive industry presents a complex process. There are many activities that precede the production process. This process depends on the customer orders and the ability of the supplier to deliver ordered quantity of raw materials.

The product observed in this paper is a wiper blade. In the windscreen wiper application, a wiper blade slides on a smooth glass surface in order to remove water and/or contaminations from the windshield (Bódai and Goda, 2014). According to these authors, wiper blades have an important role in traffic safety, because the too thick water film and the presence of contaminants hinder the view of a driver. In the company from the automotive industry analyzed in this paper, production planning, as a first phase of production management, is done according to the forecast of the customers. The goal of obtaining genuine forecasts of the industrial production index (*IPI*), makes it necessary to forecast the official quantities at least three months ahead

(Bruno & Lupi, 2004). Characterized as a push system, forecast-driven production is a highly efficient, but rigid system that utilizes historical data and projections to create a production plan and makes use of existing configurations to produce products for stock (Holweg and Pil, 2005). According to these authors, most companies from the automotive industry still rely on forecast-driven production and produce products to stock. The most important input for this kind of a system is the master production schedule created based on the forecast (Zhang & Chen, 2006).

According to the forecast, a department for production planning creates a production plan (what will be produced, when and in which quantity) and procurement plan (raw material and quantity that should be ordered). For every component used in a production, the company from the automotive industry has defined a supplier that produces and deliveries required components. The supplier has to satisfy the order of the company for defined components and to deliver exact quantity of the ordered material on a planned date. Successful company collaboration with customers and suppliers is necessary. SAP APO has the main role in coordinating information from the forecast to the production and suppliers, e.g. creation of the production plan and orders for defined materials to suppliers.

3. SOFTWARE FOR ADVANCED PLANNING AND OPTIMIZATION

There are various types of software for advanced planning and optimization. In this paper is presented the SAP APO (Advanced Planner and Optimizer) software. SAP APO presents one of the APS (Advanced Planning Systems) (Günther, 2005). This software presents a business IT-solution to supports the logistics planning along the global business network. It is an integrated computer system where the planning issues are organized into collaborative planning modules with given optimization models and solving algorithms. In the observed company the SAP APO is integrated with the SAP R/3 ERP system to form a business total solution. The integration is an exchange of data and an alignment of planning and execution processes (Dickersbach, 2005). Although new versions of SAP ERP software are available on the market, observed company still uses SAP R/3 solution because this version is completely customized according to company's business requirements. Additionally, investing in newer system versions is not economically acceptable for observed company. The performance of such a solution depends not only on the data processing efficiency, but also on the decision models (Leu & Huang, 2009). Since SAP ERP is the leading system and SAP APO is the planning system, "real" master data (from SAP ERP) can be used as master data and copied to other models/versions for simulations (such as SAP APO) (Stadtler et al, 2011). Because of this structure, SAP APO enables decision-making process.

The authors (Stadtler et al, 2011) define (from a technical perspective) SAP APO modules:
- Demand Planning (DP);
- Supply Network Planning (SNP);
- Production Planning/Detailed Scheduling (PP/DS);
- Transportation Planning/Vehicle Scheduling (TP/VS);
- Global Available-To-Promise (Global ATP).

In Table 1 are presented SAP APO modules and their basic functionalities.

Table 1: Modules of the SAP APO (adopted and modified from: Kallrath & Maindl, 2006; Stadtler et al, 2011)

Advanced planning and optimization			
Demand planning (DP)	Generates forecast planning figures that are fed into other planning modules.	Alert monitor	Warnings about an existing planning problem according to its configuration.
Supply network planning (SNP)	Coordinates strategic supply chain processes by creation of a suggestion for network design, cooperative supplier contracts, distribution structures, manufacturing programs, etc.		
Production planning and detailed scheduling (PP/DS)	Creates detailed, short-term production plans for individual production areas based on the results from master planning.		
Global available-to-promise (Global ATP)	Helps in order processing.		
Transportation planning and vehicle scheduling (TP/VS)	Determinates which quantities of items are transported via which routes in the supply chain at defined times.		

According to the (SAP Documentation, 2018), SAP APO provides a fully integrated range of functions for planning and executing processes. It supports the following:

- Intercompany interaction on a strategic, tactical, and operative planning level;
- Collaboration with logistic partners from order receipt through stock monitoring to product shipping;
- Maintenance of relationships with customers and business partners;
- Continuous optimization and measurement of the performance of the logistics network.

SAP APO is one of the leading systems that considers long-term (strategic), middle-term (tactical) and short-term (operational) planning. The planning tasks for procurement, production, distribution and sales can be solved under different planning scope and hierarchy. The different hierarchy levels are distinguished by their planning horizon and the typical level of planning details (Kallrath & Maindl, 2006). The architecture of the SAP APO is presented in Figure 1.

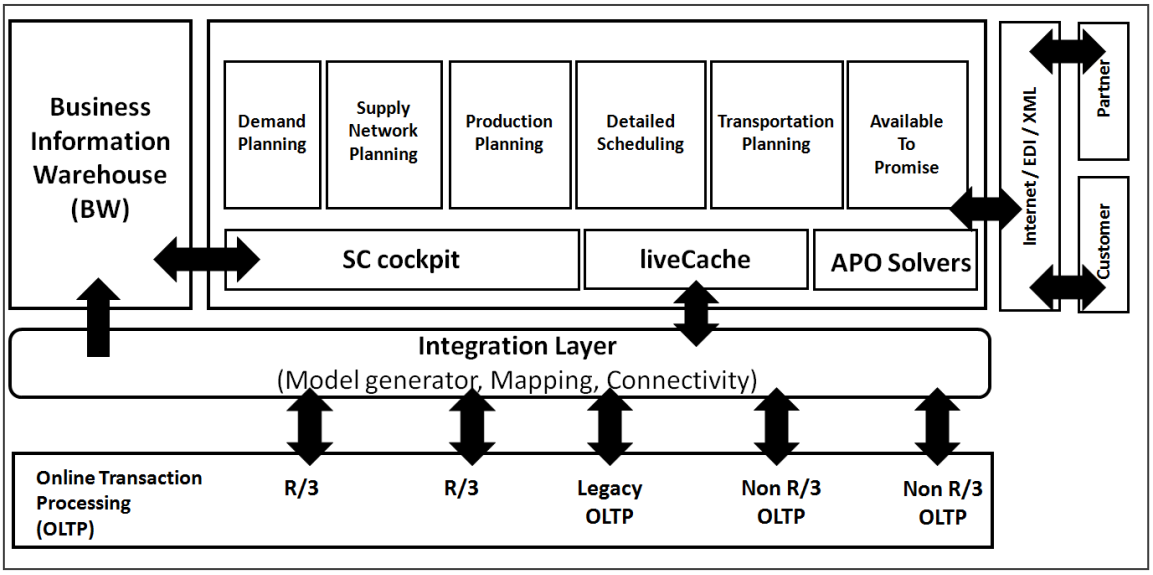

Figure 1: Architecture of the SAP APO (adopted and modified from Knolmayer et al., 2002)

4. APPLICATION OF SAP APO IN THE AUTOMOTIVE INDUSTRY

SAP APO in the automotive industry is created in order to fulfill specific requests of the company and its stakeholders. Since the automotive industry has high complexity in processes, implementation of the SAP APO in this industry can provide additional functionalities in order to fulfill specific requests.

In this paper is presented PP/DS module which can be used for following activities:

- Creation of production or procurement suggestion, in order to fulfill requests related to the final product;
- Optimization and planning of resources as well as detailed scheduling;
- Delivery planning;
- Forecasting of future demand.

Usage of SAP APO is enabled after the BOM (Bill of Materials) and material master views are created in SAP ERP. After settings in SAP ERP are available, products are visible in SAP APO. Purchasing documents are transmitted, but manipulation is done in SAP ERP. In SAP APO they are used as basic inputs.

In the observed company, strategic and tactical levels are considered as one planning horizon, since the forecasting period in PP/DS module is set to 21 months. According to that, the first area of PP/DS model application is strategic-tactical planning and the second is operational planning.

The product planning table for sales scheduling agreements (SDPT table), used for operational and strategic-tactical levels is shown in Figure 2. Sales scheduling agreement is purchasing document, made as long-term agreement between the customers and selling party (in observed company, production plant of wiper blades). SDPT table offers different views to facilitate the operative planning. With the selection of pre-defined views, a planer can choose input that will be presented in main view (customer orders, forecasted volumes or production orders). Also, time range (daily, weekly, monthly) can be defined. Interoperability between SAP APO and SAP ERP enables the usage of PP/DS module to access all information important for planning.

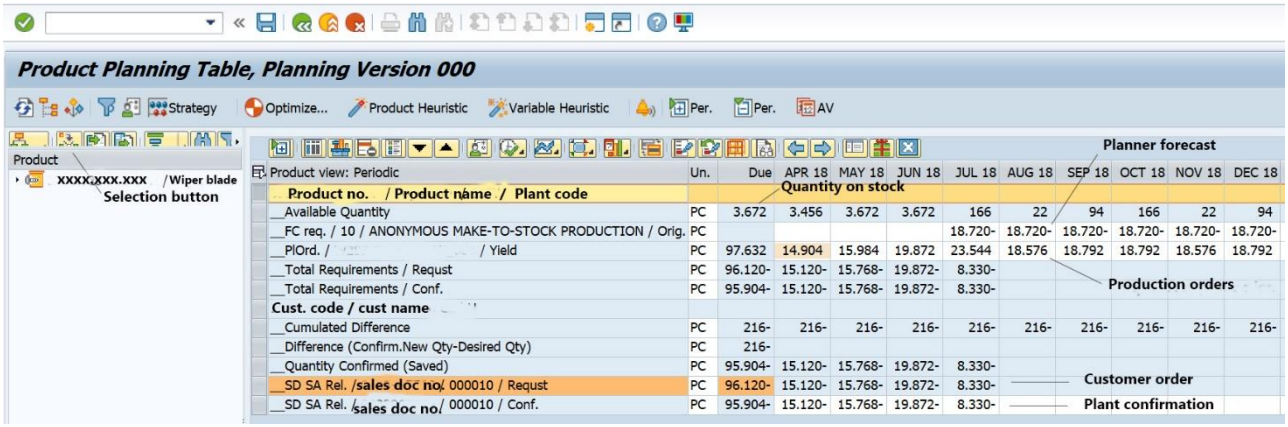

Figure 2: The product planning table for sales scheduling agreements (SDPT table) in SAP APO

4.1 Strategic-tactical planning in PP/DS module

In strategic-tactical planning, the PP/DS module is used to generate a long-term plan for the selected product group. As already mentioned, the time range in the observed company is 21 months on rolling horizon basis. The input data for the forecast are projected monthly sales quantities for various regions demand, provided by the marketing or sales department or based on actual customer orders. The output of forecasting process in PP/DS is production order. Depending on stock and production strategy, production orders can differ. Production strategy can be set as Make-to-Order (MTO) or Make-to-Stock (MTS).

The MTO strategy is used in production with a high variety of specific or expensive products. The main focus is on order and the performance measures. The most important performance measure is a delivery performance of demand fulfillment in terms of volume and date. The competitive priority is shorter delivery lead time. Main operational issues are capacity planning, order acceptance or rejection, and high due-date adherence (Soman et al, 2004). The MTS strategy is used in the production of a low variety of specific and less expensive products. The main focus is on anticipating the demand (forecast) and planning to meet the demand which has fill rate as a main priority. The main operational issues are inventory planning, lot size determination and demand forecasting (Soman et al, 2004). When production strategy is defined all necessary settings are done in SAP ERP and transmitted to SAP APO. In Table 2 is presented the comparison of a result of MTS and MTO strategy.

Table 2: MTO and MTS strategy comparison

		$Month_i$	$Month_{i+1}$	$Month_{i+2}$	$Month_{i+3}$	$Month_{i+4}$	$Month_{i+5}$	Total production order for observed period
MTO strategy	Forecast volume	100	100	100	100	0	100	
	Customer order	100	200	100	100	100	100	
	Production orders	100	200	100	100	100	100	**700**
MTS strategy	Forecast volume	100	100	100	100	0	100	
	Customer order	100	200	100	100	100	100	
	Production orders	200	300	200	200	100	200	**1200**

In Table 2 input data for strategy comparison is plant confirmation of customer order and forecast volume for the observed period of 6 months ($Month_i$ to $Month_{i+5}$). For both strategies are used following input data: the total sum of the customer orders is 700 units and forecasted volume is in total 500 units. According to the selected production strategy, production orders are defined. The basic logic used in MTO and MTS strategy in SAP APO is a comparison of customer orders and forecast volume within a time range defined in SAP ERP. In the case of MTS strategy, SAP APO sums customer orders and forecast volume. A time range for comparison is 0 days, because system transforms forecast and customer order into production orders, independently of each other. In the case of MTO strategy, SAP APO compares customer order and forecast volume within defined time range. In observed case, it is 15 days forward and 15 days backward from the day when forecast requirement is set. Due to simplification, all other time parameters are not activated. If customer order is higher than forecast volume, production order will be equal to customer order. If customer order is lower, production order will be equal to the forecast volume. MTO strategy results in production orders of 700 units while MTS strategy results with 1200 units.

In the observed automotive company, the forecast is done in SDPT table in PP/DS module. Planner adds forecasted figures in the system in specific part of SDPT table. MTS is used in cases when in production planning is included fulfillment of customer order and fulfillment of defined stock level. An example of MTS strategy is product for the secondary market of automotive components, known as automotive aftermarket. Under primary market is considered original equipment manufacturing (OEM). MTO is used when production and distribution are initiated by customer orders. Example of MTO strategy is products for the primary market of automotive components. Resulted production orders are used for identification and allocation of the capacity of machine and labor. The report in SAP APO shows future production quantities for mentioned 21 months and can be presented on a daily, weekly or monthly level. After observation and confirmation of capacities, these figures are decomposed within BOM level. Decomposition enables sending of forecasts for raw materials to the suppliers. According to transmitted data, suppliers can conduct capacity and feasibility analysis.

4.2 Operational planning in PP/DS module

The first part of operational planning refers to the usage of PP/DS for daily tracking of customer orders and dispatches. In SDPT table confirmation of customer order is done. After order confirmation (confirmed completely or partially, depending on production possibilities and raw material availability), information is transmitted to SAP ERP as input for the creation of the delivery documents. SAP APO offers easy detection of customer changes: with every new EDI (Electronic Data Interchange) from the customer, all changes in the order are marked with defined color, in order to easily track changes. Also, heuristics used in SAP APO ensure the fulfillment of the customer orders. According to customer order confirmation, production orders are created. One of the possibilities in SAP APO is automatic confirmation of customer orders which is enabled by choosing one of the pre-defined confirmation models. By choosing appropriate confirmation model, customer orders can be automatically confirmed only if their deviation is in a defined range. Also, orders can be divided according to existing production strategy (for example, if a customer sends monthly orders, but planning and orders towards suppliers are sent on a weekly level, they can be automatically divided). This reduces the manual effort needed for customer order processing in cases of a huge range of products.

The second part of operational planning refers to the usage of PP/DS for production planning and detailed scheduling. In the following six steps is described the general procedure leading from a model of the shop floor to a production schedule (Stadtler et al, 2015):

1. *Model building:* definition of shop floor model with described production processes and material flows;
2. *Extracting required data*: extractions of data from a subset of the data available in ERP system. Data regarding master and demand planning will be used in production planning and scheduling;
3. *Generating a set of assumptions (a scenario):* in addition to already existing data, production expert should integrate current and future situation and expectation in production scenario;
4. *Generating a production schedule:* production schedule will be automatically generated for a given scenario;
5. *Analysis of the production schedule and interactive modifications:* before making detail schedule, the proposed scenario should be evaluated and modified by production expert;
6. *Approval of a scenario:* once evaluated all available alternatives, the expert will choose the most promising production schedule relating to a scenario;
7. *Executing and updating the production schedule:* selected production schedule will be transferred to the MRP module - to explode the plan, to ERP system - to execute the plan and to transport planning module (if in use) - for transport organization.

Planning board for detailed scheduling, shown in Figure 3, presents the table for detailed scheduling as the main tool for production scheduling. In this table are displayed operations, orders and resources loads. Prerequisite for detail scheduling is setting of fixed horizon which will enable disturbance in scheduling and execution of the current plan. One of the PP/DS functionality allows access to one object by multiple users simultaneously. After saving, the latest saved production schedule becomes active (Dickersbach, 2005).

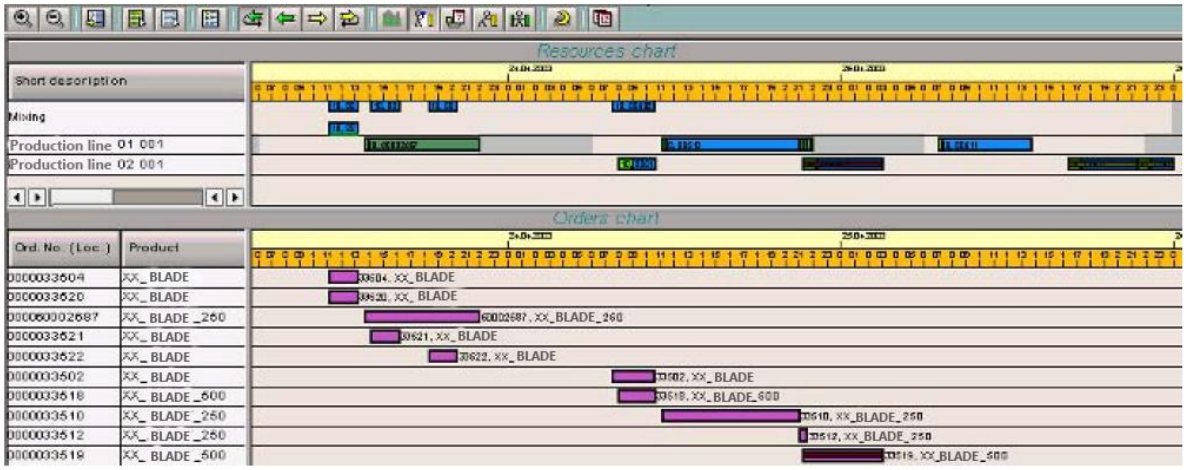

Figure 3: Planning board for detailed scheduling (adopted and modified from Dickersbach, 2005)

5. CONCLUSION

Implementation of the SAP APO is important for a company in order to provide planning and management of the entire production process. Interoperability with other modules within the SAP ERP allows tracking of all materials and problem detection at all levels in the process of adding value to the final product. SAP APO integrates with SAP ERP in a real time, thus all changes in one system are immediately transferred to another system (and reverse).

The SAP APO provides support in the planning department with the task to ensure the functioning of the company's processes. This module has various options for planning assistance (heuristics, macros, optimization models, etc.). The benefits of advanced planning and optimization software, such as APO, are reflected in the transparency of data important for decision support in production management and on the ability to apply complex planning and optimization technologies in order to create the better plan.

In this paper is presented the application of SAP APO for management and production planning process in a company from the automotive industry. PP/DS module is observed as a tool for production planning on strategic-tactical and operational levels. The aim was to present the application of SAP APO in production planning, tracking of customer orders and detailed scheduling on a real example of production process of wiper blades.

The application of SAP APO in the automotive industry has advantages and disadvantages. Some of the advantages of using this module are: easy tracking of deliveries per customer, simple detection of changes and the ability to respond on time. Significant is the ability to balance orders with automatic confirmation. This system gives planners ability to manage the production process. Disadvantages of planning with SAP APO are related to an inefficient overview of the order history. This overview requires manual operations and is only possible at the level of one product. The SAP APO also does not offer an acceptable solution for a more detailed study and analysis of customers and market behavior.

Beside wiper blades, observed company produces other components for the automotive industry. The first direction of further research of the authors of this paper would be implementation of the SAP APO in production planning process of the other components in observed company. The second direction of further research would be application of the SAP ERP in the activities of the operative production of wiper blades based on the production plans created in SAP APO.

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EXPLORING THE LIMITS OF LEAN IMPLEMENTATION IN ENGINEER-TO-ORDER ENVIRONMENT: CASE STUDY

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Abstract: *Lean has proved itself numerous times as a successful approach to productivity improvement. However, most of the evidence about success of lean comes from manufacturing environment close to the one lean originated in, i.e. stable and repetitive manufacturing. However, more empirical evidence is needed in order to analyze lean applicability in complex and dynamic environment, such as Engineer-To-Order (ETO) operations. This paper presents a case study of lean implementation in ETO company, and is aimed towards answering three questions: what lean in the context of ETO operations means, what are the limits of existing lean practices in ETO environment, and what are the challenges for lean implementation an such an environment.*

Keywords*: lean manufacturing, engineer-to-order, complexity and dynamism, case study*

1. INTRODUCTION

Since its inception, lean has become dominant manufacturing paradigm in the world, and is often considered as one of most important steps in the development of operations management (Thürer et al., 2017; Tomašević et al., 2016). Lean can be defined as a systematic effort aimed at reducing lead time by reducing non-value adding wastes (Ohno, 1988). Waste reduction is achieved through minimization of supplier, customer, and internal variability (Shah & Ward, 2007; Gong et al., 2009). Lean has helped many companies in the world to improve their efficiency. Although evidence of lean implementation success are abundant, most of them come from manufacturing environment similar to the one in which lean was originally developed in terms of product variety, volumes produced, and component assembly nature (i.e. stable and repeated manufacturing of limited array of similar products in relatively high volumes). Engineer-to-order (ETO) operations represent high-mix/low-volume environment that is highly uncertain (complex and dynamic), and is considered under-researched regarding lean implementation (Birkie et al., 2017; Hines et al., 2004). Lean might be interesting to ETO operations, having in mind that many ETO companies base their competitiveness on flexibility and short led times. Although lean strategies have been proposed in ETO sector, the extent to which lean practices are suitable for ETO operations has been questioned (Cooney, 2002). Many challenges stem from the fact that ETO environment differs significantly from the one typically found with low-mix/high-volume manufacturers. As a consequence, practitioners are often confused about what lean in the context of ETO operations means, as well as what are the limits and challenges in applying "traditional" lean concepts and practices. As a result, empirical evidence in support of or against lean implementation in ETO operations are fairly limited, and contemporary research suggests that more empirical evidence is needed in order to test the applicability of lean principles in ETO environment (Gosling & Naim, 2009; Naim & Gosling, 2011). In addition, it is recommended to move away from cookie-cutter based approach to lean implementation, and to take more contingency-based approach suitable for a specific manufacturing environment (Gosling & Naim, 2009; Naim & Gosling, 2011).

This paper analyzes lean implementation in a typical ETO company. The aim of this paper is twofold: to establish a model for lean implementation in dynamic and complex environment, and to analyze the case against this model in order to explore the limits of lean in ETO environment. The reminder of the paper is organized as follows: Section 2 presents literature review on lean in ETO environment; Section 3 presents research design; results and discussion are presented in Section 4; discussion and conclusion follow in Section 5.

2. LEAN IN ETO OPERATIONS

Lean was largely developed and applied under the leadership of Taiichi Ohno (1988). Waste reduction plays a central role in lean (Bhamu & Sangwan, 2014). Although waste is a common term in lean, it has often been taken for granted, and used in various ways. For the sake of this paper, waste is considered to be any system input (transformed resources, transforming resources) that is not transformed into a system output (fulfilled customer demand, this is neither unfulfilled nor exceeded) just-in-time (Thürer et al., 2017). Waste

can be divided in two types: type I – obvious or big waste, that can be reduced without creating another form of waste (see e.g. Liker & Meier, 2006); and type II – buffer waste, consequence of variability and uncertainty that has to be buffered in some way, that cannot be reduced without reducing its source, i.e. variability (see e.g. Hopp & Spearman, 2008). Since certain amount of variability is inherent to any system, some form of buffer has to exist (inventory, capacity, or time, see e.g. Hopp & Spearman, 2008), and it is up to management to determine which type of buffer is most efficient in a given situation. Having this in mind, lean implementation can be summarized as follows (Thürer et al., 2017): (i) eliminate obvious waste (i.e. everything that does not add value to the customer, and has no rational reason for existing); (ii) reduce both internal and external variability (i.e. decrease the requirements for buffers, thus transforming buffers to obvious waste); and (iii) right-size and balance remaining buffers in order to improve flow and reduce buffering costs (i.e. swap expensive buffer such as inventory for a less expensive one such as capacity). In addition, Jayaram et al. (2010) state that Toyota solves its problems through continuous cycle of variability elimination (acknowledging that variations exist, detecting variations, eliminating the source of variation) and standardization (standardizing the solution for eliminating the source of variation).

Although lean is considered to be universally applicable to wide array of business environments (Womack & Jones, 1996), there are authors who criticize it for its lack of applicability in operations that differ significantly from low-mix/high-volume environment that lean was developed in, stressing tool-based implementation and car-manufacturing focus as its main weaknesses (Cusumano, 1994; Hines et al., 2004). ETO is manufacturing strategy where design, engineering, and production start only after a customer order has been received, and is typically characterized by a high variety of customized products produced in low volumes, and long lead times due to the additional elements such as engineering and procurement lead time (Powel & van der Stoel, 2016). However, short lead time and high delivery reliability are deemed to be key priorities for ETO companies, rendering them order winning characteristics in addition to quality (Amaro et al., 1999; Portioli-Staudacher & Tantardini, 2012). This is why more and more ETO companies turn to lean as a way to increase their competitiveness. Still, evidence of using lean in ETO operations is scarce. Whyte & Prybutok (2001) claim that percent of non-repetitive systems with standard lean practices implemented (e.g. quality circles, TQM, Kanban, group technology, etc.) is relatively high. For example, around 60% of surveyed companies implemented Kanban, but what cannot be seen is how they implemented it, for what purpose, and what the outcomes of implementation were. Jina et al. (1997) state that cookie-cutter approach to lean implementation in ETO companies has to be avoided, and that lean implementation has to be tailored according to specificities of turbulent manufacturing systems. Some authors have taken contingency based approach by analyzing lean practices on a conceptual level, in order to determine the goal of a specific practice, and adapt the practice to specificities of non-repetitive manufacturing environment (see Djassemi, 2014; Horbal et al., 2008; Lander & Liker, 2007). Although improvements have been reported, they are piecemeal and not sufficient to generalize lean implementation in ETO environment, and the studies do not give answer to question what lean is in that specific environment.

Recognizing what lean is for ETO companies is crucial for the success of lean implementation. Inadequate understanding of lean principles, as well as lean tools and practices, resulted in misapplication, strengthening the argument that one-size-fits-all approach might not be suitable (Powell & Netland, 2016; Pavnaskar et al., 2003). Matt & Rauch (2014) suggest that, while basic lean tools such as 5S and continuous improvement might be completely applicable in ETO environment, some more advanced lean practices such as value stream mapping and Kanban have limited applicability. This is not a surprise, given the fact that context in which lean manufacturing has been developed – namely Toyota Production System – differs significantly from ETO environment, and that this fact requires lean to be re-examined, both as a philosophy and as a set of tools and practices (Powell & Netland, 2016).

3. RESEARCH DESIGN

This paper seeks to address three questions:

- What lean in ETO context means?
- What are the limits of existing lean practices in ETO environment?
- What are the challenges for lean implementation in such an environment?

This section presents the research design established in order to answer these question. Research design is presented in two subsections. First subsection gives a description of a case company, and discusses the rationale of using single case study approach. Second subsection discusses research approach and step taken in order to obtain the answer to posed questions.

3.1. Case company: rationale and description

The research focuses on a single company. Using single company can be appropriate if it provides an opportunity to observe and analyze a phenomenon previously inaccessible to scientific investigation (Yin, 2013).

Company OMEGA (real name is obscured) is selected as a typical ETO company. The company produces Point-Of-Sale (POS) and Point-Of-Purchase (POP) products such as shelves, displays, overhand dispensers, kiosk displays etc. Most products are produced on an ETO basis, where company performs all steps of product realization, from design and engineering, prototyping, to manufacturing and delivery. The company serves a turbulent marking, and has to deal with demand variability both in production volume and mix. Demand is irregular and unpredictable, while products are mostly one of a kind in regard to design and characteristics. The company is subject external influences, mostly from customers, who are trying to enforce their orders as the most important ones. Product routings vary in sequence and length, although the flow of material is considered to be directed. External influence coming from suppliers is present as well, mainly as a consequence of small order volumes, due to the fact that production volumes are relatively low as well.

The company has a long-standing experience with lean implementation, and has had some success (according to employees), mainly with shortening lead times. In order to analyze the experience the company had with lean implementation, and answer the questions that have been posed, a set of semi-structured interviews has been conducted. Process manager, production manager, sales representative, designer/engineer, and chief of digital printing took part in interview sessions. Interviews lasted roughly 45-60 minutes, were recorded and later transcribed. In addition to interviews, archival data analysis and direct observation have been used in order to ensure triangulation.

3.2. Lean implementation conceptual model

Having in mind the definition of waste and steps for lean implementation stated in section 2, conceptual model of lean manufacturing has been devised. Large amount of variability can be attributed to variability (Hopp & Spearman, 2008). However, one must be careful when eliminating variability in ETO environment, since some of the variability is inherent to ETO operations, and can present source of competitive advantage. Therefore, variability can be classified into three categories (Deuse et al., 2018):

- Variability which must be eliminated (non-value adding) – causing fluctuations and losses in productivity or product quality;
- Variability which cannot be eliminated immediately or entirely (non-value adding) – current work conditions dictate the existence of variability, or variability is due to common causes;
- Variability which must not be reduces, at least directly (value adding) – it represents customer benefits, and therefore should be buffered and managed (demand variability, process routing variability, work content variability, etc.).

The conceptual model for lean implementation is given in Figure 1, with the inclusion of variability classification scheme. This inclusion puts lean implementation in special context of ETO operations, and shows what lean operations are in a specific environment, and how they can be achieved.

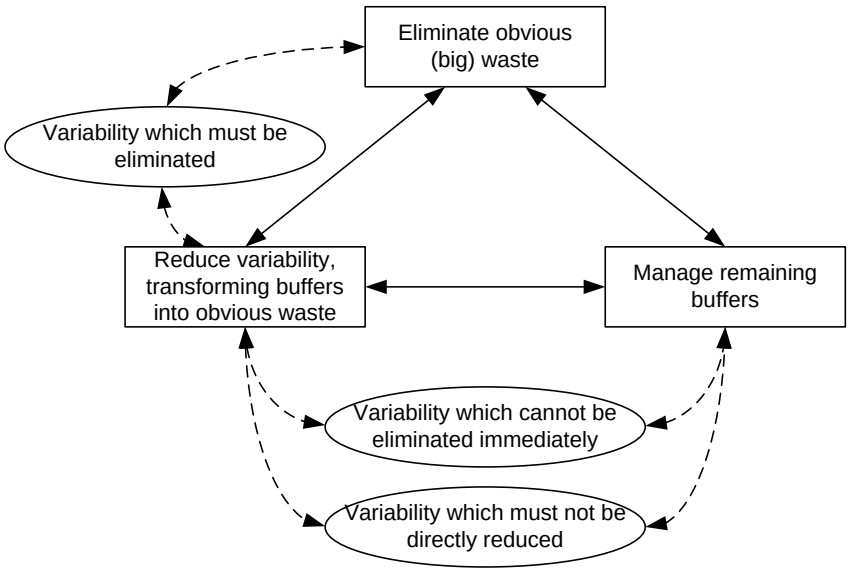

Figure 1: Lean implementation conceptual model

The model is tool-agnostic, and tries to encompass the substance of lean, without prescribing practices that should be used. As such, it is universally applicable, and it shows what the essence of lean is. It has special value for ETO operations, as it takes into account specificities of variability present in a specific environment. Lean implementation in company OMEGA will be analyzed against the proposed model.

4. CASE ANALYSIS AND RESULTS

All of the interviewees claimed that lean implementation can be deemed successful, at least to some extent. Archival data show that lead times have been shortened, and that lead time distribution became narrower with lean implementation, making lead times more predictable. Other operational performance measures were not collected systematically by the company, so only indirect connection between them and lean implementation could be established. Management was supportive, and thought that lean implementation might be beneficiary to the company. However, it was evident that management lacked deeper knowledge about lean, which oriented the company towards tool-based lean implementation. Employees were encouraged to actively participate in continuous improvement efforts,

The company has implemented standard lean tools, such as 5S, visual management, SMED and TPM. 5S implementation is regularly measured through audits, and the score is in constant growth. TPM has reduced machine downtime, increasing the availability of the equipment. Both 5S and TPM procedures are well maintained and available at all work places. 5S and TPM implementation reduced some variability in processing time, giving workers more time to perform value adding work. The company tried to standardize operating procedures (mainly through efforts to maintain Quality Management System), but they were not always followed. Working procedure disruptions were not seen as opportunities for improvement, but often led to abandoning the procedure. Special attention was given to setup reduction, where SMED (Single-digit Minute Exchange of Die) method was applied. Setup activities were analyzed and standardized, and new setup procedures were devised.

It is interesting to note that lean implementation started with Kanban. However, Kanban usage was strange to say the least. The company realized that Kanban cannot be implemented in the way it usually is in repetitive manufacturing environment. Still, they were persistent to lead Kanban implementation to some conclusion. The result was that none of the goals of Kanban implementation were fulfilled. Kanban did not limit the level of work-in-process (WIP), nor did it control the flow of material and information in any way. It ended up being some form of work list, communicating the worker what should be done on what work order..

Table 1 shows the analysis of lean implementation against conceptual model presented in Figure 1.

Table 1: The analysis of lean implementation in company OMEGA against the conceptual model

Implementation step	Type of variability	Type of problems	Actions taken	Buffer mgmt.
Eliminate obvious waste	Must be eliminated	Over-production; Waiting; Equipment availability; Over-processing;	Visual management; 5S; SMED; Continuous improvement; TPM;	No buffer management required
Reduce variability	Cannot be eliminated	Processing times; Common cause variability;	SOP; Worker flexibility; Worker training	Excess capacity
	Must not be eliminated	Demand variability; Work content variability;	No actions taken	Excess capacity; Excess level of WIP

Table 1 shows that most basic lean tools and practices (e.g. 5S, TPM, SMED, etc.) can be used in ETO environment just the same as in repetitive manufacturing environment. These tools are used to eliminate most recognizable types of waste (*muda*). What was not addressed well were overproduction (this will be discussed later in the text) and over-processing. Over-processing starts at engineering, where engineers thought that products that are more complicated then customer required had more value. In addition, engineers were pressured by short due dates, which prevented product refinement. This means that product manufacturability was rarely analyzed, which led to over-processing in manufacturing. However, problems can occur when *muda* is due to *mura*, and *mura* is not being recognized. This situation might require some type of buffering, before source of variability is eliminated.

Problems occur with reduction of variability that cannot be eliminated immediately or must not be eliminated. Some actions have been taken in order to address variability that cannot be eliminated immediately or entirely, such as worker flexibility and training, and standard operating procedures. However, order complexity and constant pressure caused often for standard procedures to be abandoned. This type of variability is usually buffered with capacity, which is common type of buffer in non-repetitive and job shop manufacturing (although it might be expensive). Still, company OMEGA did not use this type of buffer in a systematic manner. Capacity planning was at a low level, and production manager was mainly occupied with day-to-day activities. This is why short term capacity adjustment in the form of extra shifts was the action of choice. But capacity adjustments were erratic, often just one day in advance.

Most problems came with variability that must not be eliminated, but must be managed in some way. Demand variability can be high, but customer enquiry management was not considered as a possible solution. All orders were accepted, usually on customer terms, since a lost sale is considered to be a problem even if the company was aware that customer requirements regarding delivery date might not be met. Variable demand resulted in periods of starvation (when demand was low) and congestion (when demand was high). Kanban was used, but it did not deal with this type of problem, since management was not fully aware of Kanban goals and functionality. Kanban might have limited applicability in ETO environment, but this does not mean that principles of pull production are not applicable. The question is which the right way for them to be operationalized is. The result was high level of WIP, and often over-production (producing earlier that was needed). Rationale behind high levels of WIP was that some kind of work has to be done every day. This means that orders were released to shop floor immediately when the product design has been finished. This affected lead times, leading to lead time paradox, where earlier order release causes longer lead times.

It is obvious that company OMEGA missed many opportunities to lower variability, or to manage remaining variability and buffers. Table 2 summarizes some of those missed opportunities.

Table 2: Some of potential opportunities to address problems in company OMEGA

Potential opportunities	Problems that might be addressed
Customer enquiry management	Demand variability
Order splitting	Processing times variability; Work content variability;
Pull production (CONWIP, Workload control, etc.)	Over-production; Excess WIP; Shop-floor congestion; Work flow management; Starvation avoidance and congestion prevention; Lead time reduction and predictability; Waiting;
Design for manufacturability	Over-processing; Processing time variability;

The analysis shows that most potential opportunities lie in the field of pull production. There are many benefits that might stem from pull production, but ETO companies are often puzzled how pull production can be implemented, having in mind that replenishment system (e.g. Kanban) cannot operate in dynamic environment. However, main intention of pull system of limiting WIP (Ohno, 1988; Hopp & Spearman, 2004) could and must be put to use in ETO operations, since limiting WIP can have significant impact on lead time shortening (Little, 1961). Also, as this case confirms, ETO companies rarely explore the possibilities of customer enquiry management that might reduce at least some of demand variability.

What is also evident from the case is that the company was not aware of the length of the value chain, which starts with design every time the order is placed. What was also out of the sight that all steps in value chain are highly coupled. Focus of lean implementation was mainly on production, but what company failed to acknowledge was that large amount of variability in production is due to problems earlier in value chain, e.g. in design or procurement.

5. DISCUSSION AND CONCLUSION

Being lean for a ETO company means the acknowledgement of the notion that variability that causes waste and hinders the performance exists, but that some of this variability is needed due to characteristics of ETO operations, and that they have to be carefully managed. Some variability can be eliminated, and this is where traditional lean tools and practices come in handy. However, traditional lean implementation is limited to basic tools, and real challenge is to find a way to implement advanced principles that cannot be operationalized in the same way as in repetitive manufacturing. This requires deeper understanding of what lean is, and how leanness can be achieved. In addition, this means that cookie-cutter lean implementation needs to be avoided, since it can warp lean and turn it into its opposite. This means that lean implementation must be based on underlying principles, while it is up to company to find the best way to put those principles

to work in practice. It might require out-of-the box thinking, and finding solutions that might appear different to those recognizable as standard solutions.

Greatest challenges lie in obtaining unhampered flow of material, i.e. the field of pull production. Pull production represents one of the most recognizable features of lean production. However, most of the limits are due to the nature of the pull. While repetitive manufacturers use replenishment pull, ETO companies should use capacity pull, where signals for order release are not sent when certain quantity of goods have been consumed from supermarket, but rather when certain amount of capacity has been freed (i.e. when some work order has been finished). There are some possible solutions for pull implementation in ETO environment, such as CONWIP (Spearman et al., 1990) or COBACABANA (Land, 2009). Seeing that high level of WIP is a common thing in ETO operations, pull would be a good way to manage WIP buffer.

Some potential for variability reduction lies in customer enquiry phase, where special terms might be offered to customers for following a certain pattern when ordering (steady orders in regular time intervals, or standard quantities), instead exclusively for ordering large quantities. This would stabilize the inflow of the orders, which will in turn stabilize the shop floor. Customer enquiry management would require for some orders to be declined, which is an unlikely situation in ETO environment. On the other hand, managing lead time as a buffer might also serve as a form of customer enquiry management mechanism, where quoting long lead times might buffer some variability, but long lead times can also discourage some customers from ordering.

This paper sought to address the question of lean applicability in ETO environment. Lean can help ETO operations to improve competitiveness, since it is aimed at reducing lead times, which is one of order winning factors. However, lean implementation call for caution, since ETO environment is significantly different than the one lean originates from. In order to assess the limits of lean implementation in ETO environment, and to identify challenges of lean implementation, conceptual model of lean implementation has been devised. Typical ETO manufacturer was analyzed against devised model. As case study showed, implementation of standard lean toolset is constrained by characteristics of ETO operations, where practices are limited to basic tools (5S, TPM, continuous improvement, etc.), and that real challenge lies in obtaining unhampered flow, which is one of the basic principles of lean production, and requires implementation of more advanced practices, such as pull and heijunka. This calls for out-of-the-box thinking when devising tools that might be more appropriate for ETO environment, which in return requires deeper and tool-free understanding of what lean is, and what are its underlying mechanisms.

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WASTE ELIMINATION IN CONTEXT OF WORKPLACE CLOSURE AND STABILIZATION AND LEAN PRODUCTION

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Abstract: *In the last few decades, the need for business improvement is growing due to the turbulent environment. In order to remain competitive, companies are looking for ways to increase the main business performance - productivity. This paper shows how identification and subsequent elimination of wastes (Muda) can help in workplace closure and productivity gain. The key factors that impact on low productivity were analyzed, which is the first step for workplace closure and stabilization. The resault of the research represent how, by eliminating wastes, a company, through workplace closure and stabilization by means of waste elimination, can increase productivity.*

Keywords*: productivity, productivity improvement, waste, workplace closure, Muda.*

1. INTRODUCTION

Productivity is one of the key factors for measuring the performance of the manufacturing system (Rawat, Gupta & Juneja, 2016). Snyman and Smallwood (2017) say that the continual increase of productivity is the main factor to stay competitive.

Every company needs a manufacturing system which is capable of producing the high quality product with the minimum input (Rawat, Gupta & Juneja, 2016). This can be achieved by keeping the manufacturing system productivity high. Productivity measurement can show whether the level of productivity is satisfactory. Because of that, organisations are continuously reviewing their methods and skills in order to increase their value-added outputs with fewer resources (Snyman & Smallwood, 2017).

By improving productivity, an organisation can benefit from cost and quality advantages in comparison to its competitors (Snyman and Smallwood, 2017). Companies with a low level of productivity can hardly survive in a today's turbulent environment. Otherwise said, companies with a low level of productivity are creating wastes. Low productivity samples can be identified the best by consideration the smallest organizational cell – the workplace.

The workplace represents the smallest organizational unit of production in which the worker, labor and work items are located (Mileusnić, 1977). Moreover, as Mileusnić (1997) says from the perspective of work organization in the workplace and organization of the production process, there are three basic organizational forms of workplaces: open, closed and stabilized workplace.

Open workplace represents the lowest level of work organization in the workplace, where three types of waste are identified: work breaks and disruptions due to the poor organization (G_1), work of workers resulting from the poor organization (G_2) and unrealized output as a result of poor organization and work method (G_3). Closed workplace is an organizational form of a workplace with a high level of organization, where the waste of G_1 and G_2 are eliminated. The condition for creating a stabilized job is to close the workplace. Closed workplace is the most effective and humane, and the work performance is the greatest (Radović, 2011). At that time, productivity is at the highest level and exists everything that is needed to make the worker perform only operations that add value to the product (Mileusnić, 1977).

On the other hand, Lean manufacturing has been receiving attention lately from lots of organizations. More and more companies are now combining lean with their other improvement principles. Lean production recognizes seven types of wastes, which are known for one word – *Muda* – the Japanese term for waste (Womack & Jones, 1996).

This paper shows the connection between organizational waste in open workplace and Lean waste. The focus of this paper was how elimination of wastes can influence productivity improvement, in the light of workplace closure and stabilization. It also shows the principles for measuring productivity and wastes in organization, and the conections between identfying wastes in order to close and stabilize workplace.

2. THEORETICAL BACKGROUND

Not everything that happens in a day's work adds value. In fact, the vast majority of the typical worker's labor is *movement* and very little indeed is actually *work* (Hirano, 2009). In workplaces, everything that is organizational good and what is not good can be recognized. Most often, the organizational shortcomings of the whole company are reflected in the workplace in the production process.

It is not easy to find all wastes, when wastes appear in many aspects. In a factory, *useful* is the same thing as *value-adding* (Hirano, 2009). The processing done in the factory is what adds the most value to the products. Everything that does not add value is a form of waste. Hirano says that *waste does not process anything, nor does it add any value.* Womack and Jones (1996) say that waste means specifically any human activity which absorbs resources but creates no value.

„No factory is without waste" (Hirano, 2009, p. 147). How much waste a factory contains, depends the most on how well it responds to its problems. The wastes that destroy so many factories often starts with simple incorrect responses to problems (Hirano, 2009). Sometimes the entire operation can be some sort of waste, because there is a cheaper way to do the same operation. It is especially important to start from the right place and identify all problems.

2.1. Organization of workplaces as an elementary production process

The level of organisation is a measure of quality of organization (Radović, 2011). Early mentioned, organitation recognizes three types of workplace: Open, closed and stabilized workplace. Open workplace has the lowest level of organization (Mileusnić, 1977). At that time the worker is least productive. Only when a worker is productive, value is being created and everything else can be considered a waste. Causes of low productivity can be different: the worker is not assigned the appropriate task, the worker is absent from the workplace, an adequate division of work is not carried out, there is no proper documentation. All of these activities that do not add value are divided into three groups: G_1, G_2 and G_3 (Radović, 2011). The time period in which the productivity and wastes of a company is measured is called the available time (Radović, 2011).

G_1 waste represents breaks and interruptions in work due to the poor organization. The causes of these wastes can be different: the worker is not in the workplace, there are no materials, tools and documentation, the machine is defective and exists waiting. Since G_1 wastes represent a break in operation, it can be concluded that in this period of available time no value is being created for the customer.

G_2 waste includes the work of a worker resulting from a poor organization. This includes poor programming and planning production, preparation of production done by workers, poor labor division, finishing or repairing of products with defects and quality control while the machine is in use. All this results in value not being created for the customer.

G_3 wastes are the most difficult to identify and measure. This represents an unrealized outcome or a poor method of work at the workplace. In this case the worker works, but with not the best method of work. (Radović, 2011) The scheme (Figure 1) shows productivity Pr, wastes G_1, G_2 and G_3, available time (Shift hours), worker occupancy Z and capacity utilization rate ηk.

Occupancy (Z) represents the part in available time in which the worker is working (Radović, 2011). If the worker is busy, it does not mean that he creates a value. In the case of productivity, the worker should be busy. However, the employee is busy even when it does not create a new value (this includes wastes G_2 and G_3). Capacity utilization rate η_k is the part in available time that includes productivity of worker, unrealized outcome or a poor method of work at the workplace (G_3) (Radović, 2011). This is the portion of time where value is created for the customer, although not always in best possible way.

According to the study conducted in selected companies, the relationship between productivity and waste was found. There was a big gap between them. Productivity accounted for only 40% of the time available, while 60% of the time was spent on not different types of wasteful activities (Radović, 2011). The scheme notes that the possibilities for improving the organization of production and the work process in general are high (Figure 1).

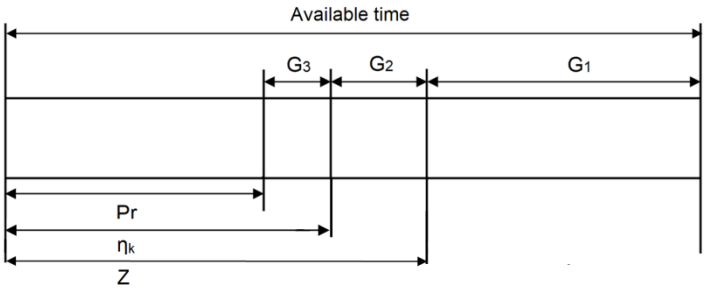

Figure 1: Structure of available time at workplace (Radović, 2011)

Mileusnić (1977) mentions that the organization of workplaces should be a closed type workplace and allow workers to get a fully prepared job, in the case that all conditions for production are met. In order to increase the productivity of the organization and improve business results, a reorganization of production is required. The measures to be taken consist of the reorganization of the workplace and the entire work organization, as this is the requirement that production at the workplaces is optimally carried out.

Closed workplace is distinguished by the fact that unnecessary work breaks in workplaces, due to organizational disadvantages, are excluded and that the useless work is reduced to a minimum (Mileusnić, 1977). The worker should only perform his work at the workplace, while other workers provide, deliver and dispatch work for their position. The worker should not interrupt work in order to bring the job or take it and his workplace should provide that the work is continuously running.

Psycho-physiological conditions and working environment conditions are also studied in organizing the workplace. Mileusnić (1977) says that the purpose of studying operations and its components is to make the work of workers easier, to reduce his efforts and to increase the output. In order to ensure the proper delivery and dispatch of work and tools for work, there should be a workshop preparation in the process (Mileusnić, 1974). Workshop preparation should allow workers in the production process to use their time on product development.

Good workshop preparation might not be sufficient condition for workplace closure and stabilization. Mileusnić (1977) says that it is necessary to establish a good connection between the procurement function that acquires the necessary material and tools for operation, as well as the sales functions that ensure the sale of products. If the workplaces have the appropriate employees in the production, they organize appropriate training and ensure the health of the employees, then the human resources contribute to the process of workplace closure. Studying, measuring, improving and humanization of work at workpalce is also an important step in workplace closure. When productivity is increased, a good level of organization is established and a workpalce closure is created, then the conditions for a stable job are created. The stabilized workplace is organized in the most rational way, and then the worker only performs activities that add value to the product (Mileusnić, 1977)

2.2. Elimination of waste in Lean production

At the international level, a lot of attention is attached to Japanese production philosophies, and as one of them to Lean production. Lean production is a production philosophy that shortens waiting times eliminating wastes between receiving orders and distribution to the customer (Vasiljević & Slović, 2015). Vasiljević and Slović (2015) say that Lean is a system of integrated elements that work together to increase the performance of the production system over time. Lean forces attention to how the value is generated rather than how any one activity is managed.

One of the main principles of Lean production is elimination of waste – *Muda* (Womack & Jones, 1996). Lean production should provide cost savings by eliminating all forms of wastes. As a basis for defining waste, it is necessary to classify the activities of the company on:

1. value aided activities,
2. non-value aided activities,
3. necessary non-value adding activity (Hines & Taylor, 2000).

Value adding activity are activities that, in the eyes of the final customer, make a product or service more valuable. Non-value adding activity represents activities that, in the eyes of the final customer, do not make a product or service more valuable and are not necessary even under present circumstances. These activities are clearly waste and should therefore be the target of immediate or short term removal. Necessary non

value adding activity are those activities that, in the eyes of the final customer, do not make a product or service more valuable but are necessary unless the existing supply process is radically changed (Hines & Taylor, 2000).

In manufacturing or logistics types of environment, the gap between those three activities is high. Hines and Taylor (2000) have developed a guide to the proportions of these three types of activity that might appear in a company before any lean improvements. The total value stream time of a company is: 5% value adding activity, 60% non value adding and 35% necessary but non value adding activities (Hines & Taylor, 2000). This is represent on Figure 2.

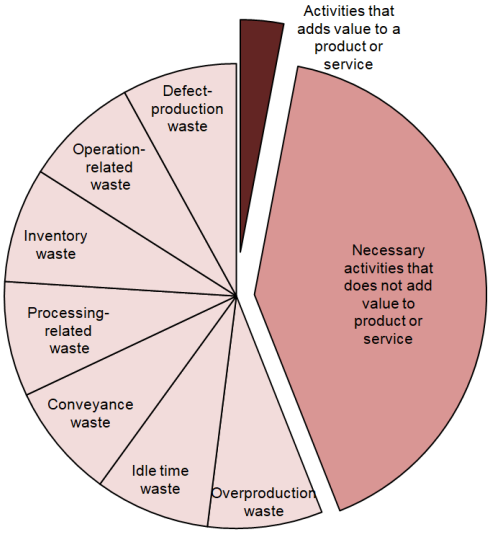

Figure 2: Structure of activities and wastage in production (Slović & Vasiljević, 2015)

The Toyota Production System relies on elimination of waste as essential. Taiichi Ohno (Hirano, 2009), a Toyota executive, identified seven types of waste found in any process:

- Overproduction waste – production of products that is not needed.
- Inventory waste – in-process inventory or finished products waiting to be shipped.
- Conveyance waste – unnecessary transport of parts under production.
- Defect-production waste – production od defected products.
- Processing-related waste – unnecessary operations in production.
- Operation-related waste – unnecessary movement of people working on products.
- Idle time waste – time spent waiting for something.

Each type will be analyzed in the continuation of the paper.

3. WASTE ELIMINATION IN CONTEXT OF WORKPLACE CLOSURE AND STABILIZATION AND LEAN PRODUCTION

Productivity represents how much of management resources are required for a certain amount of management results (Sakamoto, 2010). When a company is looking for the best method for productivity improvement, it is important to decide which methods they should implement. Combining Lean with other improvement principles, companies can easily improve their productivity. The goal of waste elimination in workplace closure and stabilization is also the productivity improvement. In this paper will be found a connection between this two principles.

If the productivity level is low, it is probably because of wastes that causes organizational disorder. Different problems within the organization affect the generation of wastes, which then reduce productivity. By applying these principles (elimination of waste in workplace closure and in the Lean production), the company can identify what are the wastes that affect the business. In the following table, the activities are identified, columns show productivity and wastes G_1, G_2 and G_3. In rows are given activities that add value to the product or service, the necessary activities and seven types of waste – *Muda*.

Table 1: Wastes in open workplace and wastes in Lean – *Muda*

Lean		Open workplace			
		Pr	**G3**	**G2**	**G1**
Value Adding Activities		+*			
Non-value adding Activities		+		+	(+)
Wastes - Muda	Overproduction			+	
	Idle time				+
	Conveyance			+	(+)
	Processing-related		(+)	+	
	Inventory			+	
	Operation-related		+		
	Defect production			+	

* + represents explicit connection, (+) represents implicit connection

Based on indicators, it is possible to sufficiently determine productivity of production, where the highest wastes are in time, the extent to which the capacity utilization rate can be increased and in what direction it should be operated (Radović, 2011). The direction of the organization's development should be such that the design of the new organization of work and its implementation create conditions for the workplace closure (Mileusnić, 1977).

Necessary activities are necessary because of the abilities of the existing process and they require radical changes for eliminating (Slović & Vasiljević, 2015). Necessary non-value adding activity includes the time when the worker is productive, but also the waste of G_2. This means that in addition to the necessary activities, the employee also performs work preparation activities, which is not in his workplace specification. The worker should not prepare workplace, but it is necessary that other workers who are in charge of it, provide, deliver and dispatch work for his position. He does not create a new value, but the activity is necessary because its non-execution would lead to an interruption, or G_2 would be converted to G_1. Therefore, it is necessary to recognize what aree the organizational reasons by which the worker should prepare for work, and work on their removal, so that G_2 can be transformed into productive work.

Overproduction waste can be defined as “producing what is unnecessary, when it is unnecessary, and in an unnecessary amount” (Hirano, 2009, p. 164). The overproduction also represents when the products are produced outside the optimal production plan. The worker at the workplace should only produce the planned amount from the optimal production plan, however in this case the worker has produced much more. The worker can also work on products that are not planned for him, probably because he does not have the right information, material or resources. The cause is poor production organization, and this type of waste is classified as a waste of G_2. Hirano (2009) says that overproduction waste is the worst of all forms of waste, because it contributes to inventory waste, and the inventory naturally leads to more transportation. All this increases the cost of production and the creation of inventories of products that can not be sold. Although overproduction is not directly G_3, because it increases G_3 in case the working method is not examined and rationalized, or because the worker has an opportunity to do with a bad method. Then the waste is double: G_2 because the worker is producing out of the optimal production plan, and G_3, because the worker works in an inadequate way. The worker should always have the correct production plan and comply with it. By closing the workplace, part of the waste of G_2, or overpoduction waste, would turn into productive work.

A special kind of interruption in work is waiting in the workplace, because the worker is not provided with a job. Idle time waste is a term that includes both human idle time and machine idle time and covers a wide variety of cases (Hirano, 2009). Idle time is generally time spent waiting for something. The cause may be, for example, a procurement function that did not provide material. This leads to delays and waiting, which is also identified as the type of waste (Idle time). This is the only type of waste that is classified as a waste of G_1. Absence of workers from the workplace is not classified in any type of waste and it should be further analyzed, in order to be classified into a one of categories of wastes.

In the event when the waiting period is eliminated, the worker would receive a fully-fledged job, it would still not be enough to close the workplace, because the breakdown of work is due to the organizational disorder of the workplace. These wastes due to poor organization represents G_2, identified in 5 types of waste: Overproduction waste, Conveyance waste, Inventory waste, Defect-production waste and Processing-related waste.

Hirano (2009) says that Conveyance waste is a term for covering everything from conveyance made necessary by poor layout, material handling (such as picking things up, setting them down, and stacking them up), and just moving things around. Conveyance wastes are classified as G_2 wastes because they represent a poor organization of labor. However, if the transport of worker is considered as a break in operation, this type of waste could also be the waste of G_1. The worker then stops because of transporting, if he works alone or if someone needs to be replaced. At the transport, in which others carry out the transport process, there is only G_2 waste.This can be seen on Figure 3. The arrows indicate that wastes (*Muda*) may belong to several types of wastes G_1, G_2, G_3. The black arrows show a direct classification, and the red ones shows how can wastes be classified under different conditions.

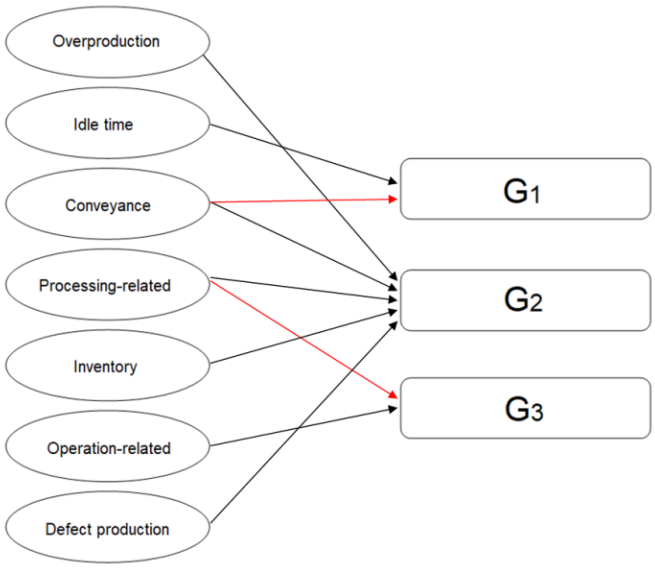

Figure 3: Connections between wastes (*Muda*) and wastes G_1, G_2 and G_3

Sometimes, the waste can be seen in the conveyance system as the consequence of long conveyance distances and heights or insufficiently used conveyor systems. The reorganization of layout in woorkplace could be the solution for eliminating conveyance wastes. The main goal is to transform those wastes into productivity, for also increasing the capacity utilization rate η_k.

Processing-related waste indulges in unnecessary operations in production and therefore are classified as a waste of G_2. Poor organization and programming of production is a problem for people at higher level of organizational hierarchy. They can be eliminated by product modification, reprogramming the production process, using just-in-case logic, etc. (Vasiljević & Slović, 2015) However, if processes in production are not clearly defined, it may happen that the worker performs operations that are not intended for production. Then those losses could be classified in G_3.

Inventory waste are including not only wastes in the warehouse, but also in-process inventory. This means materials, parts, finished products and whatever that is located between or in the end of operations (Hirano, 2009). Inventory wastes represent the waste of G_2, because inventories are the result of procurement or production, the amount of production which exceeds actual production needs.

Operation-related wastes are the only wastes that belongs to G_3. The worker then works on creating value for the end user, but does not do it in the best possible way. The worker makes unnecessary movements that affect the longer duration of the operations, and consequently the lower productivity. Workers should be trained in order to rationalize their work method and be a part of creating standard operating procedures (SOP). Workers should be actively involved in creating standard operating procedures to better accept and respect them.

Defect-Production waste is the waste associated with costs for inspection of defects in materials and processes, customer complaints, and repairs (Hirano, 2009). This type of waste is the waste of G_2 because there are omissions at the organization level. Causes of defective products can be: inaccuracy in documentation, inadequate process control and product quality, poor condition of equipment, inadequate training of workers, etc. (Vasiljević & Slović, 2015)

Good organization needs work, so for the beginning it focuses on eliminating unnecessary traffic, for example, changing laiout. Different quantitative methods can determine the empty movement of workers, the

efficiency of the system, and in this way obtain the true images of the performance system. This could have the effect of reducing interruptions and increasing productivity. Then, work preparation should be done, which results in great wastes. Better operational preparation, constructive and technological documentation and synchronization with procurement and sales functions is necessary.

In order to reduce the necessary activities, alternatives for existing operations should be analyzed. In time, it is considered whether there is a modern machine for some operation or a better way of working. Closing workplace for the purpose of productivity also includes calculating the indicators of occupancy and the degree of capacity utilization. When Z is high it does not mean that the productivity is also high. It is important to analize how the worker is busy. Also, the degree of capacity utilization increases with increased productivity.

In order to close the workplace it is necessary to organize a work place so that only the productive work is done. This proces of workplace closure can be difficult in implementing the improvement because of some reasons:

1. being unable to recognize waste as it occurs in the factory;
2. waste remains hidden within abnormal conditions or problems in the factory and is thus not readily apparent;
3. even when waste becomes evident in connection with abnormal conditions or problems in the factory, people do not know enough to recognize the waste (Hirano, 2009).

It should be careful not to convert one type of waste into another, and the elimination of activities that does not add a value to a product or service at the moment, but are necessary, does not actually turn into wastes (G_1 into G_2). Radović (2011) believes that in practice, the conclusion comes from observing financial performance indicators. That image of a working organization can not be complete. Therefore, it is necessary to identify several different indicators on which the exact quality of organization of the production process and the process of work as a whole will be determined.

4. CONCLUSION

Productivity improvement, in every organization, should be the main factor for business improvement. For productivity improvement, companies should improve their performance by utilising performance measures, reorganizing the proces of production that causes problems and establish stabilized workplace. Many companies are also have implemented certain methods of improvement like 5S, Kaizen and Kanban.

Various factors were analyzed: productivity, activities that add and do not add value to the end product, necessary activities, waste – *Muda* and the way to close and stabilize workplace. Both principles, workplace closure and stabilization and waste elimination, cover various possibilities that cause workplace wastes, and can be said to be complete in identifying wastes. G_1, G_2 and G_3 and *Muda* elimination are perfect for businesses as the starting point for improving productivity. Both methods are applicable in an enterprise and it is very useful to apply them in order to have a complete picture of the performance of the company. There is a significant synergetic effect, because the structure of the available time can serve to quantify the results of elimination of waste, through the calculation of indicators, such as the degree of capacity utilization and occupancy. Eliminating wastes can be the starting point for improving productivity. Many companies have also implemented certain methods of improvement like 5S, Kaizen and Kanban, which are the solution in the long run.

The waste elimination has positive influence on productivity improvement. The benefits of workplace closure and elimination of wastes are enormously, because of the resaults they bring. The identification of wastes is the first, but not the least important, step in eliminating wastes. It is necessary to have a good knowledge of the enterprise, to identify the processes within the enterprise, then the problems and their causes. Both principles cover the various causes that cause wastes at workplace, and can be said to be complete in identifying losses. Both methods are capplicable in an enterprise and it is very useful to apply them both for a complete picture of the performance of the company.

The direction of future research is the practical application of the workplace closure and the elimination of waste as an integrated methodology in practice. A workshop would be analyzed from both workplace closure and waste elimination views, in order to see what effects this approach whould have on productivity improvement. Practical case, would give the right picture of productive work and wastes, and the results would also be used to illustrate productivity improvements, and to further develop this synergetic approach to workplace closure and waste elimination.

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INFORMATION AND COMMUNICATION TECHNOLOGIES AS SUPPORT FOR INVENTORY CONTROL IN THE AUTOMOTIVE INDUSTRY

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Abstract: *This paper presents four types of information and communication technologies as support for inventory control in the warehouse, on the example of the company from the automotive industry. Considered information and communication technologies are: voice technology, pick-to-light technology, barcode technology and drone technology. The Analytical Hierarchy Process (AHP) method was used to analyze and select the best technology based on ten defined criteria. The aim of this paper is to present one of the methods to select the most suitable type of information and communication technology for inventory control in the automotive industry.*

Keywords*: Information and Communication Technology, Inventory Control, AHP, Comparative Analyze, Automotive Industry*

1. INTRODUCTION

Information and communication technology presents a unique name for a group of technologies that can be applied to problem-solving, including inventory control. Those problems can appear during activities in the warehouse: searching, finding, identifying, preparing, packing and sending final product to the customer. The process of preparing products for delivery can be simplified and stabilized by application of information and communication technologies. Reduction of activities needed for products preparation, walking paths through the warehouse and lifting of heavy weights can be gained through this application (Richards, 2017). According to (Wild, 2002) inventory control presents the activity of organizing the availability of products to the customers. The main goal of inventory control in the warehouse is to meet customer needs on time, with an aim that inventory and procurement costs stay on low level (Wild, 2002). It is necessary to organize inventory control in a way that will enable improvement of the production process, customer satisfaction, labor humanization and employee satisfaction.

The paper is organized as follows. In the second chapter are presented four types of information and communication technologies that can be applied for improvement of inventory control in the warehouse of the automotive industry. There is an explanation of technologies' methods, areas of their possible application, but also problems that those technologies can solve. In the third chapter are defined the most important criteria for the warehouse workflow. Based on defined criteria, quantity analyzes and comparison of those technologies is carried out by application of the AHP method. Also, the most suitable technology is selected based on results of this analysis. The fourth chapter presents the conclusion.

2. INFORMATION AND COMMUNICATION TECHNOLOGY AND INVENTORY CONTROL

Inventory control in the warehouse is very important in modern management and it has a main role in the whole supply chain (Atieh et al., 2016). It is necessary to track product movements from supplier to the warehouse, stock inventory, movements through the warehouse-from entry to shelves and from storage places to the exit zone. Besides this, it is also important to track product movements from the warehouse to the customers in order to ensure delivery on time. Setting up more efficient inventory control system in the warehouse is important to achieve the best possible results in key performance (costs, customer satisfaction, orders collection, orders packing, etc). Also, humanization of labor cannot be disregarded (Caridade at al., 2017). It is necessary to provide adequate space organization in the warehouse for product manipulation. This includes marking zones for product receiving, storage and dispatch zones, as well as paths for workers and transport movement in the warehouse.

In addition to good warehouse organization, it is necessary to establish automation in processes which are performed in the warehouse. This automation can be gained through the implementation of information and communication technologies that can enable control of inventory level and provide adequate and real-time information (Atieh et al., 2016). The main purpose of applying information and communication technologies

in the warehouse is to increase the efficiency of warehouse operations, in order to ensure that customers receive products on time. Usage of information and communication technology in inventory control reduces the need for labor. Processes, which these technologies are used for, decrease number of workers important for the performance of all necessary activities in the warehouse (Richards, 2017).

2. APPLICATION OF INFORMATION AND COMMUNICATION TECHNOLOGY IN INVENTORY CONTROL

A large number of information and communication technologies have been developed in last few decades and have found application in many industries. This paper presents four information and communication technologies that can be implemented in the warehouse for improvement of the inventory control. Those are the following technologies: voice, pick-to-light, barcode and drone. RFID (Radio Frequency Identification) technology also presents one of the information and communication technologies that can be implemented as a support for improvement of the inventory control. But, the implementation costs (information system, equipment, trainings, etc.) are higher than the costs for the implementation of the barcode technology. This presents the main reason why priority was given to the barcode technology and why RFID technology is not considered in this paper.

2.1. Voice technology

The basic principle of voice technology is a verbal transmission of instructions. There is a subsystem within a voice technology system that provides instructions based on information of inventory availability and storage location. Using this technology, workers receive information as instructions for actions they have to perform in order to pick needed products for delivery. In addition, workers send information about the execution of the given instructions in the form of voice report, but also notifications about changes that can influence the voice system workflow. The system accepts and records received notifications. Voice technology allows two-way communication between worker and the system, which increases the accuracy of work. Headsets with a microphone are required equipment of implementation of the voice technology. Workers carry them in order to receive instructions from the system and to send feedback. Besides headsets, Internet connection (LAN-Local Area Network or RF-Radio Frequency) is required to be installed in order to enable simple communication (The Ackerman Company, 2002). This technology is fully adaptable to all types of dialects, accents, and languages. The communication requires adequate encryption of products and storage locations. In a case there is not enough required inventory on the storage location, workers send information to the system that provides feedback as an action needed to be taken. One advantage of the voice technology is the accurate instruction of what to do and provision of the exact answer to the asked question. Thus, all confusions, problems, and mistakes made by workers can be eliminated (Berger & Ludwig, 2007).

2.2. Pick-to-light technology

Pick-to-light technology enables improvement of worker's ability in the warehouse activities. This improvement is shown as the increase of workers' efficiency expressed by the number of orders executed in the unit of time. In pick-to-light technology, light signals are used for highlighting storage locations where workers have to pick required product units. Each storage location contains a device that emits light signals and displays quantities needed to be picked. A storage location that is systematically detected as the location where the desired product can be found emits light signals and gives a sign to the workers where they can take products needed for the customer order. After finding a required amount of the product, workers have to press a button to send a signal to the system as a confirmation of the fulfilled action. If the confirmation is successfully accepted by the system, storage location will stop lighting. Information of inventory level is automatically updated in the system (Bragg, 2011). This technology is used in warehouses organized by zone, where a group of workers is in charge of executing given orders in each zone. When the products are picked in one zone, all containers, boxes and other types of packaging are sent to next zone, where light signals define products for the further picking. Pick-to-light technologies require the adequate organization of the main warehouse that involves well-arranged logical structure, in order to make the process of picking and packaging more efficient. Its application in the warehouse improves the organization of work by keeping every worker in his zone with the exact task schedule to be performed (McCrea, 2015).

2.3. Barcode technology

A barcode presents a group of bars and spaces arranged according to a set of rules that determines the way of presenting data. Different bar and space patterns are used to express different symbols, readable only by

a scanner (Islam & Shuva, 2010). Barcode technology is an optical technology for displaying all data from a barcode of one product. Although it was discovered decades ago, it is still in use today with all new technologies. Application of this technology creates savings, raises the level of automation, and does not require complicated and expensive implementation (Kuglin & Hood, 2008). The barcode is characteristic and easily recognized because of the parallel black lines of different thickness. The encrypted part of barcode contains the same data as lines in an alphanumeric array of characters below black bars.

Regardless the type of the barcode technology that is applied in the warehouse, there are four main components (Singh & Sharma, 2009):

- *Barcode printer*: allows printing of barcodes in order to follow the movement of the product;
- *Barcode*: can be directly applied to products or storage locations (as labels);
- *Barcode scanner*: allows reading of data from barcode lines by decoding and translating them into a format understandable for a computer system;
- *Database*: a set of data of all items that movement is monitored with barcode technology. All information from barcode lines is connected with information in a database. When some changes occur and when the barcode is scanned, it is updated in a database.

Barcode technology is mostly used for inventory control in the warehouse. The main reason for that is the low cost of purchase and installation, large savings in time needed for the performance of the warehouse activities and update of the inventory level in the system. Activities that barcode technology can support are: updated inventory level in the system, automation of products receipt and dispatch, and tracking of storage locations and products movements.

2.4. Drone technology

The drone is one of the latest information and communication technologies that can be used for support of inventory control without human interference. Drones use cameras with technology based on geolocation that enables movement with predefined flight path through the warehouse. Besides this, it is also important to have devices that will help in creating flight path, activating drones, commanding, flight monitoring and control. For this, it can be used mobile devices, such as smartphones, tablets, and others. Drones can be used to define current inventory level in the warehouse and to locate products needed for realization of the orders. Drone technology is compatible with other information and communication technologies, such as barcode and RFID technologies. The combined application of previously mentioned technologies can significantly automate warehouse activities. Application of the drone technology minimizes the need for human recourses and enables faster performance of all activities in the warehouse. This technology can provide accurate information about inventory level and automatically send it to the system for inventory control, based on the application of barcode or RFID scanners that are located on drones. The application of this technology can determine the exact location of the requested product in the warehouse.

The use of drone technology is suitable for storage areas with high storage shelves that can put workers at risk of falling while scanning products. The main advantage of this technology is that one drone can replace a large number of passive RFID readers because of the ability to move around the storage space. The drones are completely safe technology since they do not come in contact with people. They are small size and they do not disturb workers during everyday activities. In order to prevent accidents and injuries at work, it is necessary to mark the area of drones and inform workers (Lechmaher, 2017).

3. SELECTION OF THE MOST SUITABLE INFORMATION AND COMMUNICATION TECHNOLOGY FOR INVENTORY CONTROL

The previous chapter presents the information and communication technologies' function in the inventory control, their characteristics, advantages and possible application in problem-solving. Base on that, criteria for application of the AHP method are defined, in order to do the comparison of the chosen and presented information and communication technologies and to select one technology as the most suitable for inventory control in the warehouse in the company from the automotive industry.

The most important criteria for the inventory control in the warehouse are:

1. *Administrative productivity*: the improvement of administrative activities in the warehouse, that determines the method of data transmission from the source of creation to the location of application;
2. *Labor productivity*: workers' performance in a certain period of time;
3. *Accuracy*: precision in work during the performance of warehouse activities, as well as data validity in the system for inventory control;

4. *The automation level*: reduction of human recourse participation in the warehouse activities;
5. *Ergonomic performance indicators*: security in working conditions in the warehouse;
6. *Error occurrence*: the possibility of error occurred during the performance of the warehouse activities;
7. *Updated inventory stock*: update of the inventory level in the system;
8. *Work safety*: safe working environment;
9. *The simplicity of use*: the simplicity of workers' training process;
10. *Costs*: procurement, implementation and training costs for application of the information and communication technology in the warehouse.

The AHP method is used to compare and select the most suitable information and communication technology for improvement of the inventory control. This method is an effective tool for complex decision making and helps to the decision makers to set priorities and choose the best decision. It is also a method of optimization because it chooses the best possible solution among all given alternatives (Bhushan & Rai, 2007). The main purpose of AHP method is to choose the optimal solution for a problem in order to achieve and satisfy the set goals.

The alternatives that are compared by the AHP method are:
1. Voice technology;
2. Pick-to-light technology;
3. Barcode technology;
4. Drone technology.

Figure 1 presents all parameters of AHP method used for selecting the most suitable information and communication technology for inventory control.

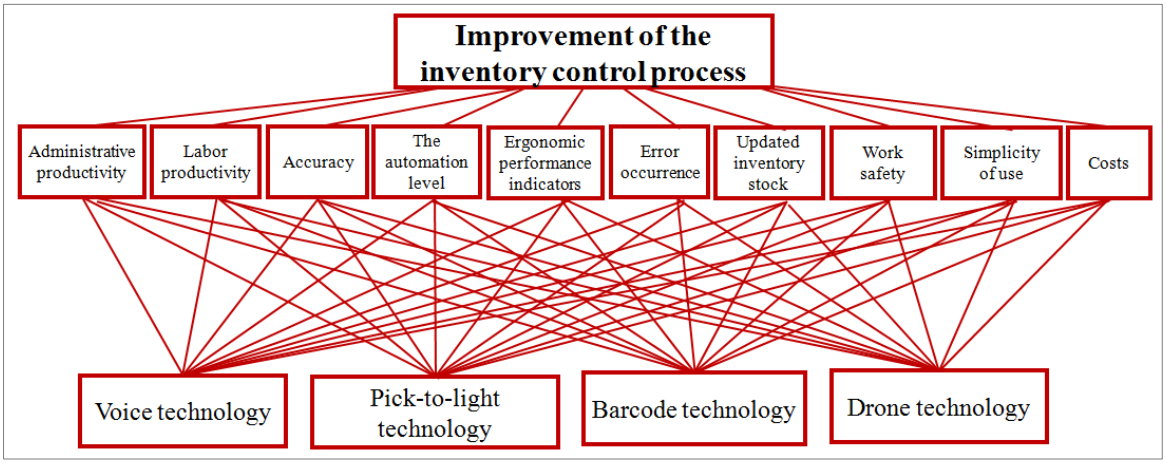

Figure 1: Parameters of AHP method for selection of the most suitable information and communication technology for the improvement of the inventory control

After defining all parameters of AHP method, it is necessary to assign grades to the pair of alternatives in relation to all level attributes. For comparison and assign priority to alternatives, AHP method uses a table of relative scores named *The fundamental scale*, created by (Saaty, 1987). Table 1 presents the rating values for each part of this scale.

Table 1: The fundamental scale (Saaty, 1987)

Intensity of importance on an absolute scale	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments
Reciprocals	If activity *i* has one of the above numbers assigned to It when compared with activity *j*, then *j* has the reciprocal value when compared with *i*
Rationales	Ratios arising from the scale

Decision maker estimates alternatives by assigning rates from 1 to 9, according to his preference among alternatives. A rate 1 is given when decision maker has the equal preference between comparing alternatives. A rate 9 expresses extremely strong domination of one alternative (Bhushan & Rai, 2007).

The final rank among all alternatives is obtained through multiplying criteria weights with values given as a result of alternative comparison against certain criteria. This is known as the additive sum. The best alternative has resulted with the highest value of the additive sum. Considering that selection of the best possible alternative among given information and communication technologies for inventory control is a complex problem (contains ten criteria and four alternatives), rules of transitivity and consistency must be applied. They ensure that alternatives have corresponding rates and ranks.

3.1. Comparative analyze of information and communication technologies

In the next step of applying AHP method it is necessary to compare all alternatives versus defined criteria. In order to assign rates to alternatives and comply with transitivity and consistency rules, all alternatives are ranked by each criterion based on the preference of decision maker. An overview of this analyzes is shown in Table 2, with following abbreviations: VT – voice technology, LT – pick-to-light technology, BT – barcode technology, DT – drone technology.

Table 2: Alternative evaluation ranks according to defined criteria

Administrative productivity	Labor productivity	Accuracy	Automation level	Ergonomic performance indicators	Error assurance	Updated inventory stock	Work safety	The simplicity of use	Costs
VT	DT	VT	DT	DT	ST	VT	VT	BT	BT
DT	LT	DT	VT	LT	GT	LT	LT	LT	LT
LT	VT	LT	LT	VT	DT	DT	BT	VT	VT
BT	BT	BT	BT	BT	BT	BT	DT	DT	DT

It is also necessary to make criteria prioritization in order to determine the significance of each criterion in relation to the others. In order to simplify the prioritization of defined criteria, decision maker determines a list of ranked criteria, as an additional step in AHP method. The proposed ranked list of criteria is:

1. Accuracy;
2. The automation level;
3. Updated inventory stock;
4. Labor productivity;
5. Administrative productivity;
6. Error occurrence;
7. Work safety;
8. Ergonomic performance indicators;
9. The simplicity of use;
10. Costs.

The criteria prioritization is based on their interdependence and comprehensiveness. For example, the automation level of inventory in the warehouse affects other criteria, such as accuracy, updated inventory stock, and labor productivity. It has a higher rank in relation to those criteria. Work safety and ergonomic performance indicators are lower ranked because all criteria for higher position contribute to achievements of these two. Determination of the initial rank of available alternatives by each criterion, as well as criteria prioritization allows priority assignment to alternatives and their normalization.

3.2. Results

Tables 3 and Table 4 present rates of alternatives and criteria that are determined as a result of estimation process in AHP method. According to a certain assessment of all alternatives and criteria, and their established weights, it is easy to comply with final decision matrix. It consists of alternatives presented in the columns and the criteria presented in the rows of the matrix. Table 5 presents final decision matrix.

Table 3: The rates of criteria prioritization

Criteria	Accuracy	Automation level	Updated inventory stock	Labor productivity	Administration productivity	Error occurrence	Work safety	Ergonomic indicators	The simplicity of use	Costs
Accuracy	1.00	2.00	2.00	3.00	3.00	3.00	4.00	4.00	5.00	7.00
Automation level	0.50	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00	7.00
Updated inventory stock	0.50	0.50	1.00	2.00	4.00	3.00	4.00	4.00	5.00	7.00
Labor productivity	0.33	0.50	0.50	1.00	2.00	2.00	2.00	3.00	4.00	7.00
Administration productivity	0.33	0.33	0.25	0.50	1.00	4.00	2.00	2.00	4.00	6.00
Error occurrence	0.33	0.33	0.33	0.50	0.25	1.00	3.00	2.00	3.00	6.00
Work safety	0.25	0.25	0.25	0.50	0.50	0.33	1.00	2.00	3.00	6.00
Ergonomic indicators	0.25	0.25	0.25	0.33	0.50	0.50	0.50	1.00	3.00	6.00
The simplicity of use	0.20	0.20	0.20	0.25	0.25	0.33	0.33	0.33	1.00	7.00
Costs	0.14	0.14	0.14	0.14	0.17	0.17	0.17	0.17	0.14	1.00
∑	*3.84*	*5.51*	*6.93*	*10.23*	*14.67*	*17.33*	*21.00*	*22.50*	*33.14*	*60.00*

Table 4: The results of criteria normalization

Criteria	Accuracy	Automation level	Updated inventory stock	Labor productivity	Administration productivity	Error occurrence	Work safety	Ergonomic indicators	The simplicity of use	Costs	AVG
Accuracy	0.26	0.36	0.29	0.29	0.20	0.17	0.19	0.18	0.15	0.12	0.2219
Automation level	0.13	0.18	0.29	0.20	0.20	0.17	0.19	0.18	0.15	0.12	0.1809
Updated inventory stock	0.13	0.09	0.14	0.20	0.27	0.17	0.19	0.18	0.15	0.12	0.1642
Labor productivity	0.09	0.09	0.07	0.10	0.14	0.12	0.10	0.13	0.12	0.12	0.1065
Administration productivity	0.09	0.06	0.04	0.05	0.07	0.23	0.10	0.09	0.12	0.10	0.0936
Error occurrence	0.09	0.06	0.05	0.05	0.02	0.06	0.14	0.09	0.09	0.10	0.0741
Work safety	0.07	0.05	0.04	0.05	0.03	0.02	0.05	0.09	0.09	0.10	0.0576
Ergonomic indicators	0.07	0.05	0.04	0.05	0.03	0.02	0.05	0.09	0.09	0.10	0.0501
The simplicity of use	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.03	0.12	0.0855
Costs	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.0155

Table 5: Decision matrix

Decision matrix	Voice Technology	Pick-to-light Technology	Barcode Technology	Drone Technology	Weights
Accuracy	0.4451	0.1598	0.0796	0.3154	**0.2219**
Automation level	0.2111	0.1204	0.0391	0.6293	**0.1809**
Updated inventory stock	0.5133	0.2900	0.0574	0.1393	**0.1642**
Labor productivity	0.1428	0.2760	0.0418	0.5393	**0.1065**
Administrative productivity	0.3555	0.1914	0.2280	0.2251	**0.0936**
Error occurrence	0.2924	0.4614	0.0648	0.1814	**0.0741**
Work safety	0.5975	0.2458	0.1019	0.0548	**0.0576**

Ergonomic indicators	0.1122	0.2051	0.0455	0.6373	**0.0501**
The simplicity of use	0.0682	0.1136	0.2731	0.5451	**0.0355**
Costs	0.1278	0.2494	0.5868	0.0360	**0.0155**

The final result of alternative estimation is obtained by the additive sum, by multiplying alternative rates with criteria rates and summing all results by each alternative and criteria combination. If O_{ij} presents the rate of alternative *i* in comparison with criteria *j* and if P_j presents weight of criteria *j*, additive sum A_i of alternative *i* can be expressed as is in formula (1) (Bhushan & Rai, 2007).

$$\text{Ai}= \sum_{j=1}^{10} Oij * \ Pj \tag{1}$$

Table 6 presents a final result of AHP method consisting of rates and ranks of compared alternatives. The best alternative for improvement of the inventory control in the warehouse is drone technology with rate 0.3537. Voice technology is in second place with the rate of 0.3359. Considering the extremely small discrepancy between the rates of those two technologies, it is important to clearly emphasize the domain in which the drone technology is better than voice technology and to highlight the difference between them. Drone technology is more dominant in the criteria with higher priority. It has a considerably higher level of automation because its application reduces the need for human recourses during the activity performance. Data transmission is completely electronic. Ergonomic performance indicators are highly ranked, considering that implementation of drone technology prevents workers from any kind of physical work, because of the high level of automation. Accuracy in finding the required storage locations and collecting required and valid data is one of the biggest advantages of the drone technology.

Table 6: AHP method results

Alternatives	Rank	Rang
Voice technology	0.3359	2
Pick-to-light technology	0.2187	3
Barcode technology	0.0917	4
Drone technology	0.3537	1

Criteria that reduce the overall drone technology results are: error occurrence and updated inventory stock. These two criteria are interdependent. Considering that drone technology is high-level technology, its reliability must be observed. Therefore, it is necessary to procure high-quality equipment in order to avoid stagnation and process errors. Work safety also has a lower rank that indicates providing of needed space for drone movement in order to protect workers from possible injuries. Drone technology is the most expensive alternative. For this reason, to the procurement, implementation, and training costs have not been given priority over other criteria that were considered more important by the decision maker.

Implementation of the drone technology in the warehouse has its own limitations, considering warehouses of the automotive industry. This industry considers warehouses of significant space dimensions that indicate a large number of drones in order to improve the productivity of inventory control. Well functioning of the drone technology depends on the quality of equipment (hardware and software), important for reducing the number of errors that may occur.

4. CONCLUSION

The support of information and communication technologies for improvement of the inventory control in the warehouse presents a necessity in modern terms of business. Some of the goals are reduction of the time required to perform the activity in the warehouse, as well as increasing productivity and customer satisfaction with product quality and deadlines for delivery. In this paper are presented four information and communication technologies: voice technology, pick-to-light technology, barcode technology and drone technology. All these technologies can be used as a support for solving problems in the warehouse. The function of certain technology determines the level of improvement of the inventory control. AHP method is used for comparison and selection of the most appropriate information and communication technology for the inventory control. It requires the definition of all criteria that decision maker considered as relevant. Defined criteria enabled comparison of selected technologies.

As a result of the application of AHP method presented in this paper, drone technology was selected as the most appropriate information and communication technology for improvement of the inventory control in the warehouse in the automotive industry. This technology has the highest ratings by defined priority criteria: accuracy, the automation level, labor productivity and errors occurrence. The disadvantages of this technology are: the high purchase costs of high-quality equipment and the need to reorganize the existing storage space to enable functioning of this technology. Drone technology, as one of the latest information and communication technologies, is still in the process of development which affects on high costs of the necessary components. But, application of this technology is almost unlimited. As a highly reliable and efficient solution, drone technology can be used as a support to the improvement of inventory control in the warehouse of the automotive industry.

Today, information and communication technologies are rapidly developing. Changes in business circumstances and development of technology influence on a creation of new technologies. These changes affect the selection of other information and communication technologies (as alternatives) that implies the definition of new criteria in AHP method. This and application of other decision-making methods are the directions of further research of the authors of this paper.

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SPREADSHEET APPLICATION AND ALTERNATIVE DEVELOPMENT DIRECTIONS FOR A DIGITAL AGE

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Abstract: *This paper presents an overview of present-day spreadsheet technology usage and future directions of its development. It introduces some of application areas of spreadsheets, analyzes new challenges that digital business environment brings up and questions whether is this type of technology competitive in the period of Big Data and increased need for processing large amount of data. The paper points out some of the new directions of spreadsheet development which effectively respond to the modern business needs and are the basis for further development of this technology, such as spreadsheet model for handling streaming data, platforms that allow collaborative work within spreadsheets and framework for end-user spreadsheet-based service composition, which are described in this paper.*

Keywords*: spreadsheets, spreadsheet development, end-user development, collaborative spreadsheets, contemporary business challenges*

1. INTRODUCTION

Since they were firstly introduced, over the past 30 years, spreadsheets have become ubiquitous tool, which is inevitable in today's business world. Spreadsheet programs represent response to customer needs and preferences expressed through the market. These applications constantly evolve in order to increase user satisfaction. They have found their application in a wide range of organizational functions, in different areas of industry and become widely accepted and necessary in everyday tasks. Spreadsheets are one of the most successful end-user software development tools. End-users are usually domain experts, which are not interested in learning software development methodologies. Consequently, spreadsheet is just perfect for them. Spreadsheet users work in a variety of business functions: finance, engineering, manufacturing, marketing, sales and administration, etc. Many professionals make important decisions based on spreadsheet models and simulation analysis. Organizations rely on them in record keeping, forecasting, analyzing, planning etc. Spreadsheets are extensively used as data storage, manipulation and modelling tool.

Despite overall acceptance of spreadsheets in the areas of business and science, arising question tackles capability of these tools to meet growing needs of contemporary companies and business people. Modern business of digital age implies rise of Big Data and Artificial Intelligence (AI), as well as mobile and tablet computing, for which spreadsheet have not been fully adjusted. This paper is oriented towards key questions related to future directions of spreadsheet development, possible adaptations or adjustments and alternatives for these technologies. The paper presents examples of: spreadsheet enhancement for stream processing and streaming data handling, a virtual space for tabular data exchange that exploits the typical permanent asymmetric cell links supported by spreadsheets, a platform for distributed spreadsheet collaboration and composition and a framework that implements requirements for spreadsheet-based service composition.

Starting from this point, the paper is organized as follows. Section 2 presents and describes some of the most important spreadsheet application fields. Section 3 points out some of the challenges that modern business puts ahead of spreadsheet users, which consequently lead to responses to those challenges through developed spreadsheet solutions described in Section 4. Finally, the last section relates to conclusions and summary of all the above mentioned.

2. APPLICATION AREAS OF SPREADSHEETS

Spreadsheets imply diverse areas of application. Initially, creation and development of this program was directed to accounting and finance. Even more, according to Power (2004), the name itself originates from the accounting jargon: "A *spread sheet* is a large sheet of paper with columns and rows that organizes data about transactions for a business person to examine. It spreads or shows all of the costs, income, taxes, and

other related data on a single sheet of paper for a manager to examine when making a decision". Although application area is significantly expanded, spreadsheets still represent inevitable tools in accounting and finance field. Having in mind that the role of the management accountant has shifted from capturing and recording transactions to business issues analyzing, preparing of financial ledgers and comprehensive reports are almost impossible without spreadsheet solutions (Spraakman et al., 2015). Spreadsheets are inevitable tools for traditional responsibilities such as planning, budgeting, forecasting as well as newer decision-making responsibilities (Bradbard et al, 2014). Despite ubiquity in this area, numerous experiments show that spreadsheets can be very dangerous for business, because of their error-proneness (Caulkins et al., 2007; Panko, 2005, Panko & Aurigemma, 2010, Powell et. al., 2008). Within European Spreadsheet Risk Interest Group (EuSpRiG) conferences a lot of significant evidences about spreadsheet errors that caused huge financial losses have been collected and presented over the last fifteen years (European Spreadsheet Risks Interest Group - spreadsheet risk management and solutions conference, n.d.). Consequently, spreadsheet risk awareness has been significantly increased and researchers have proposed a number of techniques and automated tools aimed at supporting end-users in the development and usage of error-free spreadsheets (Jannach et al., 2014).

Spreadsheet applicability can be considered from the aspect of logistics and supply chain management. Supply chain problems can be effectively presented and analyzed in spreadsheets. Spreadsheet can be appropriate environment for implementation of different analytical methods, aimed at obtaining of the feasible and practicable solutions (Smith, 2003). The use of spreadsheets as decision making software tool for logistics is driven by the need to optimize and integrate the supply chain. These tools are effective in determining the optimum number of distribution locations, the appropriate mix of transportation modes, production scheduling, inventory optimization, product rationalization, strategic planning exercises, etc. In comparison to the specialized logistics software, spreadsheets provide required flexibility through the analysis from many different perspectives. These models can be easily modified and enhanced in order to reflect new situations and options. The user can add complexity to the model, in compliance with the increase of experience and knowledge about the process. Spreadsheets may implement simulation or optimisation models or both in the same time. Understanding of spreadsheet simulation models represents a basis for understanding of different logistics problems, which is important for practical investigations or for further shifting to special software (Djordjevic & Vasiljevic, 2013). Of course, complex logistics or supply chain problems require advance knowledge of spreadsheet modelling and domain knowledge. Although this can be considered as one of disadvantages, because of spreadsheet popularity which is partially based on the ease of usage without formal programming education, an alternatives of spreadsheet modelling and simulation require much longer learning curve. Logistics and supply chain managers are usually more familiar with spreadsheets then with programming languages. Additionally, errors in such models may cause inconceivable consequences.

Spreadsheets are related to engineering area, too. They have become accepted computational tool and a powerful platform for engineering calculations. Relatively simple and flexible development, the use of named ranges and labels that enhance readability of formulas and ability to manipulate matrices have contributed to the popularity of spreadsheets in this field. The use of macros for looping and other high-level programming needs, and its widespread availability and portability also promoted its acceptability (Oke, 2004). Considering wider area there are many examples: use of spreadsheet programs in electromagnetic (Yamani & Kharab, 2001), complex multidisciplinary engineering models implemented as spreadsheet models (Birch et al., 2014) business modelling in spreadsheet (Leong & Cheong, 2008), spreadsheets for operations research problems (Munisamy, 2009), production planning (Walton & Metters, 2008) and production research in spreadsheets (Johnson, 2002), spreadsheet simulation models as a platform for understanding of discrete events and system dynamics (Robinson, 2003), etc. Another significant advantage, provided by spreadsheets, is research modeling. Spreadsheet research modeling can be defined as a usage of spreadsheet program as a tool for structuring, exploring and understanding of different engineering problems. In this manner, modeling process enables cognition of key questions, problem redefining, construction of main logic and even a solution obtaining.

When it comes to the field of education, it is necessary to highlight usability and adaptability of spreadsheets. Examples of successful integration of spreadsheets and different subject curriculum are numerous: management science courses (Grossman, 2006), operations management (Gardner, 2008), logistics management (Djordjevic & Vasiljevic, 2013), engineering education (Oke, 2004), business modelling (Leong & Cheong, 2008), finance and accounting (Howcroft, 2006; Willis, 2016), decision modelling (Regan, 2005; 2006), decision support systems (Palocsay & Markham, 2002), etc. Spreadsheets enhance the collaborative component of education, with an increased focus on the learning process. These applications reduce the need for tedious calculations allowing greater attention to be focused on the subject itself. Even more, students are encouraged to design and develop their own templates and models in each content area, aimed at problem solving and decisions making based on quantified evidence. Spreadsheets enable motivating of

students. Students can model problems by themselves quickly, in that way understanding of problems is easier, and very important, students can see result of their work in the short time (Đorđević et al., 2017). In spite of the overall acceptance of spreadsheets in educational area, methods of incorporating spreadsheets in curriculum are often questionable. There is a common misperception that spreadsheets are somehow "easy" to use. However, the spreadsheet is a powerful rapid development computer programming language that requires software engineering for serious work. People struggle to efficiently build effective, transferable spreadsheet models. Students need certain spreadsheet engineering principles that they do not know, but value highly when they learn them (Grossman, 2006). According to Grossman (2006), spreadsheet engineering education should be considered as a hierarchical model where levels are: skills, capabilities and practices. Additionally, spreadsheet management principles and standards related to documentation, usage, modification, sharing and archiving are often not included in the content of the curriculum.

Certainly, beside described spreadsheet application areas, there are many others. According to research presented in Baker (2006), which included almost 1600 respondents, spreadsheet end-users work in a variety of business functions: finance, engineering, manufacturing, marketing, sales, administration, etc. Interesting example of spreadsheet prevalence, presented in Iyengar & Svirbely (2005), includes even medical-related spreadsheets, where MS Excel spreadsheets encoding medical algorithms from 45 different areas of medical practice.

3. CHALLENGES OF CONTEMPORARY BUSINESS WORLD

It is indisputable that essential spreadsheet features have enabled overall success and acceptance of this technology, over the past three decades. However those characteristics are also the cause of a number of constraints and challenges. Spreadsheet error-proneness represents burning issue in the professional and research communities. Errors caused by insufficient user's knowledge or even simple omission are easy to make but difficult to detect. Further, spreadsheet models are usually developed in an informal manner, intuitive, without any formal rules, standards and good design practices as well, which consequently leads to erroneous spreadsheets and bad decisions. Bad decisions caused by spreadsheet errors results it financial losses, business failure or industry and research horror stories (Croll, 2009; Thorne, 2013; Herndon et al., 2014). As it is previously mentioned, there are many researches proposing a number of techniques and automated tools aimed at supporting end-users in the development and usage of error-free spreadsheets (Jannach et al., 2014). Furthermore, high error rate is consequence of hidden underlying structure of spreadsheet models. Understanding of wider hidden structure, especially when formulas interact across worksheets is quite difficult.

Although spreadsheet represents one of the favourite tools of end-users, because they are enabled to build their own supporting software tools, which directly encode their expertise, this same ability may cause problems. Usually, end-users are not professional programmers familiar with software development methodologies and standards. Professional programmers understand the difficulties of creating error-free code and they are trained to avoid errors (Powell et al., 2009). Spreadsheet developers are mostly self-taught and consequently less aware of dangers that errors pose. Additionally, end-users often don't have "clear picture" about spreadsheet model structure and elements.

Another important constraint of spreadsheet technology is limited scale. According to Birch (2018) "Current spreadsheets are unable to scale to support large datasets which are increasingly encountered. While the maximum number of rows Microsoft Excel supports has increased from 65536 (2^{16}) to 1,048,576 (2^{20}) over the last decade, this limit is still frequently less than the data encountered and which professionals seek to gain insight from".

In addition to the existing restrictions, contemporary business sets new challenges for spreadsheet tools. Challenges, which include Big Data analytics, end-user computing, mobile computing, digital business, cloud computing, unquestionably shape the evolution and use of spreadsheet technology. Increased volume of data requires external databases or files or APIs, while spreadsheet should provide new mechanisms for working with such data. Another interesting idea considers extraction of algorithms from spreadsheet and application over data in the cloud. Data analyzes should be extended beyond structured numeric data, in accordance with heterogeneous and unreliable data. Although, spreadsheet data analysis tools constantly evolves, further incorporation of machine learning algorithms for classification of data or advanced statistical tools for model testing, is necessary. Certainly, cloud based spreadsheets are already all around us and this direction is the opportunity for the large amounts of computing to be applied to models, as well as online collaboration and joint analyzes. However, online spreadsheets open new questions related to multi-user editing, shared workbooks and overall security and accuracy issues.

Considering fast-growing changes in technology, increased need for processing large amount of data and all the above mentioned, there comes up a question “How can we make the most of it by using spreadsheets and is this technology appropriate in contemporary business environment?”. In order to satisfy needs of modern users, related to data processing, spreadsheet technology is directed toward modification. Following section represents some of new, alternative manners of developing spreadsheets, aimed at keeping up with new technologies and tasks that modern business puts ahead of it.

4. NEW DIRECTIONS OF SPREADSHEET DEVELOPMENT

People are still struggling to respond to the challenges of modern business of digital age, using only spreadsheets. In accordance with the needs those challenges bring up, many authors developed spreadsheets in order to adapt them to these needs. This section presents some of the new, and in some sense alternative directions of developing spreadsheet technology which can keep up with the challenges of nowadays business.

4.1. A Spreadsheet Model for Handling Streaming Data

Considering the fact that nowadays data analysts often have a need to work with some real-time data such as market orders, news feed, sensor network data etc. appropriate tool for working with this type of data is necessity. This data usually originated from web and in order to use it one has to write a complex code which provides streaming of real-time data. Even though creating these types of tools, which provide streaming data from web and possibility of manipulating with, it requires a lot of time and effort. Additionally one of important flaws is lack of customization. In order to overcome this flaw and to make easier creation of such a tool, authors Chang and Myers (2015) developed a dynamic model using spreadsheet that allows end users to work with streaming data from web data sources. There are a few possibilities that the model provides to its users: first, model allows users to stream data from web without need to preprogram sources of streaming into the tool; second, it presents a design for spreadsheet cell “metadata” which further describes cell’s value with information about source and fetched time and consequently allows user to manipulate streaming data within spreadsheet; and finally it’s possible to pause and restart streaming at any moment. Also, it enables gathering of data from web input elements, such as textboxes on websites. The biggest point of difference of this model is its ability to provide temporal information of time when data are retrieved, whereby user is allowed to manipulate with it in the way he/she wants. This tool is a web application with client-side spreadsheet and a backend server where all of the streamed data is stored.

- The key features of the tool are (Chang & Myers, 2015):
- Creating a data stream in the spreadsheet – in order to do so, the user needs to enter URL in the source pane of the tool, and to select spreadsheet range where data pulled from the web should be shown;
- Manipulation of streaming data by using temporal information – each streamed cell contains metadata for value stored in that particular cell, concretely about its source and fetched time. Consequently, data can be displayed or manipulated by using its value, source and temporal information. In order to access metadata of cell, authors have provided formulas called *FETCHTIME(cellName)* which shows retrieval time of cell and *SELECTBYTIME(startTime, endTime, range)* which returns data in defined range that has been streamed between *startTime* and *endTime*;
- Streaming time control – the user can set when he/she wants data to be streamed;
- Stream data from web input elements – a user can stream data from web UI elements such as textboxes or forms;
- Save and close a spreadsheet – a user has possibility to save a spreadsheet on the server and to choose whether to save streamed data after closing a spreadsheet.

4.2. SpreadComp platform

Nowadays, a lot of organizations, regardless their size, use spreadsheets in order to process data of some critical business processes. Data processed in such a way usually have to be shared between some employees whereby spreadsheet-based “distributive workflow” has to be created (Mangiante, Maresca & Roncarolo, 2012). To make it possible, there has to be created collaborative way of working with these spreadsheets among employees within organization. It could be performed by using cross-spreadsheet links, manual techniques (copy and paste) or by sharing spreadsheets through e-mail. All of these mentioned possibilities have many flaws in domain of various kinds of errors, security and data loss. Authors of *SpreadComp* (Mangiante, Maresca & Roncarolo, 2012) state that spreadsheet users should not work with tools other than spreadsheet applications in domain of collaboration. From this perspective, authors created a platform based on three collaboration (data sharing) patterns:

1. Flat scenario – the simplest scenario in which user shares data from his spreadsheet with other users via internet network. User selects range of data within his spreadsheet that he/she wants to share and

uploads it to the file which then becomes available to the other users. File is linked to its source, so file gets updated when changes are made in its source. This scenario is base for other two.
2. Reverse peer to peer scenario – case in which user requests other user to provide him data by filling out predefined template in the form of formatted spreadsheet area. After receiving request, data provider fills out template with requested spreadsheet data and sends it back to requester.
3. Composition scenario – this scenario implies a complex collaboration which includes several users and/or templates where is determined from whom the data is provided and who is its consumer.

In order to make collaboration possible, the platform is based on client-server architecture. Client part is in the form of Excel's add-in by which user can control operations of data import and export. *SpreadComp* server communicates with Client Add-In via Web Service which provides a set of functions that allows users to be authenticated and to perform CRUD (Create, Read, Update, Delete) operations on exported/imported data. Server includes spreadsheet engine and enables uploading of a file to a server, aimed at reevaluation of the file as a result of changes in its source, even when the client's Excel file isn't opened. A web application includes platform which enables administrator to manage user accounts and to control whether the whole process is taking place in the right way.

4.3. The Spreadsheet Space

Spreadsheet Space is a virtual space for tabular data sharing that is based on cross-spreadsheet links by which spreadsheets in different systems can be connected. Connection is established through Internet with no limitations. The *Spreadsheet Space* empowers spreadsheet interconnection and allows its users to develop a variety of models based on this technology. One of the biggest advantages of this platform is a power of cloud-based sharing additionally empowered by security of desktop application. In order to provide these abilities synchronization of spreadsheets has to be established, which is implemented by cross-spreadsheet references. Those references present dependencies of cells from different spreadsheets. Because of its dependency, update of a cell in one spreadsheet can trigger updates in other dependent cells which mostly belong to other spreadsheets.

In order to understand how the platform works, the terms "view" and "image" has to be explained. Creating a "view" is associated with choosing element, which can be a cell, a range of cells or table. "View" is created and controlled by spreadsheet user and presents a persistent copy of associated element. "View" is also, constantly synchronized and is only associated with its element. On the other hand, "image" is associated with view and through it, with spreadsheet element itself. Using an "image" other user can obtain data that "view" creator provided. Synchronization among spreadsheets is maintained as a combination of synchronizing between "view" and element, and between "image" and "view".

Exchange of data between users is triggered by requests which are made by users itself. In order to request data sharing, user fills out a form as a formatted cell range, called spreadsheet overlay, and exposes it to other users as a "view". Then, invitation to targeted users is sent with attached form, or forms which they have been requested to fill out or receive. As soon as all the participants have confirmed their participation, data sharing is taking place.

The *Spreadsheet Space* platform uses system which includes the server and client software. The server is responsible for persistency and synchronization, while the clients are associated with spreadsheets and software platforms by which they can participate in *Spreadsheet Space* platform. Users of this platform have pointed out some of the key factors of successful acceptance of its usage, and those are: known interaction patterns, trust and a sense of security.

4.4. Spreadsheets as a Service Composition Tool

There are a lot of spreadsheet users that on a daily basis create their own solutions for automatization of their work within spreadsheets. They are end-user developers because their main job is outside of computer science and they use simple techniques and methods in order to be more efficient during regular work. The main goal of authors (Obrenović & Gašević, 2008) was to enable spreadsheet-based service composition where various services could be achieved by end-users through spreadsheet formulas. In order to do so, authors created *AMICO:CALC*, a framework for end-user spreadsheet-based service composition. It is an extension of middleware platform called *AMICO* which makes easier process of adaptation, abstraction and mediation of various software services. *AMICO:CALC* connects spreadsheets to different software services with simple user interface enabled. Two main parts of *AMICO:CALC* are (Obrenović & Gašević, 2008): middleware for heterogeneous services (which allows choosing and starting diverse services) and spreadsheet extension for service composition (functions for service composition). Compared to other existing solutions, the biggest point of difference of this framework is its wider scope, because it can work with various software services and it integrates additional services. In order to make various service

composition, user can use functions for reading and updating, *AMICO* variables developed by authors Obrenović and Gašević (2008): *AMICO_WRITE(<variable-names>,<values>)* and *AMICO_READ(<variable-name>).* The first one updates variables with given values, while second one updates the spreadsheet when new value is received. These functions allow user to organize the input and output of services. One of the examples of this framework usage is selection of coordinates from Google Maps service to the updates of spreadsheet cells, and then calculation of distance between these coordinates.

5. CONCLUSION

This paper presents some of the most important spreadsheet application areas and in the same time points out some of the major issues and challenges that modern business puts ahead of spreadsheet users. Furthermore, the authors of the paper indicated a few of alternative development directions, which should provide the answer to the question whether spreadsheet can "survive" in the future. Described newly developed spreadsheet solutions include handling streaming data, collaborative work within spreadsheets and end-user spreadsheet-based service composition.

At the present time, it cannot be known for sure weather elements necessary for spreadsheet improvement going to become regular part of the software or external complimentary tools. All of that imposes another new challenge for spreadsheet users, who will be oriented toward permanent learning of additional tools and effective usage of them. In the same time, spreadsheet should remain simple and flexible tool for working with data, analyzing and modeling. Indisputably, development of spreadsheets has to driven by the needs of modern business. Spreadsheets can keep up with the challenges of contemporary business world only by further development of this technology. In a view of modification of existing technologies and their adaptation to the needs of modern business, spreadsheets are very convenient, because of their widely user-acceptance and possibilities for end-user development, which allows creating models and applications by users whose main job is outside of computer science. Regardless organization size, presented spreadsheet solutions are very useful for all of those who are processing a large amount of data on a regular basis and want to use well known and easy to learn software for analyzing their business processes.

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THE S&OP: PRACTICAL AND ADVANCED MID-TERM PRODUCTION PLANNING

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Abstract: *This paper aims to present and explore the process of Sales and Operations Planning in production companies in Serbia. The Sales and Operations Planning (S&OP) is practical and advanced mid-term planning process where company define production planning strategy to fit intermediate-range demand from market and production capacities. The paper outlines S&OP process according to applicable view from company managers and executives and the advanced view from management science. Besides, this process is described from the organisational point of view, i.e. hierarchy and connection among S&OP activities and people who participate in them. The result of the S&OP process is the plan that determines aggregate levels of production. Furthermore, the sales and operations plan links strategic company goals to production and coordinates the various planning efforts in a business, including: marketing planning, financial planning, operations planning, human resource planning, customer lead time (backlog) planning, new product development planning. The select part of this paper is dedicated to advanced concepts in S&OP where techniques of mathematical programming dominate. In addition, the author also presents the level of S&OP application in SME and large companies in Serbia and benefits of S&OP implementation on enterprises performance.*

Keywords*: Sales and operations planning (S&OP), aggregate production planning, advanced production planning, mixed integer programming, production companies in Serbia.*

1. INTRODUCTION

If we ask the management of a company, what would be the ideal sales and production plan, the answer will be fixed for the longer period. Fluctuations in business impose problems for managers to continuous review the defined plans. Adjustment of demand and supply (by the quantity and mix) must be on the short, medium and long-term, of course with best enterprise performance. Demand and supply synchronisation is determined through forecasting sales, capacity planning, production volume, workforce level, inventory planning, procurement, marketing, logistic, and other value chain activities.

This paper presents the concept of sales and operations planning (S&OP) process that helps managers to find the midterm solution for the balance between forecasting of customers' sales and enterprises business operations and capacities. The S&OP is defined as making intermediate-range decision to balance supply and demand, integrating sales, financial and operations planning (*Stevenson*, 2009, str. 611). From a manufacturing perspective, the S&OP provides the basis to focus the detailed production resources on achieving the firm's strategic objectives (*Vollmann et al*. 2005, p. 61). Similarly, *Gansterer* (2015) name this process as aggregate production planning, with the meaning of balancing capacity requirements and production quantities for medium-term planning horizons. The S&OP helps managers to obtain answers on these issues: the mid-term sales forecasting, mid-term flexibility of operations and their capacity, the key milestones in rolling planning horizons, different scenarios and actions for adverse events (*Vollmann et al*. 2005, str. 80). *Jelačić* (2017, p. 25) defined the S&OP as a very important tool, particularly for integrated business planning (marketing, operations, finance) and media for connection of strategic plan with daily business operations.

The S&OP problem in this paper is considered from two sides of view on this problem. The First view is the practical process of adjustment managerial decision about planning business operation. The second view presents the scientific answer to this problem with mathematical models which aim is to provide support in the decision making process. This paper is structured as follows: After the introduction, section 2 presents the concept of S&OP. Section 3 describes the organisation of this process as well as the small survey on the S&OP application in Serbian companies. Section 4 presents the advanced concepts of S&OP. Section 5 concludes the paper.

2. SALES AND OPERATIONS PLANNING

The Sales and Operations Planning (S&OP) is probably the least understood aspect of manufacturing planning and control. However, the outcomes from a well-designed and well-executed the S&OP are huge (*Vollmann et al.*, 2005, p. 60). The S&OP is positioned between strategic and operational planning level. Actually, the S&OP is like a tactical level of planning for the period from one to 18 months. In the S&OP, planning impulse comes from strategic level (top-down) and then continues to the Master Production Schedule (MPS), from the other side, input data for planning, analysis and making decisions, comes from the bottom-up side.

The S&OP links company's strategic goals to production and coordinates the various planning efforts in a business, including marketing planning, financial planning, operations planning, human resource planning, etc. If the sales and operations plan does not represent an integrated, cross-functional plan, the business can fail to succeed in its markets. (*Vollmann et al.* 2005, p. 60). The S&OP also provides the key communication links for top management to coordinate the various business planning activities (strategic planning, marketing planning, resource planning, financial planning, demand planning). Figure 1 shows the S&OP main connection (*Vollmann et al*. 2005, p. 61). Marketing initiatives dealing with entry of a new product in the market can be coordinated with an increase in production capacity to support the marketing plans. At the same time, financial resources are organised to maintain the working capital for the inventories.

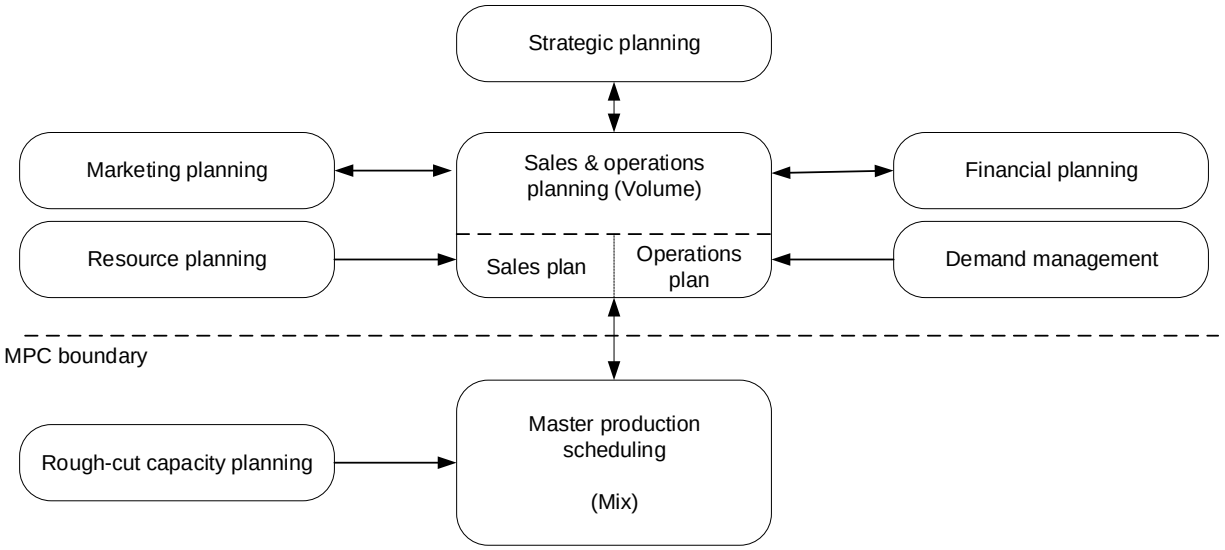

Figure 1: Key linkages in S&OP (*Vollmann et al.* 2005, p. 61)

Figure 1 also shows the S&OP link with demand management, which is realised through order entry, order promising, physical distribution and forecasting. The S&OP link with resource planning is achieved through capacity and material requirements (raw materials, parts, subassemblies). The S&OP is a process for determining aggregate levels of production, and it provides the framework within which the Master Production Schedule (MPS) is developed. Subsequent the MPS decisions can be planned and controlled, and material resources and plant capacities can be coordinated in ways that are consistent with strategic business objectives (*Vollmann et al.* 2005, p. 61). The S&OP links with the MPS and resource planning provide the essential data for what-if simulations of alternative plans. In that manner, quick evaluation of alternatives can facilitate the S&OP process.

There are four fundamental dimensions in S&OP: demand, supply, volume and mix. When demand exceeds supply, customer service decrease because manufacturing cannot provide the number of products required by a customer. Consequently, cost increase due to overtime, and quality suffers. Similarly, when supply goes beyond the demand, the effects are the following: inventories rise because of an imbalance between demand and manufacturing capacity; layoffs of workers results from production rate reduction and plant efficiency drops (*Vollmann et al. 2005*, p. 61). The primary goal is to maintain a proper balance between demand and supply and to provide early warning signals when they are becoming unbalanced (*Vollmann et al. 2005*, p. 61).

Two other fundamentals are volume and mix. The volume concerns big-picture decision about how much to make and the production rates for product families, while the mix concerns decisions about which individual products to make, in what sequence and for which customer order. Smart companies carefully plan their volumes first and then focus on mix decisions. If the amounts are efficiently planned, mix decisions become

much more comfortable to cope with (*Vollmann et al.* 2005, p. 62). The volume concerns rates: overall sales rates, production rates, aggregate inventories, and order backlogs. Unlike the MPS, the planning object in the S&OP is significant product families (a group of products that have similar characteristics), and the planning horizon is typical 15 to 18 months (*Olhager*, 2013). One of the S&OP issues is product families' determination, i.e. defining how many groups of product to consider in developing the sales and operations plan. *Vollmann et al.* (2005, p. 78), recommended six to twelve families. As a result of adequate volume planning the problem of the mix (individual products, orders and SKUs) in the MPS become more easier. Then, the MPS is a result of disaggregation of the S&OP process (*Vogel, Almada-Lobo, & Almeder*, 2017), where we defined the time for production and quantity of individual products. The MPS is base for further detailed planning activities: material requirements planning, job scheduling, raw material and components ordering, production dispatching (*Ivanov, Tsipoulanidis, & Schönberger*, 2017). The MPS might be stated in units that use particular bills of material to manage complicated operations and do not correspond to the units to communicate with top management (*Vollmann* et al. 2005, p. 63). However, the S&OP has that role of communication.

Figure 1 also presents that, the S&OP is divided on the operations plan (OP) and sales plan (SP). The OP is the planned production stated on the aggregate basis, for which manufacturing management is to be held responsible. The SP is base on a forecast of demand. The operations plan does not have to be equal to an estimate of aggregate demand. According to *Vollmann* et al. (2005, p. 63), it is not always profitable to satisfy all of the demand in a peak monthly period, but production would be levelled over the course of a seasonal cycle. Likewise, a strategic objective of improved customer service may result in the aggregate production more than aggregate demand.

The S&OP process in the literature (*Heizer & Render*, 2011; *Stevenson*, 2009), is also known as aggregate production planning. The S&OP is perhaps broadly defined because it includes financial planning consideration of operations decision and top management final decisions, however in the central and core part of this process is the domain of aggregate production planning. According to (*Omerbegović-Bijelović*, 2005, p. 69; *Gansterer*, 2015), aggregate production planning (AP), means the plan for aligning the capacity of production with demand in the mid-term, from 3 to 18 months in advance, i.e. determining aggregate volumes and period for production. *Gansterer* (2015) also defined the AP as integrated planning and coordination of enterprise resources (labour workforce, machine and tools capacity, inventories) and demand for quantity of different types of products in times period in which they are produced. Additionally, the AP can be observed for whole value chain of diverse production/service units. The S&OP and AP mechanism consider next decisions production rate, workforce level with hiring and firing, inventories level, overtime and under time production and work, alternative capacity forms such as outside contracting. The primary goal is a minimisation of overall costs (inventory cost, backorders cost, cost of workforce and production) in observing period.

Heizer & Render (2011, p. 547), and *Stevenson*, (2009, pp. 616-618) observed two main options in the AP and S&OP:

Capacity options:

a) Change of inventory level – this options is realised through a adjust of inventory level as a result of demand fluctuation and constant level of production. The advantage of this option is constant production level with steady workforce, which influences the stability of production organisation. Disadvantages of this options are: high inventory costs which can be 15-40% of product price (costs of: storage, insurance, manipulation, obsolescence, opportunity cost, stockout cost, cost of non-satisfied demand);
b) Change of workforce level (hire and lay off workers) and consequently change of production rate – one way for balancing among production and demand is constant correction of production and workforce level according to demand. The advantage of this options is the minimisation of overproduction and inventory cost. The disadvantages of this option are workforce fluctuation, which result of cost of training for rookies and severance pay for firing people. Also, the productivity of newly hires people, not on a high level. The Layoff is a process of omission people with knowledge and experience. Change of workforce level also means overtime, slack time, part time and under time work of employees. *Imai* (2017, p. 244) stated that in some industries in Japan, part-time or under time workers make 50% of total workforce. Part-time and seasonal workers are mainly present in the service sector.
c) Subcontracting – Enterprise subcontract jobs with other similar enterprises during period of increased demand. This option takes the risk of product quality and delivery time as well as customer cession to another enterprise form the same industry.

Demand options:

a) Influence on demand – when the forecasted demand is at the lower level than production capacity, demand can be increased with the impact of marketing mix elements (product, price, promotion, and place).

b) Backorders – in a period of increased demand, an enterprise can accept orders with longer lead-time to maximise capacity utilisation over the more extended period and to satisfy customers that are willing to wait.
c) A seasonal mix of product – Enterprises adopt portfolio products with complementary demand pattern and this result in its relatively constant demand and capacity utilisation during all time periods.

Enterprises usually combined all mentioned options to defined midterm production strategy which are the essence of S&OP/AP process. Typical basic or pure strategies for meeting uneven demand (*Stevenson*, 2009, p. 618) are:
Chasing demand strategy – implies to match production rate according to forecasted demand period by period. This strategy is realised via next options: production rate change, hire and lay off workers, overtime and undertime.
Level strategy – is achieved through two directions „maintain a level workforce“ and „maintain a steady output rate”. As a result of this strategy, we have inventory change, growth and decline, from period to period.

Beside two pure strategies, in practice there much more mix of this two strategies through a combination of different options (a, b, c) and their decision variables, to obtain minimal costs in the planning period. The S&OP/AP strategy with minimal costs, i.e. optimal strategy is not always easy to find. However, different methods and techniques help in finding an optimal strategy (*Thomé et al*., 2012). General procedure for realizing the AP, according to *Stevenson* (2009, p. 618), include next steps: 1) Forecast demand for each period; 2) Determine capacities for each period (regular, overtime, subcontract); 3) Identify company or department policies that are pertinent; 4) Determine unit costs (workforce, inventory, production rate); 5) Develop alternative plans and their costs; 6) Select the plan that best satisfies objectives, otherwise return to step 5.

3. ORGANISATION AND APPLICATION OF S&OP PROCESS

If we ask the management of a company, what is the S&OP process, they will replay that this is the process of making mid-term planning decisions, which coordinate sales and production activities with forecasted demand and market requirements. The S&OP is the process that is realised through a series of cyclically held meetings, which are maintaining at different levels and among different sectors. The S&OP aim is a generation of precisely defined and relevant information (plans, indicators and performances) for management decision making (*Đorđević*, 2017., p. 44). Hence, in the process of making mid-term strategy, i.e. plan, representatives of various organisational units participate (demand and supply manager, production manager, purchasing manager, financial manager and CEO). The S&OP cycle is present, in Figure 2, with following types of meeting:
Product review – within this meeting, product range/portfolio are revised, new products, which will be launched in next period, are eventually defined. Furthermore, the particular brand performances, as well as future marketing activities, are reviewed.
Demand review – within this meeting, sales department estimate demand volumes in general time periods. The base for this activity is information about the market, its potential growth and decline, and sophisticated method for forecasting future demand.
Supply review – this meeting prepare the answer, as a result of the previously defined information. Results of this meeting are outlined midterm production and supply strategy and scenarios. The critical issues for this phase are: Can we produce already defined products? Can we satisfy sales through production and supply? Are there enough capacity to meet forecasted demand? Are the supply costs adequate? The result of supply review meeting is production strategy, which includes the balance of production resources and inventory levels with customer service level.
Financial review – aims to harmonise and approved all previously defined assumptions, analysis, and decisions, with business indicators (costs of supply, profit, investment, and cash flow).
Top management business review – the purpose of this top management meeting is to defined final strategy, i.e. midterm plan, which is based on all other decisions from previous phases. This review is not the end of the S&OP process. The S&OP is rolling and continual planning process, which is realised once a month. Like each other planning process, it needs to adjust to specifics of particular company or industry.
Types of meetings, their agenda and frequencies are not fixed defined. Moreover, the development of the S&OP process and it’s primary activities may be different which depend on organisation implementation of this process. *Lapide* (2005 p. 14) presents in detailed the Maturity model of the S&OP process implementation with next four stages: marginal process, rudimentary process, classic process, ideal process. The difference of this four stages of the Maturity model refers to formality and integration of planning process, level of organisation of planning process, use of IT, and collaboration with other value chain participants.

To examine the level of production planning development, and the S&OP application we surveyed large, small, and medium-sized production enterprises in the Republic of Serbia. In the period from September and November 2017, we examine 79 production companies with the self-administered questionnaire. Here we present the small part of the survey with relevant questions for S&OP topic: the organisation level of planning process, the integration level of planning process, the application of aggregation planning method. The primary respondent groups were owners and employees (operations manager and planers) from production enterprises. The enterprises were from next categories by size: 29 are from the category of large enterprises, 53 are SMEs. Mean value of the total number of employees, in surveyed enterprises, was (M = 226), with standard deviation (SD = 335.7). Surveyed enterprises were from the following categories, observing the type of manufacturing process: 39 enterprises from make-to-order category, seven from engineering-to-order, and 32 from make-to-stock category.

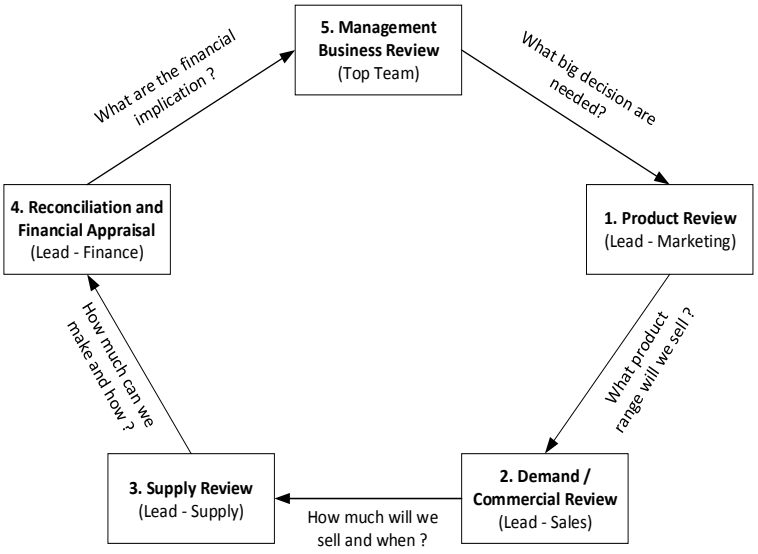

Figure 2: The S&OP cycle with different meetings (*Đorđević*, 2017., p. 44):

The significant questions in the survey about the level of production planning development were:
The organization of production planning process, the scale with next levels: 1 – Plans are created by owner/manager of company; 2 – plans are created by production managers 3 – plans are designed by group of production managers and planers; 4 – During the planning process, decisions are coordinate with other organizational units (marketing, finance, HR); 5 - During the planning process, decisions are coordinate with other value chain participants.
The integration of production planning process within the entire enterprise planning system, have next levels: 1 – planning activities are not connected and there is no interchange of data within the planning system; 2 – planning activities are connected, the data interchange is realized manually, by physical data input into forms and tables; 3 – planning activities are connected, the data interchange is realised across spreadsheet tools (e.g. MS Excel tables); 4 – planning activities are connected, the data interchange are obtained across automated electronic data interchange system (EDI); 5 – planning activities are connected, the data interchange is obtained across totally automated and integrated planning system within ERP software;
The application of aggregate production planning method the scale with next levels: 1 – have not heard about the mentioned method; 2 – have heard about the mentioned method, still do not use it; 3 – have heard about the mentioned method and you plan to implement it; 4 - have heard about the mentioned method, and you use it occasionally in production planning; 5 - have heard about mentioned method, and you use it frequently in production planning.

Table 1: Survey results

Observed variables and their values (1-5 scale)	Mean (M)	Standard deviation (SD)
The organisation level of the planning process	3,18	1,52
The integration level of the planning process	3,09	1,12
The application of aggregate production planning method	1,65	1,16

The survey results on the sample of 79 enterprises in Serbia are presented in Table 1, in the form of mean values (M) and standard deviation (SD) in respondents answers on previously defined questions.

First, we present result about organisation level of production planning process. The results obtained on the observed sample (N = 79), shows that the organisation level is on average (*M* = 3,18; *SD* = 1,52). This result indicates that, on average, there is a group production planning by the team of managers and planers. However, the plans are not in tune with other organisational units and sectors, which is the case in the S&OP process. The second result was about integration level of production planning process. Among surveyed enterprises in Serbia, integration of production planning process was on the average level (*M* = 3,09; *SD* = 1,12). More precisely, it means that particular activities in the production planning process are connected, and the data are interchange across spreadsheet tools. This results point out that there is still more opportunity for improving the level of production planning development at Serbian enterprises, as well as the S&OP is still a big challenge for implementation. As regards to application of aggregate production planning, results show the very modest level of implementation in surveyed Serbian enterprises. The average values (*M* = 1,65; *SD* = 1,16), in the studied sample, were among questionnaire statement about ignorance and just conversance of this method without any implementation.

Notwithstanding that survey results, which presents the condition of Serbian enterprises, were not favourable, *Đorđević* (2017, p. 46), show numerous advantages of the S&OP implementation in case of some companies. Table 2 presents benefits in the form of quantitative indicators. The same author (*Đorđević*, 2017, p. 46) stated the next qualitative indicators of advantage in S&OP implementation: reduction of redundant activities, better response to customer requirements, employees' teamwork, increases the level of responsibility.

Table 2: Benefits of implementing the S&OP process. Source: *Đorđević* (2017, p. 46)

No	Benefit	Value difference (Δ)	direction
1.	Profit margin	5,5-8,5%	↗ increase
2.	Sales forecast accuracy	42-84%	↗ increase
3.	Raw material and finished goods inventory	25-31%	↘ reduction
4.	Obsolescence of product	31-40%	↘ reduction
5.	Stock-out	46%	↘ reduction
6.	Planning delivery time	25%	↘ reduction
No	**Benefit**	**Value level**	
1.	Service level (OTIF)	82-91%	

The particularly significant benefit of the S&OP process is obtained strategy of production resource capacity adjustment. Different decisions about production capacity adjustment have a different period. For example, decisions about expansions of production capacities, through purchasing of new production equipment, machines, can be realised in a few months. On the contrary, an introduction of new shift schedule with new engage workers and overtime work is a decision that can be achieved in the short term, several days in advance. Depending on a difference between required capacity (which is defined across demand) and available capacity (which is a consequence of machine and workforce condition), it is necessary to identify recommendation for increasing available capacity. Examples are increase of Overall Equipment Effectiveness, purchasing of new equipment, machines and tools, new workforce shift plan, subcontracting, investments in new production facilities.

Plans that are adopted in the S&OP process are further transfer to master production schedule (MPS), where the product mix and precise volumes by every SKU are defined, and rough schedule by production line in time. Bearing in mind that capacity of different value chain participant may limit the capacity of leading manufacturer, adequate information from the S&OP process at the right moment, may be of crucial importance. In that manner, the S&OP and aggregate planning found its importance in planning of other activities in the value chain.

The S&OP processes primarily use internal supply-demand data (customer orders, shipments, on-hand inventories, and production capacities) as inputs. More recently, external information from other value chain participants (using the concepts: Vendor Managed Inventories (VMI), Collaborative Planning, Forecasting, and Replenishment (CPFR), Point of Sale (POS)), provide for every company, external information about future supply and demand. (*Lapide*, 2004).

3. ADVANCED CONCEPTS OF THE S&OP PROCESS

In the S&OP there is the strong need for modelling determination of the best mid-term production planning strategy with mathematical programming techniques. This part of the paper presents the advanced approach for modelling aggregate production and inventory planning which is the result of the S&OP process. For mathematical modelling in the S&OP process, it is particularly important to define following parameters in every period: production rate, sales forecast, the method for determining costs, the volume of workforce and

their production rate. In the next model of mixed integer programming (*Vollmann et al.* 2005, p. 415), the aggregate plan is determined on a product family basis. The product families are defined as groupings of products that share common manufacturing facilities and setup times. In this case, overall production, workforce, and inventory plans for the company are mostly the summation of the plans for individual product lines. The mixed integer programming mathematical model provides one method for determining the number of units to be produced in each product family, in each period. The goal is to find the best aggregate plan with the lowest value of criteria function, i.e. total cost function.

$$min \sum_{i=1}^{n}\sum_{t=1}^{m}\left(C_{si}\sigma\left(X_{it}\right)+C_{mi}X_{it}+C_{Ii}X_{it}\right)+\sum\left(C_H H_t+C_F F_t+C_o O_t+A_{1t}C_R W_t\right) \quad (1)$$

subject to

$$I_{i,t-1}-I_{it}+X_{it}=D_{it} \quad \left(for\ I=1,...,n\ and\ T=1,...,m\right) \quad (2)$$

$$A_{1t}W_t+O_t-\sum_{i=1}^{n}X_{it}-\sum_{i=1}^{n}\beta_i\sigma\left(X_{it}\right)\geq 0 \quad \left(for\ t=1,...,m\right) \quad (3)$$

$$W_t-W_{t-1}-H_t+F_t=0 \quad \left(for\ t=1,...,m\right) \quad (4)$$

$$O_t-A_{2t}W_t\leq 0 \quad \left(for\ t=1,...,m\right) \quad (5)$$

$$-Q_i\sigma(X_{it})+X_{it}\leq 0 \quad \left(for\ t=1,...,m\ and\ I=1,...,n\right) \quad (6)$$

$$\sigma\left(X_{it}\right)=\begin{Bmatrix}1 & if\ X_{it}>0\\ 0 & if\ X_{it}=0\end{Bmatrix} \quad (7)$$

$$X_{it},I_t,H_t,F_t,O_t,W_t\geq 0 \quad \left(for\ t=1,...,m\right) \quad (8)$$

$$Q_i=A,\quad Q_i\geq\sum_{t=1}^{m}D_{it} \quad (9)$$

Where:

X_{it} - Production in hours of product family *i* scheduled in month *t*.

I_{it} - The hours of product family *i* stored in inventory in month *t*.

D_{it} - The hours of product family *i* demanded in month *t*.

H_t - The number of employees hired in month *t.*

F_t - The number of employees fired in month *t.*

O_t - The overtime production hours in month *t.*

W_t - The number of people employed on regular time in month *t.*

$\sigma(X_{it})$ - The binary setup variable for product family *i* in month *t.*

C_{si} - The setup cost of product family *i*.

C_{Ii} - Inventory carrying cost per month of one labour-hour of work for product family *i*.

C_{mi} - The material cost per hour of production of family *i*.

C_H - The hiring cost per employee.

C_F - The firing cost per employee.

C_o - The overtime cost per employee hour.

C_R - Regular time workforce cost per cost per employee hour.

A_{1t} - The maximum number of regular-time hours to be worked per employee in month *t*.

β_i - Setup time for product family *i*.

A_{2t} - The maximum number of overtime hours per employee in month *t*.

n - The number of product families.

m - The number of months in the planning horizons.

$Q_i = A$ - Large number used to ensure the effects of binary setup variables;

The criteria function (1) presents the total cost function, which includes cost of regular workforce, cost of hire and fire, cost of inventory on hold, cost of overtime and undertime, cost of setup time. Following explanations of constraints in the mathematical model is presented: (2) inventory constraints; (3) production and setup constraints; (4) workforce level change constraints; (5) overtime constraints; (6) setup constraints; (7) binary constraints for setup. Furthermore, constraints (6) and (7) in mathematical model assumes all the setups for product family occurs in the month in which the end product is to be completed. Constraint (7) is a surrogate constraint for the binary variables used in constraint 6. This constraint forces $\sigma(X_{it})$ to be nonzero when $X_{it}>0$, since Q_i is defined as at least the total demand for a product family over the planning horizon; (8) nonnegative constraints. Additional constraints should be added to the model to specify the initial conditions as the start of the planning horizon; that is, constraints specifying beginning inventory for the product family I_{io}, and workforce level in the previous month W_o, are required. Likewise, constraints defining workforce level at the end of the planning horizon, and minimum required closing inventory balance at the end of each month in the planning horizon may be added.

4. CONCLUSION

This paper presents Sales and Operations Planning (S&OP) process from the production-planning point of view. After the detailed introduction of the S&OP concept, this paper presents the survey on level of production planning development and implementation of S&OP concept in enterprises in Serbia. The results show that this concept is on the low level of application. Furthermore, the process of production planning in Serbian companies is at the middle level of planning organisation and integration. These results show that there are much more challenges for improvement. Additionally, the S&OP is still the big issue for Serbian enterprises. The particular part of the paper is dedicated to the advanced concept of the S&OP. It tries to find answer on following question: How can aggregate production planning can be modelled using mathematical programming technique? The author presents the model of mixed-integer programming. Further research in this field of study should focus on detail analysis of the S&OP implementation level in Serbian companies. Also, the author intends to apply the proposed mathematical model in real business practice.

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DEVELOPMENT OF A MODEL FOR DETERMINING THE NUMBER AND PLACEMENT OF ACCESS POINTS TOTHE PUBLIC POSTAL OPERATOR NETWORK

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Abstract: *This paper shows a developed methodology for defining access points to the Public Postal Operator (PPO) network. Based on an analysis of postal services market, which has shown the ongoing process of liberalization in the Republic of Serbia (RS), we have suggested a methodology for determining the number and placement of access points; this method will ensure the universal postal service (UPS) throughout the whole country and competition in urban and rural areas. The main purpose of the study is to create a dynamic model which will define possible alternatives and set criteria for optimization. In this paper, optimization of access points has been done applying qualitative methods (the Delphi Method and Scenario method) and the method of multiple criteria analysis. Optimal postal network access points will contribute to faster development of e-commerce and goods distribution in the whole country.*

Keywords*: postal network, postal market, access points, liberalization, optimization*

1. INTRODUCTION

Until recently, the postal services sector in the Republic of Serbia was focused primarily on providing traditional postal services (letters and packages). However, the evolution of modern technologies, electronic communications and the Internet have directed the development of postal services towards new e-postal services, e-commerce and digitalization. The postal network, due to its availability and uniqueness, opens up new possibilities for meeting users' needs on the communications market, which gives it a significant role in an overall development in the digital era.

In the Republic of Serbia, the Public Postal Operator is „Post of Serbia“, which is the leader in the field of electronic communications, which is confirmed by CePP - Centre for Post of Serbia E-business. CePP is a multimedia service provider that offers e-services to meet users' needs, while guarantying top protection of electronic transactions and transferred information. CePP offers numerous electronic services, grouped in categories (e-post, e-government, e-finance and e-commerce), and Serbian Post Certification Authority (SPCA) is of great importance because it issues digital certificates, which are intended for all participants of electronic business in the Republic of Serbia, regardless of whether they are legal or natural persons.

Analysis of PPO postal services in the RS shows a constant decrease of letter posts since 2012. The number of letters in 2016 dropped by 12 million comparing to 2015. The number of packages has also deteriorated greatly over the last few years, whereas the number of express and courier services has grown (Strategy, 2017). Considering that the postal sector is changing fast and that the volume of express services is constantly on the rise, whereas letter posts decreases, it is necessary to redefine and improve many business processes and activities within the postal system, in order to ease the shipping of goods purchased on the Internet and create new possibilities for postal market development.

The level of development of the postal market can be monitored through the UPS share in the total scope of services. According to National Regulatory Authority (NRA), in 2016 the UPS accounted for 91% of all postal services, whereas the revenue of the UPS in 2016 was 49%. This implies that commercial services are very profitable and therefore it is important to stimulate e-commerce, which is expanding in the whole world (Strategy, 2017).
The access is supposed to balance the UPS provision, because the PPO is, unlike other competitors, obliged to provide the UPS (Tehnika, 2017). Determining the number and placement of access points on the PPO network would facilitate the expansion of distributing centres and collection points for online purchased items, which would propel the progress of e-commerce and e-exchange, especially when the RS becomes a member of the EU and the borders are removed. Hence, it is important to offer a unique platform for postal network access, with available parcel collection points, with a developed information communication basis and available PPO resources.

2. POSTAL NETWORK ACCESS IN THE REPUBLIC OF SERBIA

The Directives of European Parliament and Council on the liberalization of the postal market limit the postal monopoly and harmonize the obligations of its members towards the common universal service (Unterberger, 2016). One of the recommendations of Directive 2008, in order to achieve sustainability of the USO, was that *"Member states of the European Union have to adopt measures to ensure access to postal network under transparent, proportionate and non-discriminatory terms, whenever this is necessary in order to protect the interests of users and/or promote effective competition"*(Directive 2008/6/EC)**,** in order to protect the interests of users and ensure continuous, quality and sustainable provision of a universal postal service"(Unterberger, 2016).

Access to the postal network implies that the access user shall receive postal items from postal services users, then give them in at an agreed point of access to the postal network for further routing, transport and delivery to the addresses of the recipients, or to act in the same way with their own items, or to use postal network in which the access user delivers mail to the addressee. The analysis of past experiences in a number of countries that have already defined access to the postal network has shown that the models of access differ and are specific for each country (Unterberger, 2016). Each country based on its demographic, social and economic characteristics, as well as numerous characteristics of the postal services market, defined the access points as well as all other necessary conditions (prices, type and quantity of shipments), but the manner of definition was not determined.

It is known that postal operators can use two basic access models: *upstream* and *downstream* access (Dieke et.al., 2013). Downstream activities require a local network for the delivery of postal items, while all other activities take place upstream. Upstream activities include the acceptance, grouping, sorting, and stamping of mail from different sources, before accessing the public network (ERGP, 2012; ERGP, 2013).

In the Republic of Serbia, the PPO (at the same time the only provider of the UPS) is PublicEnterprise "Post of Serbia", which is comprised of around 1500 post offices covering almost all remote locations. The UPS market is partly liberalized, and postal operators (57 of them on the territory of Serbia in 2016, according to UPU) are given a possibility to provide the universal service without owning a network, except for reserved postal services (letters weighing up to 100 grams, paper and electronic money orders, judicial letters and administrative and misdemeanour procedure letters).

The Republic of Serbia is a candidate for EU membership and the main prerequisite for opening negotiation chapter 3 (Right of establishment and freedom to provide services) is the enforcing of Directive 2008/6/EC, which requires the implementation of postal network access, as well as other activities. Although the access is available in the RS (Ordinance 2014 and Ordinance 2016), no postal operator has actually submitted a Request for accessing the PPO network.

Reasons for this are described in the paper (Unterberger et al.,2016) and an analysis has shown that none of the postal operators is interested in providing the UPS, and that there are multiple factors affecting the postal network access. The first and most important factor is the presence of reserved postal services, as well as operators being insufficiently informed, poor cooperation with NRA. A study in the paper (Šarac et al., 2017) has shown that alpha coefficient values from the point of view of "expected" and "delivered" are fairly similar. The difference between expected and experienced values is quite small ($\alpha_{expected}$= 0,87 i $\alpha_{experienced}$ = 0,86), allowing us to conclude that the public postal network can meet the expected requirements of accessing operators. Analysis of the scenario of a complete market liberalization (access to all UPS) in the paper (Unterberger et al.,2017) envisages a significant increase in the number of postal operators providing UPS (at least five postal operators will provide the UPS).

According to the given scenario, this paper develops a model for determining the number and placement of access points on the PPO network, which will provide access to all users in different places on the network, in a complete market liberalization.

3. METHODOLOGY FOR DETERMINING THE NUMBER AND PLACEMENT OF ACCESS POINTS

For defining a methodology for determining the number and placement of access points on the PPO network, the following steps are suggested:

Step 1: Pinpointing possible alternatives

Step 2: Specifying types and number of criteria

Step 3: Solving a multicriteria task using the Promethee method (determining the type of preference function, relative weight coefficients, etc.)

Step 4: Ranking the alternatives

The research starts with a supposition that all postal network units can also be units for users to access the postal network, because this would meet the criterion of general accessibility as well as sustainability of the UPS.

In the RS all postal network units on the whole national territory are grouped into levels according to their share in business. The criteria for classifying post offices into levels are: average total work per month (in norms of minutes) in the last year and average monthly revenue in the last year (Ordinance, 2015). According to these criteria, all post offices on the RS territory are grouped into: posts out of levels, top level and posts from I to VIII levels.

4. METHODOLOGY IMPLEMENTATION AND DISCUSSING RESULTS

4.1 Pinpointing alternatives

Every multicriteria problem implies a number of alternatives and criteria for ranking and choosing (Nikolić, 2012). Defining alternatives (access points) has been done according to the Ordinance on grouping postal units (Ordinance, 2015) and according the scenario analysis and experts' opinion that access points can also be at start postal units (upstream approach) or at postal units (downstream approach). Apart from defining postal units categories, experts claim that possible access points are also Regional Postal-Logistic Centres (RPLC) and Local Postal-Logistic Centre (LPLC). Twelve alternatives given for dealing with the problem of multicriteria ranking are shown in Table 1.

Table 1: Definition of alternatives (access points) (Unterberger, 2016)

ALTERNATIVE – POINT OF ACCESS			
A1	Posts out of levels – start points	A7	RPLC - start
A2	Posts out of levels –destination points	A8	RPLC –destination
A3	Posts from I to III levels - start	A9	LPLC - start
A4	Posts from I to III levels - destination	A10	LPLC - destination
A5	Posts from IV to VIII levels - start	A11	All posts - start
A6	Posts from IV to VIII levels -destination	A12	All posts - destination

4.2 Defining criteria

The choice of criteria in a multicriteria analysis is a fairly complex and responsible job, because the choice of criteria has a direct effect on the process, and on the final ranking of the alternatives. According to (Radojičić & Žižović, 1998) the choice of criteria is very significant because leaving out a criteria also leaves out some of the requirements for the alternatives, whereas having too many criteria can mean some of them are unnecessary. Therefore, opinions of experts from scientific institutions, Ministry, NRA, and public postal operators in Serbia and Croatia, have been used. The following criteria have been defined:
K1: Number of postal network units
K2: Avoided costs for letters
K3: Avoided costs for packages
K4: Access points capacity
K5: Existing demand for access

K1: Number of postal network units
The number of postal network units is a very important criterion in defining the postal network access, because it provides a necessary condition for the availability of the UPS and the whole postal network. In order to perform the access, the exact number of postal network units has to be defined. The number of postal network units is available and can be determined for each specified alternative, according to the Ordinance on categorizing postal units into levels (Ordinance, 2015).

Based on work-sharing done by operators accessing postal network, there are certain cuts in work, that is, in PPO activities. These cuts are shown in norms of minutes and calculated for "letters" and "packages". The amount of avoided costs depends on the location of access. Letter posts (letters up to 2 kg, insured items and recorded delivery items) and packages in UPS represent the greatest part within the scope of the UPU (Unterberger et al.,2016). Therefore these two types of postal items are referred to as "letters" and "packages". According to the Ordinance on statistics and norms (Ordinance, 2006) in which standardized

timings for all types of mail are given, certain activities for letters, from collecting to delivery, and for packages are selected. The average value of norms of minutes for work operations performed from collecting to delivering letters is 2.68, whereas for packages that value is 3.64.

The results in the paper (Blagojević et al., 2013) indicated the percentage of each technological stage in various services, which is used in the paper for an accurate estimation of activities in certain types of costs. For "letters", collection stage accounts for 15% of costs, outward sorting accounts for 11%, transport for 10%, inward sorting for11%, and delivery for 41%.

Table 2 shows savings which postal operators will have if they use each of the alternatives with letters and packages, which represent avoided costs for the PPO.

Table 2. Cost percentage of each technological process stage for letters and packages (Unterberger, 2016)

Alternative	***Percentage of technological process stages for LETTERS***	*collection* U_{p1} *= 15 %*	*outward sorting* U_{p2} *=11 %*	*transport* U_{p3} *=10 %*	*Inward sorting* U_{p4} *= 11 %*	*delivery* U_{p5} *= 53 %*
	Percentage of technological process stages for PACKAGES	*collection* U_{k1} *=13 %*	*outward sorting* U_{k2} *= 11 %*	*transport* U_{k3} *=24 %*	*Inward sorting* U_{k4} *= 11 %*	*delivery* U_{k5} *= 41 %*
A1	Posts out of levels – start points	√				
A2	Posts out of levels –destination points	√	√	√	√	
A3	Posts from I to III levels - start	√				
A4	Posts from I to III levels - destination	√	√	√	√	
A5	Posts from IV to VIII levels - start	√				
A6	Posts from IV to VIII levels - destination	√	√	√	√	
A7	RPLC - start	√				
A8	RPLC - destination	√	√	√		
A9	LPLC - start	√				
A10	LPLC - destination	√	√	√		
A11	All posts - start	√				
A12	All posts - delivery	√	√	√	√	

Avoided costs for PPO (in norms of minutes) for letters ($U_{letters}$) *and packages* ($U_{packages}$), *for the alternative* ***A1 "Posts out of levels – start points"*** are calculated using relations (1), (2), (3), and (4):

$$\mathrm{U_{letters}} = \mathrm{N_{mp}} \times \frac{\mathrm{U_{p1}[\%]}}{100\%} \tag{1}$$

$\mathrm{N_{mp}}$ –average value of norms of minutes for letters is 2.68
$\mathrm{U_{p1}}$ – collection stage, for letters (Table 2)

$$\mathrm{U_{letters}} = 2{,}68 \times \frac{15\ [\%]}{100\%} = 0{,}40\ norm\ of\ minutes \tag{2}$$

$$\mathrm{U_{packages}} = \mathrm{N_{mk}} \times \frac{\mathrm{U_{k1}[\%]}}{100\%} \tag{3}$$

$\mathrm{N_{mk}}$ - average value of norms of minutes for packages is 3,64
$\mathrm{U_{k1}}$ – collection stage, for packages (Table 2)

$$\mathrm{U_{paketi}} = 3{,}64 \times \frac{13\%}{100\%} = 0{,}47\ norms\ of\ minutes \tag{4}$$

For the alternative **A2 "Posts out of levels – destination points"** savings on letters and packages are calculated using relations (5) to (12):

$$U_{letters} = \mathrm{N_{mp}} \times \frac{\mathrm{U_{p1}[\%]}}{100\%} + \mathrm{N_{mp}} \times \frac{\mathrm{U_{p2}[\%]}}{100\%} + \mathrm{N_{mp}} \times \frac{\mathrm{U_{p3}[\%]}}{100\%} + \mathrm{N_{mp}} \times \frac{\mathrm{U_{p4}[\%]}}{100\%} \tag{5}$$

$\mathrm{U_{p2}}$, $\mathrm{U_{p3}}$, $\mathrm{U_{p4}}$, $\mathrm{U_{p5}}$ – proportion of the stages of outward sorting, transport, inward sorting and delivery, for letters

$$U_{letters} = 2{,}68 \times \frac{15\%}{100\%} + 2{,}68 \times \frac{11\%}{100\%} + 2{,}68 \times \frac{10\%}{100\%} + 2{,}68 \times \frac{11\%}{100\%} = \tag{6}$$

$$\boldsymbol{U_{letters} = 1{,}26\ norms\ of\ minutes} \tag{7}$$

$$U_{parcels} = \mathrm{N_{kp}} \times \frac{\mathrm{U_{k1}[\%]}}{100\%} + \mathrm{N_{kp}} \times \frac{\mathrm{U_{k2}[\%]}}{100\%} + \mathrm{N_{mp}} \times \frac{\mathrm{U_{k3}[\%]}}{100\%} + \mathrm{N_{mp}} \times \frac{\mathrm{U_{k4}[\%]}}{100\%} \quad (8)$$

U_{k2}, U_{k3}, U_{k4}, U_{k5} – proportion of the stages of outward sorting, transport, inward sorting and delivery, for packages

$$U_{parcels} = 3{,}64 \times \frac{13\%}{100\%} + 3{,}64 \times \frac{11\%}{100\%} + 3{,}64 \times \frac{24\%}{100\%} + 3{,}64 \times \frac{11\%}{100\%} = \quad (9)$$

$$\boldsymbol{U_{packages} = 2{,}15 \text{ norms of minutes}} \quad (10)$$

Calculating norms of minutes for other alternatives is done in a similar way, and the results are shown in the evaluation Table 3.

K4: Access points capacity

The significance of this criterion is in determining available storage space, needed for postal items which users drop off at defined access points (defined alternatives). The criterion describing the size of storage is given in numbers 1 to 5. Regional and local postal logistic centres, as well as posts out of levels, have the largest storage and are therefore given marks 5,4 and 3, whereas the least storage is in posts from IV to VIII levels, and their mark is 2. In all other posts, start and destination, the capacity is given an average mark of 2.5.

K5: Existence of demand for postal network access

Beside postal operators, consolidators and users who drop off only their items can also access the postal network (Ordinance, 2014). Consolidators are legal entities or entrepreneurs that collect postal items from various users, consolidate them and hand them over to the PPO for further processing. This criterion is significant because it increases availability of all postal services within the scope of the UPS, but also other commercial services already provided by private postal operators. Introducing this criterion into the optimization process offers a possibility for meeting users' needs on the communication market.

An analysis of opinions of experts (postal operators) on abolishing reserved services, has offered demands for postal network access, in each of the alternatives, shown in the last column of Table 3.

4.2 Evaluation of defined alternatives and criteria

The PROMETHEE Method has been used for multicriteria ranking, which gives 12 alternatives (access points) ranked by 5 criteria. Values for each criterion are shown in Table 3.

Table 3: Evaluation of defined alternatives and criteria (Unterberger, 2016)

Serial number	CRITERIA / ALTERNATIVE	Number of postal network units	Avoided costs for letters	Avoided costs for packages	Access point capacity	Existence of demand
A1	**Posts out of levels – start points**	31	0,4	0,47	3	3
A2	**Posts out of levels –destination points**	31	1,26	2,15	3	2
A3	**Posts from I to III levels - start**	169	0,4	0,47	2,50	3
A4	**Posts from I to III levels - destination**	169	1,26	2,15	2,50	2
A5	**Posts from IV to VIII levels - start**	1106	0,4	0,47	2	3
A6	**Posts from IV to VIII levels - destination**	1106	1,26	2,15	2	2
A7	**RPLC - start**	3	0,4	0,47	5	6
A8	**RPLC - destination**	3	0,96	1,38	5	5
A9	**LPLC - start**	14	0,4	0,47	4	4
A10	**LPLC - destination**	14	0,96	1,38	4	7
A11	**All posts - start**	1481	0,4	0,47	2,5	1
A12	**All posts - delivery**	1189	1,26	2,15	2,5	2

4.4. Defining the type of general criterion and Relative Weight Coefficients for each criteria

Table 4 shows the choice of a generalized criterion (function type). For calculating weight coefficient for the criteria, opinions of experts from science (Faculty of Technical Sciences, Novi Sad, and Faculty of Transport and Traffic Engineering, Belgrade), Ministries, NRA – RATEL and postal traffic (PE "Post of Serbia" and Croatian Post Inc) have been used.

The sum of relative weight coefficients is calculated by relation (11):

$$\left(\sum_{j=1}^{k} W_j = 1 \right) \tag{11}$$

where W_j , j=1,2,...,k, are weights given to each criterion and are real numbers.

The sum of all coefficients should be 1, and relative weight coefficients for each criterion are determined using experts' opinion. This is shown in (12) and (13).

$$W_1 + W_2 + W_3 + W_4 + W_5 = 1 \tag{12}$$

$$0,15 + 0,19 + 0,21 + 0,24 + 0,21 = 1,00 \tag{13}$$

Experts have given the highest mark to the criterion K4 – Access points capacity (average mark is 4.00), then comes the criterion K5 – Existence of demand and Avoided costs for packages (average mark 3.50). The criterion K1 –number of postal network units, that is a number of potential access points, should be minimized (Table 5), whereas all the other alternatives (avoided costs for letters and packages, access points capacity and existance of demand) should have maximum values. For criteria K1 and K4, preference function type II is chosen (criterion with linear preference), and for criteria K2, K3 and K5, the function with linear preference and indifference threshold is chosen.

Table4: The choice of criteria type, parameters and weights for all criteria (Unterberger, 2016)

Basic characteristics of the criteria	Tags	K1	K2	K3	K4	K5
Minimum or maximum	MIN/MAX	MIN	MAX	MAX	MAX	MAX
Relative weight coefficients	w	0,15	0,19	0,21	0,24	0,21
Preferential function	H_d	Type III	Type V	Type V	Type III	Type III
Q: Indifference	Q	-	0,37	1	-	-
P: Preference	P	3	0,82	1,57	0,86	4
Minimum	min	3	0,40	0,47	2	1
Maximum	max	1481	1,26	2,15	5	7
Minimum difference	min_r	14	0,56	0,91	1	1
Maximum difference	max_r	1478	0,86	1,68	3	6
AVERAGE	$\bar{x}$	443	0,78	1,18	3,25	3
Standard deviation	σ	560	0,39	0,76	0,99	2

Table 5: Ranking of alternatives withpositivevalues of clear stream(Unterberger, 2016)

Alternative	Rank	ALTERNATIVE	Clear stream (T)	Output stream (T^+)	Input stream (T^-)
A8	**1**	**RPLC- destination**	**0,3861**	**0,4176**	**0,0315**
A7	**2**	**RPLC-start**	**0,2249**	**0,4275**	**0,2026**
A10	**3**	**LPLC- destination**	**0,1791**	**0,3351**	**0,1560**
A9	4	LPLC-start	-0,2131	0,1980	0,4111
A2	5	Posts out of levels-destination	-0,2306	0,2179	0,4485
A4	6	Posts from I to III levels-destination	-0,3464	0,1600	0,5064

Ranking of the alternatives based on the given criteria has been done using the software tool Visual Promethee (available at www.promethee-gaia.net). Using Promethee Method the alternatives are ranked by

values of clear stream $T(a)$, and results have shown that 6 alternatives have positive values of clear stream (alternatives A8, A10, A7, A2, A9 and A4). Repeating the whole ranking procedure, for 6 alternatives (using the same criteria, the same marks, function types and weight coefficients), has given the results shown in Table 5. The highest alternative, with the highest value of clear stream has the alternative A8: RPLC – destination. Beside this alternative, alternatives A7: RPLC- start and A10: LPLC – destination also have positive clear stream value.

5. CONCLUSION

The presented methodology for defining access points combines former research on postal network access, which identified key factors which exclude demands for network access. It is important to note that the existing postal network of PPO in the RS can meet the expected future access users' demands, which would enable better utilization of automated sorting centres. In order forpostal operators and consolidators to accessthe postal network, it is necessary to completely liberalize the postal market, abolish the current reserved domain, in other words, allow the access to all postal services within the scope of the UPS. It means that users accessing the PPO's postal network could also provide for postal services from the scope of the UPS,and use available PPO information communication resources.

Postal operators planning to engage in e-commerce could access the PPO postal network in the defined access points and thus make e-commerce services available throughout the whole territory of the RS. For the whole process to take place it is necessary to have a single public postal logistic communication (PPLC) network, which would ensure mail tracking from a sender (seller) to receiver (buyer). The current PPLC network, available PPO resources and network access can connect all relevant institutions (banks, insurance companies, health institutions, state administration, etc.) and give a single platform of universal service which is crucial for further evolution of economy and e-commerce and e-exchange in Serbia.

The results of multicriteria ranking have shown that top level alternatives are regional postal logistic centres both at start points (upstream) and at destination points (downstream), as well as local postal logistic centres at destinations.The model for determining access points on the PPO network required opinions of experts from relevant institutions in the country and region, and hence it approaches the defined criteria from various aspects. The given alternatives and criteria have enabled users who want to access the PPO postal network to do it from a location they choose, according to their possibilities and performed business operations.

The support from the State and the competent Ministry is of crucial importance for the overall process of implementing the approach, which is why soon (according to Strategy, in the third and fourth quarters of 2018) further steps are expected towards the liberalization of the postal services market and adapting the postal sector in the process of joining the EU.

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