General Readiness Assessment of Industry 4.0: Evidence from Serbian Manufacturing Industry

Tanja Todorovic, Bojan Lalic, Vidosav Majstorovic, Ugljesa Marjanovic, Nemanja Tasic

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Tanja Todorovic[1[0000-0002-2264-3168]], Bojan Lalic[1[0000-0002-2202-9352]], Vidosav Majstorovic[2[0000-0001-9534-8461]], Ugljesa Marjanovic[1[0000-0002-8389-6927]] and Nemanja Tasic[1[0000-0003-0695-6671]]

[1] University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
[2] University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia
ttodorovic@uns.ac.rs, blalic@uns.ac.rs, vmajstorovic@mas.bg.ac.rs, umarjano@uns.ac.rs, nemanja.tasic@uns.ac.rs

Abstract. The implementation of Industry 4.0 concepts has significant implications for the manufacturing landscape**.** The aim of this study is to assess the level of general readiness for Industry 4.0 in the emerging economy of Serbia. The obtained results indicate that the majority of Serbian manufacturing sector has not yet embarked on the path towards transformation and implementation of advanced technologies.

Keywords: Industry 4.0, manufacturing industry, readiness assessment

1 Introduction

The prospects of Industry 4.0 indicate a substantial change in the manufacturing value chain. The introduction of highly flexible and highly productive factories of the future is gaining momentum in industries of developed regions [1]. In order to adapt to the new manufacturing paradigm, emerging markets should analyze their readiness for the implementation of Industry 4.0 concept. The aim of this paper is to evaluate the extent of usage of advanced digital technologies in manufacturing companies in the context of developing countries, i.e. Serbia.

2 Literature review

Although there is a lack of consensus regarding the Industry 4.0 definition [2], the prevailing terminology of Industry 4.0 concept entails the implementation of digital advanced manufacturing technologies into the manufacturing landscape [3], along with other non-technological enabling factors [4], [5]. Research in this field is primarily focused on companies from developed countries, whilst companies from developing countries are facing different obstacles regarding their technological and organiza-

tional capabilities to implement novel concepts [6] [7] [8]. Although emerging economies are lagging behind when it comes to implementation of advanced technologies, they have slowly begun to pave a way for inclusion of Industry 4.0 elements [9] [10]. The application of various readiness models [5] [11] [12] in order to assess the specific industry's status regarding advanced technologies implementation could indicate the industries with the highest level of Industry 4.0 penetration [13] [14]. Since Industry 4.0 is driven by advanced technologies [15] [16] as core enablers of its implementation, this paper examines the utilization of advanced manufacturing technologies as a first step in analyzing the readiness for Industry 4.0 [17].

To assess the general readiness to digitalize, it is of particular interest whether companies use and combine several technologies at the same time or in which technological fields companies are increasingly active. Regarding the nature of Industry 4.0 enabling technologies, the authors have differing points of view [18]. The Fraunhofer Institute for Systems and Innovation Research ISI developed an I4.0 general readiness assessment methodology [19] that combines the number of digital technologies used with three technological fields and thus provides information on the digitalization readiness of individual companies. The model applied in this study follows the readiness assessment methodology of the Fraunhofer ISI and aims to assess the current situation in terms of implementation of digital advanced manufacturing technologies in the manufacturing sector in Serbia. Based on this assessment, the future steps in further digitalization of economy could be planned and executed both on governmental and individual company's level.

3 Research questions

Against this background, we investigated how intensively Serbian manufacturing companies are currently implementing Industry 4.0 relevant technologies. Based on the literature review, the following research questions were proposed:

- **RQ1**: What is the level of general readiness for Industry 4.0 in Serbian manufacturing industry?
- **RQ2**: Which industries in Serbia have the highest level of general readiness for Industry 4.0?

4 Data and Methodology

Our analysis used the Serbian dataset from the European Manufacturing Survey (EMS) conducted in 2018. EMS investigates technological and non-technological innovation in the European manufacturing sector. It represents the most detailed and widest survey on industrial value-added processes and modernization strategies of companies in the manufacturing industry and is coordinated by Fraunhofer ISI. The survey is carried out on a triennial basis and targets a random sample of manufacturing companies with more than 20 employees (NACE Rev 2 codes from 10 to 33). The

Serbian dataset includes 240 companies. Concerning descriptive statistics, the sampled companies report, on average, a company size of 124 employees (SD = 207). In total, 110 companies are small firms (fewer than 50 employees), 103 companies are medium-sized (between 50 and 249 employees), and 27 companies are large enterprises (more than 250 employees). Table 1 depicts the sample distribution regarding size.

Table 1. EMS database – distribution of firms by size.

Firm size	n	%
20 to 49 employees	110	45.8
50 to 249 employees	103	42.9
250 and more employees	27	11.3
Total	240	100.0

To be able to assess the general willingness to digitalize, it is of particular interest whether companies use and combine several technologies at the same time or in which technological fields companies are increasingly active. For this purpose, the Fraunhofer ISI developed an I4.0 general readiness assessment methodology that combines the number of digital technologies used with three technological fields and thus provides information on the digitalization readiness of individual companies. The Fraunhofer I4.0 Readiness assessment approach is exclusively focused on technology and is based on seven digital technologies:

- Software system for production, planning and control;
- Digital visualization at the work place of the workers;
- Digital data exchange with customers/suppliers;
- Techniques for automation and control of internal logistics;
- Real-time production control system;
- Mobile devices for programming and operation of plants and machines; and
- Product Life Cycle Management Systems.

These are combined into the following technology fields:

1. Digital Management Systems: The first field of technology consists of "Software system for production planning and control" and "Product Lifecycle Management Systems“.
2. Wireless human-machine communication: In the second field of technology the "Digital Visualization" is combined with the "Mobile Devices".
3. Cyber-Physical Production System (CPS) related processes: The third field of technology is the "Real-time production control system", the "Automation of internal logistics" and "Digital data exchange with customers and suppliers" together.

While the first two technology fields tend to cover basic digital technologies and still have a clear distance from I4.0, the third technology field already contains the first approaches of digitally networked production. Using this grouping, therefore, those companies that are closer to I4.0 are those who use and combine digital technologies

in all three technology fields and use several of the CPS-related processes on the one hand. By contrast, companies that only apply digital technologies in one or two technology fields are less willing to work for digitally networked production in the sense of Industry 4.0

There are six different levels which are summarized graphically on Figure 1:

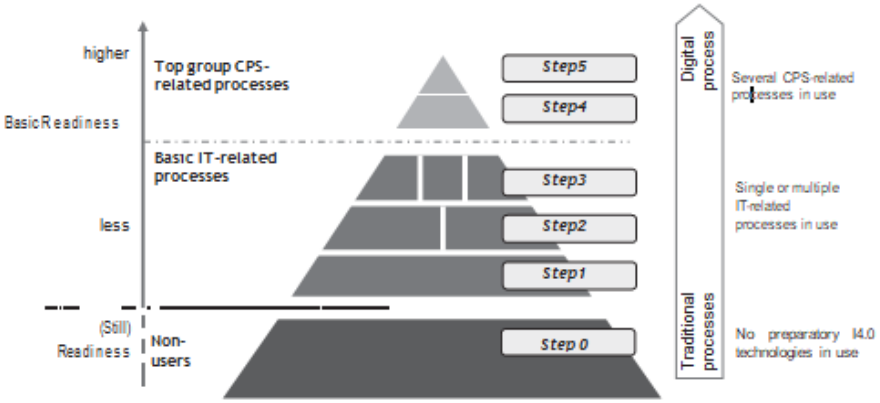

Fig. 1. Levels of I4.0 Readiness [19]

Non-users who do not (yet) have readiness for I4.0:
• Level 0: Companies that do not use any of the digital technologies studied and tend to rely on traditional production processes;
Basic levels, as a base on the way to I4.0, with still less willingness:
Level 1 (beginners): Companies that use digital processes in one of the three technology fields;
• Level 2 (advanced beginners): Companies that use digital processes in two of the three technology fields;
• Level 3 (advanced): Companies that are active in all three technology fields and use both IT-related processes and a CPS-related process.
Leading group, as a pioneer on the way to I4.0, with higher readiness:
• Level 4: Companies that are active in all fields of technology and use at least two technologies of CPS-related processes;
• Level 5: Companies that are active in all technology fields and use at least three technologies of CPS-related processes.

5 Results

The following Table 2 gives a distribution of general readiness of Serbian manufacturing firms by level of readiness.

Table 2. General readiness assessment of Serbian manufacturing companies – distribution of firms by level of readiness.

Industry	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Share on total sample (%)
10	18	4	11		4	2	16.3
11	3	2		1			2.5
12	1						0.4
13	2					2	1.7
14	6	3	1	1	1	2	5.8
15	5		2				2.9
16	6	1	3		1		4.6
17	3		3				2.5
18	2	2	1	1	3		3.8
19	1		1				0.8
20	3	2		1			2.5
21	1		1				0.8
22	6	4	4	2	1	4	8.8
23	7		2	2			4.6
24	3		1	1			2.1
25	14	7	9	5		1	15.0
26	1	1	1	1	1		2.1
27	5	1	4	2	2	1	6.3
28	4	4	6			1	6.3
29	3	4	2	1			4.2
30	2						0.8
31	3	2	1	2		1	3.8
32	1		1	1			1.3
33						1	0.4
% of total	41.7	15.4	22.5	8.8	5.4	6.3	100.0

For RQ1 (What is the level of general readiness for Industry 4.0 in Serbian manufacturing industry?), we conducted descriptive statistics presented in Table 2 and Figure 2. From the results, we could say that majority (41.67%) of manufacturing companies are still at Level 0 and just a few (6.25%) at the Level 5 of general readiness for Industry 4.0. Furthermore, for RQ2 (Which industries in Serbia have the highest level of general readiness for Industry 4.0?), the most prepared manufacturing industry in Serbia for Industry 4.0 is Manufacture of rubber and plastic products (NACE 22), followed by Manufacture of food products (NACE 10), and Manufacture of wearing apparel (NACE 14), as presented in Table 3.

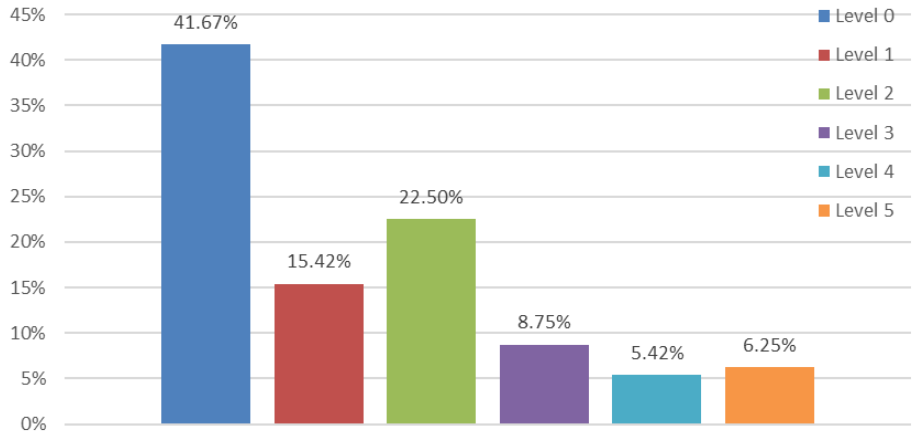

Fig. 2. Distribution of firms by level of general readiness for Industry 4.0.

As for the specific industries, manufacture of rubber and plastic products sector (NACE 22) has four companies at the Level 5, manufacture of food products sector (NACE 10) has two companies at the Level 5 and four companies at the Level 4. Finally, manufacture of wearing apparel sector (NACE 14) has two companies at the Level 5. In terms of readiness levels, it could be observed that there is significant heterogeneity even among companies in the same industry. For example, there are 2 food production companies at level 5, none at level 3 and 18 companies at level 0.

Table 3. General readiness assessment of Industry 4.0 in Serbian manufacturing companies – distribution of firms of top 3 industries.

Industry	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Rank
22	6	4	4	2	1	4	1
10	18	4	11	-	4	2	2
14	6	3	1	1	1	2	3

6 Discussion and Conclusion

This study represents the first step in analyzing the readiness of Serbian manufacturing companies for Industry 4.0. It bases on an established methodology of the Fraunhofer ISI from Germany and uses Serbian data of the European Manufacturing Survey representing the most detailed and widest survey on industrial value-added processes and modernization strategies of companies in the manufacturing industry.

The results indicate that the majority of companies in Serbian manufacturing sector have not started the transformation based on advanced digital technologies yet. Even those companies which have started to uptake some digital technologies, are on a very low level of readiness for Industry 4.0. In our sample, we could find only few companies dealing with higher levels of readiness representing rather an exception in Serbia.

One of the reasons for this situation might be the strong market-pool-oriented strategy of the manufacturing sector in Serbia following the needs and requirements of customers instead of a self-initiative in terms of the technological catch-up imitative. In other words, instead of following a technology-based competitiveness, the majority of manufacturing companies follow solely low-price market strategies. An additional argument might be the lack of political instruments for providing technological catch-up in the Serbian manufacturing sector. To identify the barriers for up-taking digital technologies, an in-depth study is to be conducted.

Looking at individual sectors within the manufacturing industry, we could identify three sectors with somewhat higher readiness levels: manufacture of rubber and plastic products, manufacture of food products and manufacture of wearing apparel. The further research should involve the deeper analysis of the underlying factors that positively influence the implementation in these sectors, with the aim to develop policy recommendation for the whole industry.

Despite the solely descriptive characteristic of the methodology, the study gives a first overview of the state of the art in terms of usage of digital technologies. As such, it contributes significantly to the current research on Industry 4.0 in emerging economies. Moreover, giving a first statistical overview, it plays an crucial role for further more comprehensive as well as in-depth studies including additional non-technological areas like human resources and competences in digital surroundings as well as the improvement of organizational and management concepts, new business models and digital innovations.

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