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INTRODUCTION

Department of Management and Technical faculty "Mihajlo Pupin" from Zrenjanin have started the organization of International Symposium Engineering Management and Competitiveness (EMC) in 2011. Since 2013 the organization EMC symposium has been supported by the following foreign partners: Szent István University, Faculty of Economics and Social Sciences, Gödöllő, Hungary, Voronezh State University, Faculty of Economics, Voronezh, Russia and University of Montenegro, Maritime Faculty, Kotor, Montenegro.

The objectives of the Symposium EMC are: presentation of current knowledge and the exchange of experiences from the field of Engineering management, consideration of development tendencies and trends in Serbia and the world as well, gathering researchers from this field with the aim of expanding regional and international cooperation, raising the level of professional and scientific work at Technical faculty "Mihajlo Pupin" from Zrenjanin, expanding cooperation with economic and educational institutions and encouraging young researchers within this field. Taking into account that this Symposium is international, the importance of this event is obvious for the town of Zrenjanin, Banat region, Vojvodina and Serbia. Organization of EMC by Technical faculty "Mihajlo Pupin" from Zrenjanin represents this scientific-educational institution as one of the major representatives of economic and social development in Banat.

Within this Proceedings are presented all accepted papers received for IX International Symposium Engineering Management and Competitiveness (EMC 2019). This year at the symposium we have 33 papers and 2 abstracts. The authors come from 11 countries: Bosnia and Herzegovina, Greece, Hungary, Iran, Macedonia, Montenegro, Russia, Slovenia, Turkey, USA and Serbia. The papers are divided into eight sessions: Plenary session, Session A: Management and operation management, Session B: Human resource management, Session C: Marketing management, Session D: Economy, Session E: IT management, Session F: Abstracts.

We wish to thank Technical faculty "Mihajlo Pupin" from Zrenjanin and the dean Prof. Ph.D Dragica Radosav for their active role concerning the organization of the Symposium. We are also expressing our gratitude to all authors who have contributed with their papers to the organization of our sixth Symposium EMC.

Symposiums EMC become a traditional meeting of researchers in June, every year. We are open and thankful for all useful suggestions which could contribute that the next, anniversary 10th International Symposium Engineering Management and Competitiveness (EMC 2020) become better in organizational and program sense.

President of the Programming Committee
Professor Dragan Ćoćkalo, Ph.D.

Zrenjanin, June 2019.

Word of Thanks

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CONTENTS

MODELLING THE USE OF INDUSTRY 4.0 TECHNOLOGIES WITH LEAN MANUFACTURING

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ABSTRACT

The lean manufacturing approach has the potential to lower production costs and increase productivity through the reduction of various forms of waste. It is evident that lean manufacturing as a business model offers stable financial performance and overall good business performance. The fourth industrial revolution or Industry 4.0 (I4.0) includes the use of evolving technologies such as cloud computing, blockchain technologies, Internet of Things, big data analysis, additive manufacturing, simulation and others. In this paper a thorough analysis of literature is conducted. Based on the findings, a theoretical model for I4.0 technologies application with lean manufacturing is developed. The model depicts an enterprise and the possible solutions for improving business performance with I4.0 technologies and lean manufacturing. The main goal of this paper is to challenge the idea of I4.0 application with the lean approach in order to achieve higher competitiveness. I4.0 technologies often require expensive infrastructure and extensive financial investments, but including lean into the "equation" it is possible to "reap" the benefits of these technologies at a lower cost. The limitations of the model are addressed and future research is proposed.

Key words: lean manufacturing, Industry 4.0, SMEs, competitiveness, waste reduction

INTRODUCTION

In this paper the application of Industry 4.0 (I4.0) technologies in accordance with lean principles and lean manufacturing is addressed. Furthermore, a theoretical model is developed for I4.0 technology application with lean manufacturing. The globalization of markets has put companies in a tough position. Namely, through globalization a large number of markets are globalized thus enterprises face a more vibrant and intense competition. This leads to the necessity for strong competitiveness of enterprises. Now, lean manufacturing can be described as an approach, as a set of methods and tools through which waste is eliminated or reduced in the enterprise (Ajmera, Umarani, & Valase, 2017). In this case, waste is registered in various forms such as time moving around product parts, defect products, transportation, waste in the form of unnecessary movement etc. (Singh, Ramakrishna, & Gupta, 2017). Lean manufacturing can positively affect business performance through reducing production costs, higher productivity, fewer waste, and reduced inventory size (Marodin, Frank, Tortorella, & Fetterman, 2019). Further, lean manufacturing has the potential to apply one or more I4.0 technologies. More often than not these technologies are complementary with the lean approach. As lean manufacturing includes an array of tools and methods, it is necessary to define business goal in order to successfully integrate an I4.0 technology within lean manufacturing. Certainly, implementing an I4.0 technology has its challenges and it opposes a risk for the enterprise. Namely, any kind of investment in a new technology has the potential to fail. Therefore, managers have to get involved into the implementation process. Now, why is the application of I4.0 technologies with lean

manufacturing principles important? The main challenge that small and medium-sized enterprises (SMEs) face is the changing market environment amid the globalization of markets. Here, competitiveness plays an important role, thus SMEs have to find a way to increase their competitive power on the market. I4.0 technologies with the lean approach offer just that.

The main goal of this paper is to analyse the application of I4.0 technologies with lean manufacturing. Further, a theoretical model for I4.0 technology application with the lean approach is developed. The first section of the paper addresses the application of I4.0 technologies. Next, the lean manufacturing principles are analysed. Afterwards, the theoretical model is presented. Finally, the conclusions are draw, and guidelines for future research are proposed..

INDUSTRY 4.0 TECHNOLOGIES AND THEIR APPLICATION

The fourth industrial revolution or Industry 4.0 includes concepts, approaches and goals through which higher productivity can be achieved (Lu, 2017). Some of the technologies that represent Industry 4.0 are cognitive computing, cloud computing, RFID technologies, Internet of Things, Internet of Value, advanced robotics, social product development, 3D printing, mobile technologies, big data and analytics, cyber security, blockchain, machine learning, Enterprise Resource Planning (ERP) and others (Lu, 2017). For example a "smart" factory based on Industry 4.0 technologies would consist of three main layers. The physical resource layer, the data application layer and the network and connectivity layer.

Further, the application of Industry 4.0 technologies are broad. In smart manufacturing systems, sensors, data collection and analysis, control and monitoring od data flow, data driven machining, modelling and predication are some of the main elements which are used (Zheng et al., 2018). The main goal of Industry 4.0 technologies are industrial applications and solutions that will bring new opportunities for enterprises. The rapid development of Information and Communication Technologies (ICT) fuels the application of Industry 4.0 technologies (Xu, Xu, & Li, 2018). In the same study it was noted that Industry 4.0 is based on cyber physical systems (CPS). These systems are the core of the fourth industrial revolution. Now, innovative engineering and technology is a necessity for Industry 4.0 to be successful. Overall, there are expectations that the fourth industrial revolution will bring forward economic prosperity to enterprises and countries who apply various advanced forms of computer science, political science, sociology, engineering and sociology through Industry 4.0 (Wilkesmann, & Wilkesmann, 2018). It is evident that similar to previous industrial revolutions, Industry 4.0 spreads to all domains of human activity. The activities in Industry 4.0 application are:

- Smart machining. This approach involves real-time manufacturing and other synchronized manufacturing solutions.
- Smart design. Virtual reality, computer-aided design (CAD) and computer-aided manufacturing (CAM) can interact with physical prototypes thus creating opportunities to combine engineering changes virtually, decreasing the need for resources.
- Smart control. Production control through cloud-enabled platforms and control of production from distance can positively affect overall business performance of enterprises. This approach further includes robot-based assembly lines, sensors and smart machines.
- Smart monitoring. Alongside control, monitoring is an important aspect of Industry 4.0 technology application in manufacturing. Through monitoring data is collected in the process of manufacturing. This may include data on temperature, speed, electricity consumption, petrol consumption, vibration intensity and intervals. Further, based on the data, real-time warnings of failures can be obtained.

When it comes to Industry 4.0 technology application it can find its place in SMEs as well as Multi-national enterprises (MNEs). It is important to discuss the possibilities and limitations of Industry 4.0 technology application in SMEs. Namely, SMEs often have limited financial resources and a limited infrastructure for smart manufacturing systems (Mittal, Khan, Romero, & Wuest, 2018). However, partial or narrower implementation and application is possible. Identifying and defining problems

would be the first step. Further, technologies that require least financial resources could be introduced. From here, monitoring and controlling is key for sustained development. SMEs have to consider the benefits and take risks when it comes to Industry 4.0 technologies. If successfully implemented and applied, these technologies could surely contribute to competitiveness and overall business performance. Furthermore, in this present paper a theoretical model of Industry 4.0 technologies in accordance with the lean manufacturing approach is developed. The complex nature of Industry 4.0 technologies are taken into consideration. In addition, the various forms of enterprises is considered. The model is mainly aimed at SMEs. Before the model is introduced, lean manufacturing is addressed.

LEAN MANUFACTURING AND ITS IMPORTANCE FOR ACHIEVING COMPETITIVENESS

Lean manufacturing can be observed as a philosophy approach to manufacturing. It is also a set of tools, principles and techniques (Bhamu, & Singh Sangwan, 2014). The main goal of lean manufacturing is to reduce waste. Waste in it various forms such as defects, inventory, waste of unnecessary motion, processing, transportation, underutilized employees or the non-utilization of the knowledge and skills of employees (Shah, & Ward, 2007). In addition, lean manufacturing can be viewed as an approach through which continuous improvement is practiced in the enterprise.

Through lean manufacturing enterprises aim on waste reduction and increased efficiency in order to adapt to the changes on the market (Behrouzi, & Wong, 2011). In the same study it was noted that the lean manufacturing system is defined by nine main variables. These variables are elimination of waste, zero defects, continuous improvement, JIT deliveries, pull strategy, decentralization, vertical information systems (VIS) and integration of various functions in the business process. Further, lean manufacturing a prominent manufacturing approach which helps enterprises to achieve higher effectiveness and efficiency in production (Buer, Strandhagen, & Chan, 2018). Surely, reducing waste and increasing productivity positively affects competitiveness. However, increased competitiveness is not guaranteed as there are often challenges in the implementation process of lean manufacturing systems.

Based on another study, expert team building, lean communication planning, situational analysis, training, lean tools and techniques value stream mapping (VSM) and/or process mapping (PM), review of acquired knowledge and lessons learned by employees and managers, lean assessment, lean monitoring and controlling, and lean sustaining (Mostafa, Dumrak, & Soltan, 2013). Industry 4.0 technologies and lean manufacturing are crucial for achieving competitiveness on a regional and global scale. The “Moving bottleneck” was also mentioned, as it is a concept of cycle time variation with support tools a techniques of lean manufacturing, which enhances and improves business activities from a logistics standpoint.

What does this mean for lean manufacturing and competitiveness and how can the lean approach affect competitiveness of enterprises? Well, with an adequate organizational culture, implementing the lean approach is easier as flexible organizational cultures tend to provide more support for innovation. In addition, the organizational culture has to be based on strong leadership and management who is focused on long-term goals and accepting changes. As mentioned before, employee skills and knowledge has to be utilized as these are precious resources in the form of intellectual capital.

LEAN MANUFACTURING MODEL BASED ON INDUSTRY 4.0 TECHNOLOGIES

A lean manufacturing model with an addition of I4.0 technology application is developed. The theoretical model is based on insights from various studies in the domain of lean manufacturing and I4.0 (Brettel, Friederichsen, Keller, & Rosenberg, 2014; Jayaram, 2016). The model consists of fifteen (15) elements. Each element is labelled with numbers, and afterwards details are provided. In addition

the model depicts a generic production line where I4.0 technologies and lean manufacturing are applied. The mentioned mode is shown on Figure 1.

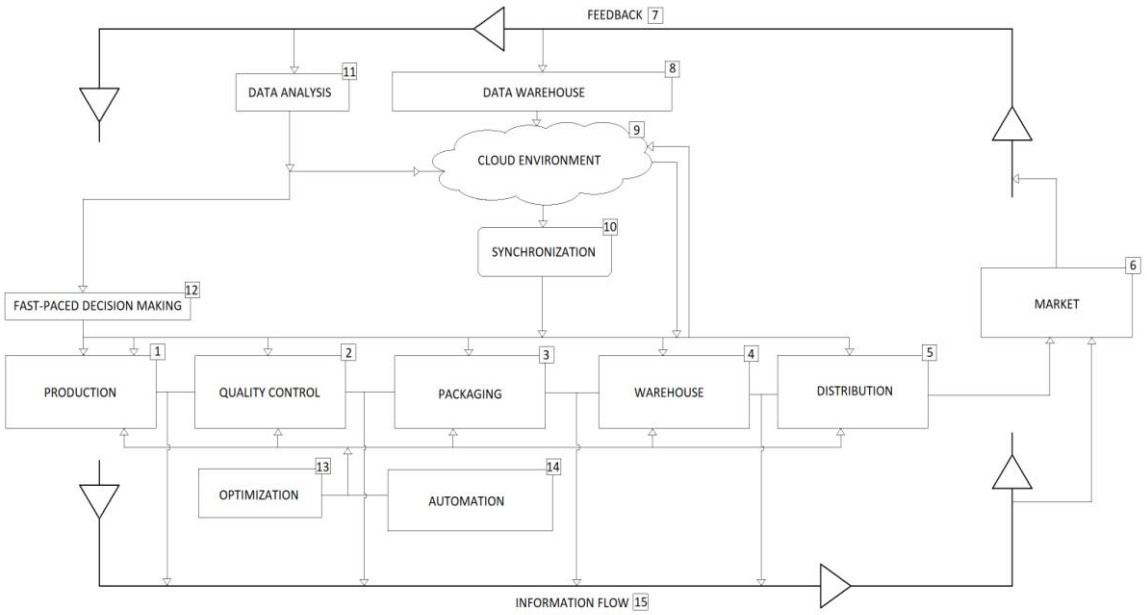

Figure 1. Lean manufacturing model based on I4.0 technologies

Further, details on the labelled elements of the model are given in Table 1.

Through these activities as part of the lean manufacturing model and the application of I4.0 technologies, enterprises could improve productivity, reduce production costs, create more value for customers and overall improve business performance. This theoretical model is certainly generic in nature. However, the goal was to develop a "default" production model which provides sufficient insight for future research in this domain.

CONSLUSION

In this paper a literature review of lean manufacturing and I4.0 technologies was conducted. In addition, a theoretical model was developed. The model depicted a generic production-to-market line with additional elements that depicted the application of I4.0 technologies and lean manufacturing principles. As mentioned, the model was based on studies which conducted significant research in this domain. It can be concluded that in today's modern business environment enterprises have to adapt to fast-paced changes on the market. The globalization of markets has put additional pressure on enterprises. Competitiveness is an imperative for survival. Quality of products and services don't always guarantee success. Additional business innovations are necessary for long-term success. I4.0 technologies are becoming more and more important for SMEs as they can provide an "edge" over the competition. Some the I4.0 technologies require significant financial resources for adequate implementation. However, there are technologies which are more cost-efficient and which don't require expensive and complex infrastructure. This implies that SMEs and startups have to take into consideration every aspect of the lean approach (lean tools, lean methods) and the I4.0 technologies as this would increase the chances for a successful implementation.

One of the main limitations of this paper is the lack of a specific model that provides more detail of the I4.0 technologies application and the application of lean tools and methods. However, this present study was focused on developing a generic theoretical model which is not too specific in regards of industry, enterprise size, products or services that are marketed. Therefore, it can be concluded that

this limitation is not severe and doesn't affect the contribution this paper. When conducting future research it is recommended to include a thorough meta-analysis of literature in this domain.

Table 1. Label description

Label	Meaning/process/procedure	Label	Meaning/process/procedure
1	Production: In the production process, tools such as Just-in-Time (JIT), Demand pull, One-Piece flow production, Kanban, Poka-Yoke and others. At the production level, the number of defect products can be lowered and also production costs can be lowered. In the first cycle of the production process, some of the I4.0 concepts such as automation, optimization and synchronization through a cloud based interface is dormant until the second cycle.	9	Cloud environment: A cost-effective solution that brings a lot of improvement to the production process. As one of the I4.0 technologies, cloud computing, and in this case a cloud environment manages to integrate information, data and to use that data for synchronization, optimization, automation and effective decision-making.
2	Quality control: Here, quality management systems, Total quality management, Fishbone diagram, and other quality tools can be applied in order to increase product quality which consequently positively affect customer satisfaction.	10	Synchronization: Through the cloud environment every business activity can be synchronized in order to lower the amount of time wasted which further leads to higher productivity.
3	Packaging: At the packaging process additional quality control should be conducted. Automation and optimization are applied after the first production cycle.	11	Data analysis: The data gathered from the beginning of the production process, and all the data stored in the data warehouse is analysed in order to predict future trends, modify the production process and develop future strategies.
4	Warehouse: The number of spare parts, warehoused products and other resources should be reduced to an absolute minimal amount.	12	Fast-paced decision making: Dynamic markets and the globalization markets put pressure on the companies. This pressure requires fast and effective decision making in order to stay competitive on the market.
5	Distribution: Mostly, one of the costliest business activities (depends on several factors). Here, lean-logistics should be applied. As data and information is collected and optimization occurs, the distribution costs can be reduced.	13	Optimization: Through the cloud environment and the gathered data, optimization of the production process and other business activities is conducted.
6	Market: In this model, the market includes customers, consumers, competitors. Information/feedback from the market is collected and stored in the data warehouse.	14	Automation: An important aspect of 4.0 technologies, where the reduction of error and the increase of productivity is achieved.
7	Feedback: Includes data from the market, production, quality control, packaging, warehouse and distribution sectors. The core element of the model, as the automation, optimization and synchronization processes are dependent on the feedback data.	15	Information flow: This is the main element of the model. Without gathering information and data there is little to no room of I4.0 technology application and lean manufacturing would also be compromised. Therefore, it is important to develop an effective information flow in the company.
8	Data warehouse: A digital warehouse where the obtained information is stored. From the through the cloud platform, data analysis is conducted, and synchronization, optimization and automation of the production process and overall business activities are conducted.		

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