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Abstract. In the process of introducing Industry 4.0 concept into the manufacturing environment companies from emerging countries are lagging behind. The rationale for this could be found in the fact that developed countries are leading this transformation, which includes digitalization and integration of manufacturing processes across the entire value chain. Low technological maturity of companies from emerging countries indicates that their focus should be on the implementation of well-established technologies. The aim of this research is to analyze the trend in implementation of Smart Manufacturing technologies in manufacturing companies from emerging country. For this purpose, data gathered among Serbian manufacturing companies through international project European Manufacturing Survey are used. The results indicate that there is a positive trend in the adoption of Smart Manufacturing technologies, which represents solid ground for Serbian manufacturers to move towards the implementation of the Industry 4.0 concept. Results presented in this research could be of use for managers and practitioners for their strategic orientation concerning improvements of production processes.

Keywords: Industry 4.0, Smart Manufacturing, Technology Adoption, Emerging Countries.

1 Introduction

Technological changes have always been a driving force for the development of the manufacturing sector. Recently, a new trend called Industry 4.0 has been introduced into the manufacturing environment [1]. This new approach is focused on digitalization and integration of processes across the entire value chain. Emerging technologies such as internet of things, big data, and cloud computing are considered as enablers of Industry 4.0, making it become a reality [2]. The main feature of Industry 4.0 is creation of cyber-physical systems in which physical objects and software are interconnected with the purpose of information exchange [3]. In order to achieve these standards, manufacturing companies are adopting various advanced technologies to gather

and analyze real-time data that can quickly be converted into useful information for the production system [4].

Since the Industry 4.0 is relatively new concept, there is a lot of ambiguity around it. There are a lot of different approaches, focusing on various areas on which Industry 4.0 has impact [5], [6]. One of the concerns lies in the fact that there is no clear understanding about the technologies that are considered as enablers of Industry 4.0 [6]. Research related to Industry 4.0 goes from analyzing widely established technologies such as Enterprise Resource Planning (ERP), to emerging technologies such as blockchain technology [7], [8]. According to Frank et al., Industry 4.0 technologies can be classified into two layers depending on their purpose [9]. One of these layers, called "front-end technologies", is primarily related to operational and market needs of the company. There are four groups of technologies in this layer, namely: Smart Manufacturing [10], Smart Products [11], Smart Supply Chain [12], and Smart Working [13]. The other layer, named "base technologies", is considered as enabler of the Industry 4.0. Technologies in this layer (i.e. internet of things, cloud, big data, and analytics) serve to provide connectivity and information exchange between front-end technologies, thus creating an intelligent manufacturing system [9], [14]. It is worth noting that from all above mentioned layers and groups of technologies, Smart Manufacturing has the crucial role in the early stage of the Industry 4.0 introduction into the manufacturing environment [15].

One more distinctive characteristic of Industry 4.0 is the difference in the approach to the research related to this concept when it comes to the level of development of the region of interest. More specifically, there is a clear distinction of the research conducted in companies from the developed countries compared to those that are focused on emerging countries [16]. This is mainly due to the fact that the idea of Industry 4.0 is born in developed countries which are now transferring their knowledge and expertise to other countries interested in the adoption of this concept [17]. This process of diffusion is relatively slow, thus making a clear distinction between developing and emerging countries concerning adoption of Industry 4.0 concept and related technologies [11]. Therefore, due to low level of maturity concerning implementation of advanced technologies, the research in emerging countries should be focused on the use of well-established technologies that represent a solid starting point for the introduction of the Industry 4.0.

Having this in mind, the aim of this research is to analyze the trend of the implementation of Smart Manufacturing technologies in emerging country (i.e. Serbia). For this purpose, we used data gathered from the European Manufacturing Survey (EMS). More specifically, we did the comparative analyses of the introduction of Smart Manufacturing technologies from two rounds of the survey (years 2015 and 2018) in order to see the trend in implementation of these technologies. This research contributes to the existing literature by presenting empirical evidence on the implementation of Smart Manufacturing technologies in emerging country, thus opening the possibilities for further research in this direction.

The remainder of the paper has the following structure. Section 2 presents the literature review, while Section 3 describes methods and data that were used for the purpose of this research. Section 4 presents the results and discussion of this research.

Finally, in Section 5 we made conclusions along with identified limitations and possibilities for further research in the field.

2 Literature review

Research related to Industry 4.0 in emerging countries is getting more attention in the last few years. The direction of these studies varies significantly. One of the most common approaches is to analyze the readiness of companies for Industry 4.0, focusing on the barriers for the implementation of this concept [18], [19]. All of these studies are on the conceptual level, using an interview approach as a tool for analysis, without any empirical evidence about the use of Industry 4.0 enabling technologies in companies. There are some attempts to put focus on the use of advanced technologies in manufacturing companies from emerging countries and their contribution to the Industry 4.0 [9], [11], [20]. The analyses in these studies are comprehensive, trying to cover vide range of emerging technologies. There is a lack of studies that are focused on specific group of technologies that form a bundle of complementary technologies. This is an important aspect that is neglected, as prior study shows that investment in emerging technologies do not always lead to expected outcomes [21]. We aim to fill this gap by analyzing one group of technologies identified as one of the enablers of the Industry 4.0. More precisely, our focus is on the adoption of Smart Manufacturing technologies in manufacturing companies from emerging country (i.e. Serbia), which are considered crucial for the implementation of the Industry 4.0 concept [9].

The main function of Smart Manufacturing technologies is to create flexible manufacturing system that is able to adapt to quick changes in the production processes triggered by market demand [4]. One of the expectations from the Industry 4.0 concept, that is enabled by Smart Manufacturing technologies, is to increase flexibility of the production system to the point of mass customization [22]. Furthermore, Smart Manufacturing technologies are focused on operations activities and product processing [10]. It is expected that these technologies contribute to the vertical and horizontal integration, virtualization, automation, flexibility, and energy efficiency [9]. In order to achieve this, the following technologies should be considered [20], [23]–[25]:

- Mobile/wireless devices for programming and controlling facilities and machinery (e.g. tablets)
- Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor
- Software for production planning and scheduling (e.g. ERP system)
- Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI)
- Near real-time production control system (e.g. Systems of centralized operating and machine data acquisition, MES)
- Systems for automation and management of internal logistics (e.g. Warehouse management systems, RFID)
- Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management
- Industrial robots for manufacturing processes (e.g. welding, painting, cutting)

- Industrial robots for handling processes (e.g. depositing, assembling, sorting, packing processes, AGV)
- 3D printing technologies for prototyping (prototypes, demonstration models, 0 series)
- 3D printing technologies for manufacturing of products, components and forms, tools, etc.)
- Technologies to recuperate kinetic and process energy (e.g. waste heat recovery, energy storage)

In order to analyze the adoption of Smart Manufacturing technologies in manufacturing companies from emerging country (i.e. Serbia) we form the following research questions:

RQ1: What is the current trend in the adoption of Smart Manufacturing technologies in manufacturing companies from emerging country (i.e. Serbia)?

RQ2: What is the expected level of the adoption of Smart Manufacturing technologies in manufacturing companies from emerging country (i.e. Serbia) in the future?

3 Methods and data

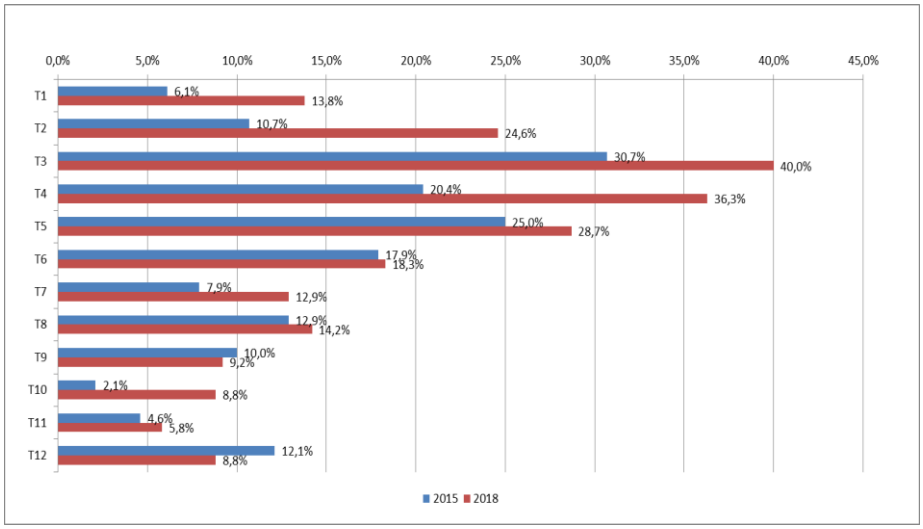
For the purpose of this study we used simple statistics. More specifically, our analysis on the use of Smart Manufacturing technologies in manufacturing companies is based on the descriptive statistics. The data for the analysis is gathered through a survey that is carried out under the international project European Manufacturing Survey (EMS) coordinated by the Fraunhofer ISI Institute from Germany. EMS is mainly focused on technological and organizational innovation in manufacturing companies, but other aspects of manufacturing processes are also considered [26]–[28]. The survey is performed each three years and targets manufacturing companies (NACE Rev 2 codes from 10 to 33) with more than 20 employees. The dataset used for the analysis in this paper is gathered from Serbian manufacturing companies and includes 285 responses from 2015 and 240 responses from 2018 round of the survey.

In both rounds of the survey (i.e. 2015 and 2018) companies were asked about the technologies that they currently use in their production processes. For our analysis technologies that belong to the Smart Manufacturing dimension are identified. We used this information to compare the use of Smart Manufacturing technologies in 2015 and 2018. In this way, the trend of the adoption of these technologies could be determined. Furthermore, companies that are not implementing Smart Manufacturing technologies were asked whether they plan to use any of these technologies in the next three years. This answer can give us the information about the possible trend of the adoption of Smart Manufacturing technologies in manufacturing companies in near future.

4 Results and discussion

The results aimed to present current trend in the adoption of Smart Manufacturing technologies in Serbian manufacturing companies are depicted in Figure 1. We have compared the share of companies that implemented Smart Manufacturing technologies in 2015 and 2018. From the results, it can be seen that for 10 out of 12 technolo-

gies there is an increase of the adoption through time. This positive trend of the adoption of Smart Manufacturing technologies represents a solid ground for Serbian manufacturers to move towards the implementation of the Industry 4.0 concept [20]. This is particularly important for companies, since these technologies should be implemented as a bundle in the phase of the maturity growth [9].



Note: T1 - Mobile devices for programming and controlling; T2 - Digital solutions directly on the shop floor; T3 - ERP system; T4 - EDI; T5 - Near real-time production control system; T6 - RFID; T7 - PLM; T8 - Industrial robots for manufacturing processes; T9 - Industrial robots for handling processes; T10 - 3D prototyping; T11 - 3D technologies for manufacturing; T12 - Technologies to recuperate energy

Fig. 1. The use of Smart Manufacturing technologies in Serbian companies in 2015 and 2018

In order to grasp the full potential of Industry 4.0 and create the environment for the introduction of emerging technologies (i.e. internet of things, big data, and cloud computing), thus creating cyber-physical industrial systems, companies should continue with this positive trend of the adoption of Smart Manufacturing technologies [2]. The results presented in Table 1, which are based on the 240 responses from the 2018 edition of EMS, are showing the intention of manufacturers to implement Smart Manufacturing technologies in near future. Based on these results, we can be confident that there will be continuance of positive trend of the adoption of Smart Manufacturing technologies in the future. Increased implementation of these technologies will create an environment for the implementation of emerging technologies, thus creating greater opportunities for companies [14]. Moreover, it is evident that Serbian manufacturing companies are recognizing the importance of catching up with developed economies in order to be competitive on the global market. If the focus of manufacturing companies is in the right direction, the investments in technologies could lead to expected benefits and increased competitiveness of manufacturing companies from emerging countries. The gradual process of technology adoption will enable companies to adapt smoothly to new manufacturing trends [16].

Table 1. Planned use of Smart Manufacturing technologies in Serbian companies until 2021

Technology	N	Share [%]
Mobile/wireless devices for programming and controlling facilities and machinery (e.g. tablets)	36	15.0
Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor	30	12.5
Software for production planning and scheduling (e.g. ERP system)	26	10.8
Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI)	24	10.0
Near real-time production control system (e.g. Systems of centralized operating and machine data acquisition, MES)	34	14.2
Systems for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	33	13.8
Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	24	10.0
Industrial robots for manufacturing processes (e.g. welding, painting, cutting)	22	9.2
Industrial robots for handling processes (e.g. depositing, assembling, sorting, packing processes, AGV)	21	8.8
3D printing technologies for prototyping (prototypes, demonstration models, 0 series)	16	6.7
3D printing technologies for manufacturing of products, components and forms, tools, etc.	15	6.3
Technologies to recuperate kinetic and process energy (e.g. waste heat recovery, energy storage)	26	10.8

5 Conclusion

The aim of this paper is to investigate the current trend and expected level of the adoption of Smart Manufacturing technologies in near future in Serbian manufacturing companies. In order to obtain results, we used data gathered from EMS. Serbian manufacturers recognize the importance of Smart Manufacturing technologies, as there is a clear empirical evidence of the positive trend in their implementation. Furthermore, we can expect the continuance of this trend in near future.

Our contribution is reflected in the fact that our analyses are focused on specific group of technologies (i.e. Smart Manufacturing technologies) that are considered as vital in the process of introduction of Industry 4.0 in emerging countries. In this way, we opened the field for more narrow and detailed analysis of the adoption of advanced technologies related to Industry 4.0 in emerging countries. Additionally, we provide empirical evidence of the adoption of Smart Manufacturing technologies in manufacturing companies from emerging country. These results could be of use for managers and practitioners for their strategic orientation concerning improvements of production processes.

We have limited this research only to Smart Manufacturing technologies to gain insight on this specific category. However, this is not the only perspective that should be considered when analyzing the use of advanced technologies in manufacturing companies. Other relevant technologies should be analyzed in the context of emerging countries as well [9], [11]. Moreover, we have analyzed the manufacturing sector in general. One of the possible directions for further research is to consider differences between companies based on their size. Furthermore, some other aspects of Industry 4.0, such as new business models and organizational enablers, should be discussed in further research [5].

References

1. H. Kagermann, W. Wahlster, and J. Helbig, "Recommendations for implementing the strategic initiative INDUSTRIE 4.0," Frankfurt, Germany, 2013.
2. Y. Lu, "Industry 4.0: A survey on technologies, applications and open research issues," J. Ind. Inf. Integr., vol. 6, pp. 1–10, 2017.
3. E. A. Lee, "Cyber physical systems: Design challenges," in Proceedings - 11th IEEE Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing, ISORC 2008, 2008, pp. 363–369.
4. S. Wang, J. Wan, D. Zhang, D. Li, and C. Zhang, "Towards smart factory for industry 4.0: A self-organized multi-agent system with big data based feedback and coordination," Comput. Networks, vol. 101, pp. 158–168, 2016.
5. A. Schumacher, S. Erol, and W. Sihn, "A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises," Procedia CIRP, vol. 52, pp. 161–166, 2016.
6. G. Culot, G. Nassimbeni, G. Orzes, and M. Sartor, "Behind the definition of Industry 4.0: Analysis and open questions," Int. J. Prod. Econ., p. 107617, 2020.
7. D. Berić, D. Stefanović, B. Lalić, and I. Ćosić, "The implementation of ERP and MES Systems as a support to industrial management systems," Int. J. Ind. Eng. Manag., vol. 9, no. 2, pp. 77–86, 2018.
8. T. Ahram, A. Sargolzaei, S. Sargolzaei, J. Daniels, and B. Amaba, "Blockchain technology innovations," 2017 IEEE Technol. Eng. Manag. Soc. Conf. TEMSCON 2017, pp. 137–141, 2017.
9. A. G. Frank, L. S. Dalenogare, and N. F. Ayala, "Industry 4.0 technologies: Implementation patterns in manufacturing companies," Int. J. Prod. Econ., vol. 210, no. January, pp. 15–26, 2019.
10. H. Ahuett-Garza and T. Kurfess, "A brief discussion on the trends of habilitating technologies for Industry 4.0 and Smart manufacturing," Manuf. Lett., vol. 15, pp. 60–63, 2018.
11. L. S. Dalenogare, G. B. Benitez, N. F. Ayala, and A. G. Frank, "The expected contribution of Industry 4.0 technologies for industrial performance," Int. J. Prod. Econ., vol. 204, no. July, pp. 383–394, 2018.
12. R. Angeles, "Anticipated IT infrastructure and supply chain integration capabilities for RFID and their associated deployment outcomes," Proc. 10th Int. Conf. Inf. Integr. Web-based Appl. Serv. iiWAS 2008, pp. 634–641, 2008.

13. T. Stock, M. Obenaus, S. Kunz, and H. Kohl, “Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential,” Process Saf. Environ. Prot., vol. 118, pp. 254–267, 2018.
14. G. Büchi, M. Cugno, and R. Castagnoli, “Smart factory performance and Industry 4.0,” Technol. Forecast. Soc. Change, vol. 150, no. October 2019, p. 119790, 2020.
15. G. Schuh, R. Anderl, J. Gausemeier, M. ten Hompel, and W. Wahlster, “Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies,” acatech STUDY, p. 46, 2017.
16. V. L. Da Silva, J. L. Kovaleski, R. N. Pagani, J. D. M. Silva, and A. Corsi, “Implementation of Industry 4.0 concept in companies: empirical evidences,” Int. J. Comput. Integr. Manuf., vol. 00, no. 00, pp. 1–18, 2019.
17. S. Bernat and S. F. Karabag, “Strategic alignment of technology: Organising for technology upgrading in emerging economy firms,” Technol. Forecast. Soc. Change, vol. 145, pp. 295–306, 2019.
18. M. C. Türkeş, I. Oncioiu, H. D. Aslam, A. Marin-Pantelescu, D. I. Topor, and S. Căpuşneanu, “Drivers and barriers in using industry 4.0: A perspective of SMEs in Romania,” Processes, vol. 7, no. 3, pp. 1–20, 2019.
19. C. J. Huang, E. D. T. Chicoma, and Y. H. Huang, “Evaluating the factors that are affecting the implementation of industry 4.0 technologies in manufacturing MSMEs, the case of Peru,” Processes, vol. 7, no. 3, 2019.
20. N. Medić, Z. Anišić, B. Lalić, U. Marjanović, and M. Brezocnik, “Hybrid fuzzy multi-attribute decision making model for evaluation of advanced digital technologies in manufacturing: Industry 4.0 perspective,” Advances in Production Engineering And Management, vol. 14, no. 4. pp. 483–493, 2019.
21. A. G. Frank, M. N. Cortimiglia, J. L. D. Ribeiro, and L. S. de Oliveira, “The effect of innovation activities on innovation outputs in the Brazilian industry: Market-orientation vs. technology-acquisition strategies,” Res. Policy, vol. 45, no. 3, pp. 577–592, 2016.
22. H. Fatorachian and H. Kazemi, “A critical investigation of Industry 4.0 in manufacturing: theoretical operationalisation framework,” Prod. Plan. Control, vol. 29, no. 8, pp. 633–644, 2018.
23. M. Pons, A. Bikfalvi, J. Llach, and I. Palcic, “Exploring the impact of energy efficiency technologies on manufacturing firm performance,” J. Clean. Prod., vol. 52, pp. 134–144, 2013.
24. R. Koren and I. Palcic, “The impact of technical and organisational innovation concepts on product characteristics,” Adv. Prod. Eng. Manag., vol. 10, no. 1, pp. 27–39, 2015.
25. M. Medojevic, N. Medic, U. Marjanovic, B. Lalic, and V. Majstorovic, “Exploring the Impact of Industry 4.0 Concepts on Energy and Environmental Management Systems: Evidence from Serbian Manufacturing Companies,” in IFIP Advances in Information and Communication Technology, 2019, vol. 567, pp. 355–362.
26. B. Lalic, S. Rakic, and U. Marjanovic, “Use of industry 4.0 and organisational innovation concepts in the Serbian textile and apparel industry,” Fibres Text. East. Eur., vol. 27, no. 3, pp. 10–18, 2019.
27. U. Marjanovic, B. Lalic, N. Medic, J. Prester, and I. Palcic, “Servitization in manufacturing: role of antecedents and firm characteristics,” Int. J. Ind. Eng. Manag., vol. 10, no. 2, pp. 133–144, 2020.
28. B. Lalic, N. Medic, M. Delic, N. Tasic, and U. Marjanovic, “Open innovation in developing regions: An empirical analysis across manufacturing companies,” Int. J. Ind. Eng. Manag., vol. 8, no. 3, pp. 111–120, 2017.