INDUSTRY 4.0 READINESS OF SLOVENIAN MANUFACTURING COMPANIES

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Abstract: *The proposed chapter deals with the use of advanced manufacturing technologies in Slovenian manufacturing companies. In our case these technologies are from digital factory technologies group. The use of selected digital factory technologies is observed through the eyes of Industry 4.0 concept, and we focus on Industry 4.0 readiness index. We present a possible Industry 4.0 readiness index and assess Industry 4.0 readiness of Slovenian manufacturing companies. Results are based on a sample of around 120 manufacturing companies, whose data were obtained through the 2018/19 European Manufacturing Survey edition. The results are presented with the use of descriptive statistics. Results show that the use of specific advanced manufacturing technologies in Slovenian manufacturing companies is quite diverse and that Industry 4.0 readiness increases.*

Key words: *Manufacturing company, Advanced manufacturing technology, Industry 4.0, Industry 4.0 readiness index, European manufacturing survey*

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1. Introduction

Manufacturing is continuously evolving from concept development to methods and tools available for the production of goods for use or sale. These days manufacturing is considered to be an integrated concept at all levels from machines to production systems to an entire business level operation (Esmaeilian et al., 2016).

When we speak about manufacturing, we think about manufacturing technologies, nowadays especially about advanced manufacturing technologies (AMT) and information-communication technologies (ICT). Main driving forces of the major technological advancements in the last 10 years are advanced digital technologies used in factories which combine ICT technologies with improved “smart” capabilities of machines and products. These technologies are a vital part of smart factory that utilize the internet of things (IoT) to realize intelligent manufacturing concepts like predictive maintenance or extensive machine to machine communication (Egger & Masood, 2020). In smart factory products, resources and processes are characterized by cyber-physical systems (CPS) (Hermann et al., 2015). The digital factory is a model of a planned or real factory used for design, planning and operations. In the smart factory, the digital factory developed during engineering should be integrated with the smart factory with its real time data and inferred statistics and information (Shariatzadeh et al., 2016). All of this has led to the creation of modular manufacturing systems where products control their own manufacturing process. These kinds of manufacturing systems would be able to produce highly individualised products in small batch sizes while retaining the economic benefits of mass production (Lasi et al., 2014).

Realizing the importance of this new paradigm, governments have created strategies and initiatives to improve the entire manufacturing sectors in their respective countries. One such example is German strategic initiative called »Industrie 4.0« which was created to increase the competitiveness of the German manufacturing sector through digitisation and interconnection (Kagermann et al., 2013). The term Industrie 4.0 or more known as Industry 4.0 has become synonymous with the fourth industrial revolution which will completely redefine the way companies manufacture products. However, since there are many new concepts and technologies being developed and introduced, it is difficult to clearly define what benefits does Industry 4.0 bring and how it benefits a company (Bibby and Dehe, 2018).

With these issues in mind, researchers have developed many different tools in the form of readiness and maturity models which help companies to assess their current state and define a roadmap for implementation of advanced technologies.

This chapter is organized as follows: first, we will introduce the concept of Industry 4.0 readiness in general. Secondly, we will present a possible Industry 4.0 readiness index. The methodological section explains the characteristics of the EMS. After that, we present the use of selected technologies in manufacturing companies, obtained with the use of Industry 4.0 readiness model. Finally, a concluding discussion is provided for the findings, where some managerial implications, research limitation and directions for future research are given.

2. Industry 4.0 Readiness

2.1 Industry 4.0 readiness and maturity concept in general

According to Schumacher et al. (2016) companies have serious problems to grasp the overall idea of Industry 4.0. One of the problems is that they experience problems in determining their state-of-development with regard to the Industry 4.0 vision and therefore fail to identify concrete fields of action. To overcome growing uncertainty and dissatisfaction in manufacturing companies regarding the idea of Industry 4.0, new methods and tools are needed to provide guidance and support to align business strategies and operations (Schumacher et al., 2016). Therefore, in the last few years different maturity and readiness models are being developed (Basll & Doucek, 2019; Lichtblau et al., 2015; Sarvari et al., 2018; Stefan et al., 2018). There is a difference between readiness and maturity: readiness assessment takes place before engaging in the maturing process (staring point), whereas maturity assessment aims for capturing the as-it-is state whilst the maturing process. Unfortunately, these models generally treat maturity and readiness as synonyms (Pacchinia et al., 2019), which is especially problem for real readiness models.

Readiness is defined as “willingness or a state of being prepared for something” (Readiness, Cambridge Dictionary) while maturity is defined as “a very advanced or developed form or state” (Maturity, Cambridge Dictionary). And finally, a model can be defined as “a representation of something in words or numbers that can be used to tell what is likely to happen if particular facts are considered as true” (Model, Cambridge Dictionary). With these definitions in mind, we can clearly establish that an Industry 4.0 readiness model tries to represent how ready an enterprise is to implement advanced technologies and concepts, while Industry 4.0 maturity model tries to represent how advanced a company is in adopting Industry 4.0. Some authors define readiness model as “the degree to which organizations are able to take advantage of Industry 4.0 technologies” (Hizam-Hanafiah et al., 2020) while others define it as “an instrument to conceptualize and measure the starting point and allow for initializing the development process” (Schumacher et al., 2016).

Schumacher et al. (2016) have proposed an empirically grounded maturity model and its implementation to assess the Industry 4.0 maturity of manufacturing companies. The model has been developed using a multi-methodological approach including a systematic literature review, conceptual modelling and qualitative and quantitative methods for empirical validation. Their main goal was to extend the dominating technology focus of recently developed models by including organizational aspects. Overall, they defined 9 dimensions and assigned 62 items to them for assessing Industry 4.0 maturity. The dimensions “Products”, “Customers”, “Operations” and “Technology” have been created to assess the basic enablers. Additionally, the dimensions “Strategy”, “Leadership”, Governance, “Culture” and “People” allow for including organizational aspects into the assessment (Schumacher et al., 2016). Table 1 provides an overview on the dimensions together with some exemplary items to support understanding.

Dimension	Exemplary maturity item
Strategy	Implementation I40 roadmap, Available resources for realization, Adaption of business models, …
Leadership	Willingness of leaders, Management competences and methods, Existence of central coordination for I40, …
Customers	Utilization of customer data, Digitalization of sales/services, Costumer's Digital media competence, …
Products	Individualization of products, Digitalization of products, Product integration into other systems, …
Operations	Decentralization of processes, Modelling and simulation, Interdisciplinary, interdepartmental collaboration, …
Culture	Knowledge sharing, Open-innovation and cross company collaboration, Value of ICT in company, …
People	ICT competences of employees, openness of employees to new technology, autonomy of employees, …
Governance	Labour regulations for I40, Suitability of technological standards, Protection of intellectual property, …
Technology	Existence of modern ICT, Utilization of mobile devices, Utilization of machine-to-machine communication, …

Tab. 1. Dimensions and maturity items of Industry 4.0 Maturity Model (Schumacher et al., 2016)

Schumacher et al. (2019) later upgraded their maturity model, where they have operationalized the Industry 4.0's concepts and success factors into 65 maturity items, which are grouped in 8 maturity dimensions: "Technology", "Products", "Customers and Partners", "Value Creation Process", Data & Information", "Corporate Standards", "Employers" and "Strategy and Leadership". The procedure model consists of 10 steps to be carried out.

Gökalp et al. (2017) have conducted literature review and have identified seven maturity models, analysed by comparing the characteristics of the models/frameworks based on a set of predefined criteria including scope, purpose, completeness, clearness, and objectivity. They have concluded that none of them satisfies all expected criteria, and they need to be improved. To satisfy the need for a structured Industry 4.0 assessment/maturity model, the authors have proposed SPICE-based Industry 4.0 maturity model with a holistic approach consisting of the assessment of process transformation, application management, data governance, asset management, and organizational alignment areas.

De Carolis et al. (2017) have developed maturity assessment method to measure the digital readiness of manufacturing firms. Different dimensions are used to assess 5 areas in which manufacturing key processes can be grouped: 1) design and engineering, 2) production management, 3) quality management, 4) maintenance management and 5) logistics management. Their maturity model provides a normative description of practices in each area and dimension, building a ranked order of.

A scoring method for maturity assessment is subsequently defined, in order to identify the criticalities in implementing the digital transformation and to subsequently drive the improvement of the whole system. Sjödin et al. (2018) have developed a maturity model for leveraging smart factory implementation. They have identified three areas: “People” (cultivate digital people), “Process” (introduce agile processes) and “Technology” (configure modular technology). Within these three areas they have identified key activities that underpin the development of smart factory capabilities and finally, they have categorized these key activities by maturity level to create a smart factory maturity model. There are 4 maturity levels in their model: “Level 1” – connected technologies, “Level 2” – structured data gathering and sharing, “Level 3” – real-time process analytics and optimization, “Level 4” – smart, predictable manufacturing.

Canetta et al. (2018) have proposed a digitalization maturity model to assess the state of a company journey towards Industry 4.0 considering five dimensions: “Strategy”, “Processes”, “Technologies”, “Products & Services” and “People”. The developed methodology starts from a strategic analysis of the company's positioning with regard to digitization issues, gradually deepening the level of detail through an analysis of the most relevant processes of the company, to eventually analyse the impact that technological and methodological changes have on activities and workforce.

Colli et al. (2018) contribution is bringing up the importance of a contingency approach within the digital assessment framework and in proposing an approach to cope with that. According to authors there is a need for making the assessment company specific. Therefore, they have developed a digital maturity assessment approach: 360 Digital Maturity Assessment, which is based on problem-based learning model.

Since many different Industry 4.0 readiness and maturity models exist, we wanted to explore how many articles have been published on this topic to this day and what dimensions, factors, or criteria they use to build the models. For the purposes of our research, we have conducted a systematic literature review using the following databases which are available online: Scopus, Web of science and IEEE. Our systematic literature review has also revealed that several different Industry 4.0 readiness and maturity models exist, which include different dimensions, factors, or criteria they use to build the models. Our finding was that the number of articles that specifically address readiness models for Industry 4.0 was a lot lower than the number of articles that address maturity of Industry 4.0. In this chapter we present 9 most frequently cited and used readiness, maturity and assessment models and their dimensions for the purpose of quickly understanding what factors, dimensions or other criteria the proposed models contain. As can be seen in the Table 2, the existing models vary in the number of dimensions and in type of dimensions that they use. While some focus primarily on technological aspect of Industry 4.0, others include so-called supporting aspects in the form of people, strategy and organizational culture of companies. Nevertheless, technology is the most important dimension in all analysed models. Another finding is that only five out of nine models include people (or employees) as part of Industry 4.0 dimension.

Article/model name	Dimensions
A maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises (Schumacher et al., 2016)	Products, Customers, Operations, Technology, Strategy, Leadership, Governance, Culture and People
Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing (Sjödin et al., 2018)	People, Process, Technology
A maturity model for assessing the digital readiness of manufacturing companies (De Carolis et al., 2017)	Design and Engineering, Production management, Quality management, Maintenance management and Logistics management
Development of an assessment model for industry 4.0: Industry 4.0-MM (Gökalp et al., 2017)	Process transformation, application management, data governance, asset management and organizational alignment
SIMMI 4.0 (Leyh et al., 2016)	Vertical Integration of company components, Horizontal integration across different value networks, Digital product development, Cross-sectional technology criteria
Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises (Schumacher et al., 2019)	Technology, Products, Customers and Partners, Value Creation Processes, Data & Information, Corporate Standards, Employees, Strategy and Leadership
360 Digital Maturity Assessment (360DMA) (Colli et al., 2018)	Governance, Technology, Connectivity, Value creation, Competence
Digitalization Maturity Model (Canetta et al., 2018)	Strategy, Processes, Technologies, Products, Services and People
IMPULS - Industrie 4.0 readiness (Lichtblau et al., 2015)	Strategy & Organization, Smart Factory, Smart Operations, Smart Products, Data-driven Services, and Employees

Tab. 2. A list of highly cited Industry 4.0 readiness and maturity models

2.2 Industry 4.0 Readiness Index

The proposed Industry 4.0 readiness index in our research was developed by Fraunhofer ISI (Lerch et al., 2016). The logic of the Fraunhofer Industry 4.0 readiness index is presented in Figure 1 and it is based on the selected Industry 4.0 enabling technologies. Since the different technologies are highly process and operation-dependent and come from different technology fields, a simple counting of the technologies used is not sufficient for an Industry 4.0 readiness index.

Therefore, these technologies are divided into three technology fields: Digital management systems, Wireless human-machine communication and Cyber-physical system (CPS)-related processes. While the first two technology fields cover IT-related processes (Industry 4.0 basic technologies) and still have a clear distance from Industry 4.0, technology field CPS already contains the first approaches to networked/digital production and can therefore be classified as Industry 4.0 closer than the other two technology fields (Lerch et al., 2016).

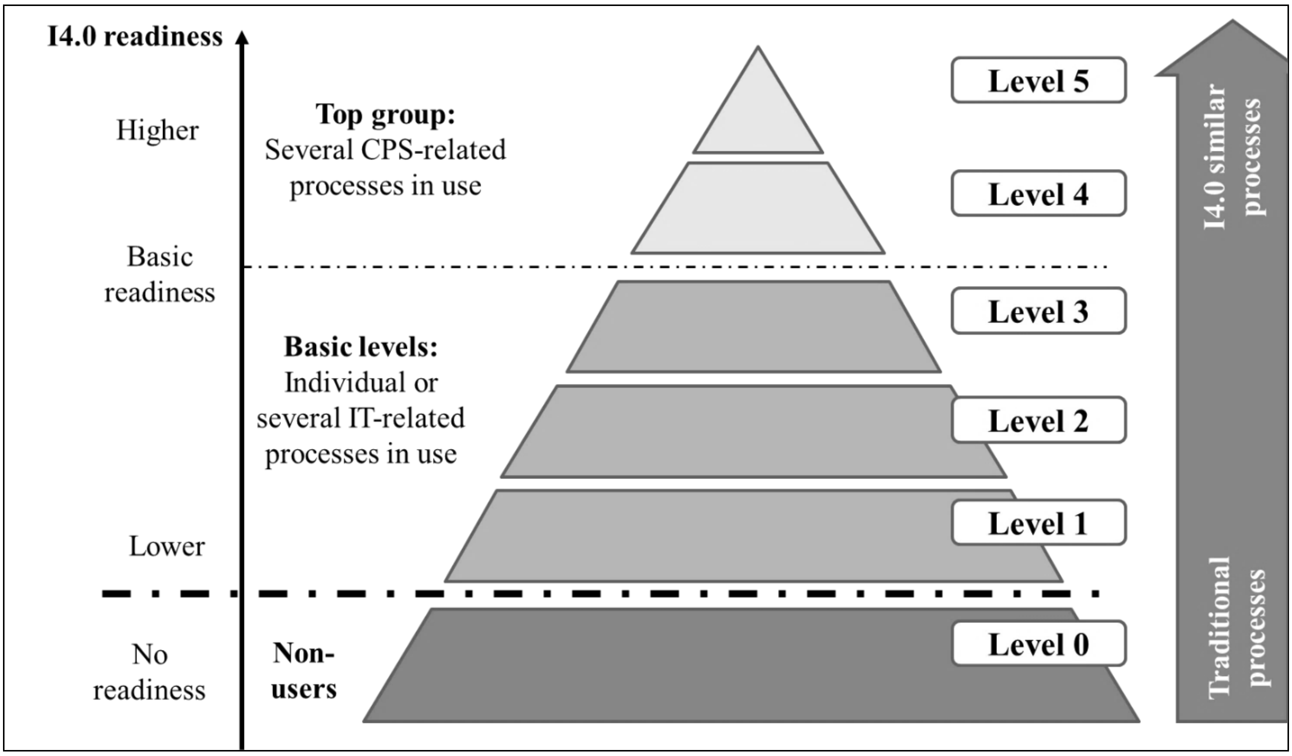

Fig. 1. Industry 4.0 readiness index

Using this grouping, the companies can be classified as Industry 4.0-close companies, which, on the one hand, use and combine several technology fields in production and, on the other hand, use several of the CPS-related processes in their production. Accordingly, Industry 4.0 readiness index results with the following main groups and levels:

Non-users who are not (yet) ready for Industry 4.0:

- Level 0: Companies that do not use any of the Industry 4.0 enabling technologies and tend to still rely on traditional production processes.
- Basic levels, as the basis on the way to Industry 4.0, with little readiness:
- Level 1 (beginners): Companies that use IT-related processes in one of the three technology fields.
- Level 2 (advanced beginners): Companies that use IT-related processes in two of the three technology fields.
- Level 3 (advanced users): Companies that are active in all three technology fields and use both IT-related processes and CPS-related processes.

Top group, as a pioneer on the way to Industry 4.0, with a slightly higher readiness:

- Level 4: Companies that are active in all technology fields 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 the CPS-related processes.

With each level, the Industry 4.0 readiness status increases or the distance to networked production decreases. While there is no readiness for Industry 4.0 in level 0, companies in levels 1 to 5 have a basic readiness. Companies that already use IT-related processes (levels 1 and 2), however, have a greater Industry 4.0 distance than companies in levels 3 to 5 that are already implementing the first elements of networked production. However, even at levels 4 and 5 it cannot be assumed that the threshold to Industry 4.0 has actually been breached. Rather, only the distance to networked production has narrowed. With the help of this Industry 4.0 readiness index, the change from traditional production to production close to Industry 4.0 can be mapped. Companies with a higher level have already made the transition more strongly than companies in the lower levels (Lerch et al., 2016).

3. Research methodology

The data for our research is obtained from the European Manufacturing Survey (EMS), a survey organized by a consortium of European research institutes and universities. EMS is a survey on the diffusion of advanced production technologies and organizational concepts in the European manufacturing industry. It investigates technological and non-technological innovation in European industries. It focuses on fields such as technical modernisation of value adding processes, introduction of innovative organizational concepts, international offshoring/outsourcing and backshoring of production and R&D activities, and new business models for complementing the product portfolio with innovative services. EMS includes at company level detailed information on innovation input, including R&D expenditure, innovation output such as the introduction of new products to the market, the qualification structure of the employees, and a number of control variables, such as company size, exports, the position of the company in the value chain, or characteristics of the main product and of the production process. In addition, data are collected on performance indicators such as productivity, flexibility, quality and returns (Dachs et al., 2019). The main objectives of EMS project are to find out more about the use of manufacturing and information technologies, new organizational approaches in manufacturing and the implementation of best management practices.

EMS takes place every three years. It is organized as a paper-based or electronic survey at a company level. The core questionnaire has six pages, with additional national specific questions the questionnaire may take up to 8 pages. It targets a random sample of manufacturing establishments with at least 20 employees (NACE codes from 10 to 33 in code C “Manufacturing”). The responding companies, therefore, present a multi-country cross-section of the main manufacturing industries, including producers of rubber and plastics, metal works, mechanical engineering, electrical engineering, textile and others. For preparing multinational analysis, the national data undergo a joint harmonisation procedure. Regarding the submission process, the respondent is always a top-level informant – production manager, plant manager, industrial director or Chief Executive Officer (CEO), depending on the size of each company – with a global perspective (or access to information) about the industrial and business requirements (Sartal et al., 2017).

3.1 Basic characteristics of Slovenian EMS

Our research is based on EMS data from Slovenian subsample from the sixth research round, namely EMS 2018. We sent out 778 questionnaires and received 119 filled-in questionnaires (15.3% response rate). Manufacturing companies in our research fall into the following NACE classification divisions:

- 22 – Manufacture of rubber and plastic products;
- 23 – Manufacture of other non-metallic mineral products;
- 24 – Manufacture of basic metals;
- 25 – Manufacture of fabricated metal products, except machinery and equipment;
- 26 – Manufacture of computer, electronic and optical products;
- 27 – Manufacture of electrical equipment;
- 28 – Manufacture of machinery and equipment n.e.c.;
- 29 – Manufacture of motor vehicles, trailers and semi-trailers;
- 30 – Manufacture of other transport equipment;
- 32 – Other manufacturing.

Table 3 present the number of companies in our database, the number of responses in each included NACE C code, response rate for each NACE code and the distribution of manufacturing companies in the total sample of respondents. As seen, the largest NACE divisions are 25, 28 and 22. The response rates differ between NACE divisions; some of them are individually not representative. Nevertheless, 119 total responses in 2018 allowed certain statistical analysis.

NACE code C	Number of companies in database	Number of responses	Response rate NACE division	Share in total sample
22	111	20	18,0%	16,8%
23	50	10	20,0%	8,4%
24	33	3	9,1%	2,5%
25	279	32	11,5%	26,9%
26	43	5	11,6%	4,2%
27	55	12	21,8%	10,1%
28	128	24	18,8%	20,2%
29	39	8	20,5%	6,7%
30	10	1	10,0%	0,8%
32	30	4	13,3%	3,4%
Total	778	119	15,3%	100,00%

Tab. 3. Characteristics of EMS 2018 sample

Figure 2 presents the structure of manufacturing companies based on their size, where the number of employees was the classifying criterion. As already mentioned we have included in our survey only companies with 20 employees and more. The largest share of respondents is from medium sized companies and the share of large companies is quite similar to the small companies share.

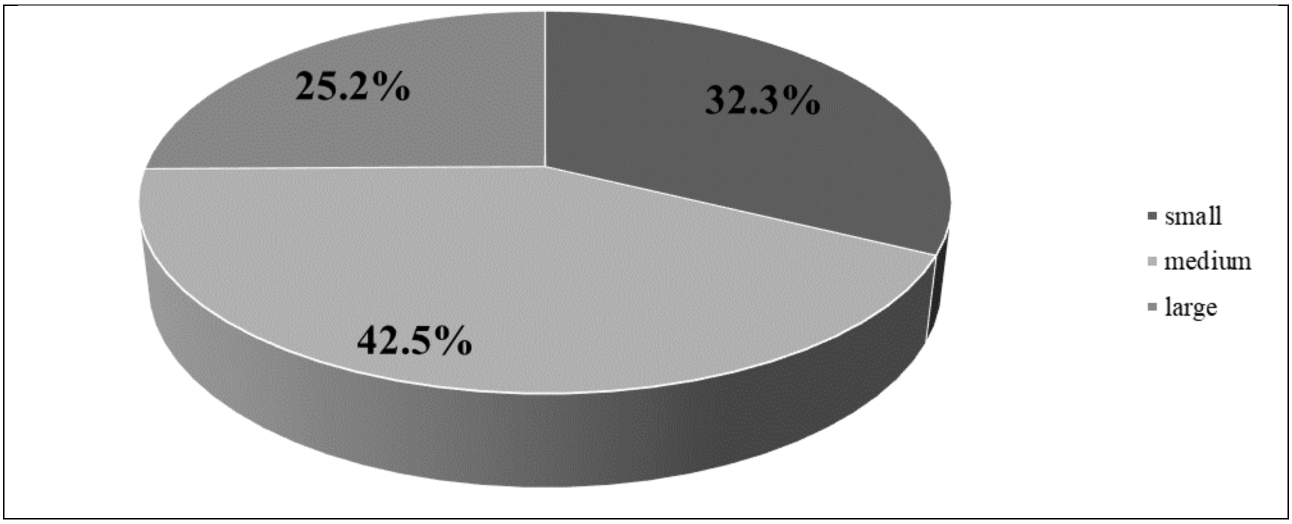

Fig. 2. Manufacturing companies based on their size in EMS 2018

We have divided manufacturing companies into two groups, based on their status as the final producer for consumers or business customers (OEM) or supplier (system supplier or supplier of parts or components). 46% of companies falls into supplier group and 54% into OEM.

4. Results and discussion

4.1 Advanced manufacturing technologies in EMS

Figure 3 presents a structural part of a question from EMS 2018 that deals with the diffusion of technologies and represents a core question for all our analysis.

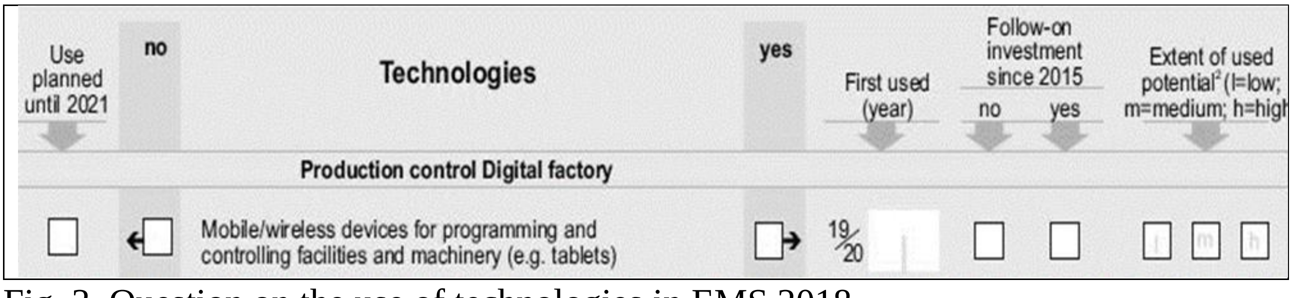

Fig. 3. Question on the use of technologies in EMS 2018

For each technology we have asked for the following information:

- Use of technology (yes/no).
- Use planned in the upcoming period of three years.
- Year in which this technology was used for the first time in your factory.

- Extent of actual utilisation compared to the most reasonable potential utilisation in the factory: Extent of utilised potential “low” for an initial attempt to utilise, “medium” for partly utilised and “high” for extensive utilisation.
- Upgrade of the already implemented technology (technologies) in the last three years – Follow-on investment since 2015 (yes/no).

In EMS 2018 we have divided 16 technologies used in manufacturing companies into 4 groups:
- Production control – Digital factory (9 technologies);
- Automation and robotics (2 technologies);
- Additive Manufacturing Technologies (2 technologies);
- Energy efficiency technologies (3 technologies).

Table 4 present general distribution of advanced manufacturing technologies in Slovenian manufacturing companies.

Advanced Manufacturing Technology	Share [%]
Production control – Digital factory	
Mobile/wireless devices for programming and controlling facilities and machinery (e.g. tablets)	32,2%
Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor	54,2%
Software for production planning and scheduling (e.g. the ERP system)	62,7%
Digital exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI)	51,7%
Near real-time production control system (e.g. systems of centralised operating and machine data acquisition, MES)	39,8%
Systems for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	20,3%
Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management (PDM)	19,5%
Virtual reality, or simulation for product design, or product development (e.g. FEM, digital prototyping, computer models)	38,1%
Artificial Intelligence (e.g. Deep Learning, Machine Learning or Neural Networks)	5,1%
Automation and robotics	
Industrial robots for manufacturing processes (e.g. welding, painting, cutting)	50,0%
Industrial robots for handling processes (e.g. depositing, assembling, sorting, packing processes, AGV)	35,6%
Additive Manufacturing Technologies	
3D printing technologies for prototyping (prototypes, demonstration models, 0 series)	32,2%
3D printing technologies for manufacturing of products, components and forms, tools, etc.	23,7%
Energy efficiency technologies	
Technologies for recycling and re-use of water (e.g. water recirculating system)	39,0%
Technologies to recuperate kinetic and process energy (e.g. waste heat recovery, energy storage)	32,2%
Energy technologies for the conversion of fossil fuels (oil, natural gas) to other sources of energy (electricity, hydrogen)	5,1%

Tab. 4. Advanced Manufacturing Technology adoption in EMS 2018

4.2 Industry 4.0 readiness index in Slovenian manufacturing companies

As already mentioned, for the purpose of our readiness index we have divided technologies into three technology fields: Digital management systems, Wireless human-machine communication and Cyber-physical system (CPS)-related processes. We included 7 out of 9 technologies from the Digital factory group. Figure 4 presents all three technology fields in Industry 4.0 readiness index and technologies from our research:

- Digital management systems: The first technology field is formed by software systems for production planning and scheduling (ERP) and the product lifecycle management systems. These are classified as the basic technologies of IT and digitization and are thus assigned to IT-related processes.
- Wireless human-machine communication: In the second technology field, the digital visualization is summarized with the mobile devices. This field is also assigned to the I4.0 basic technologies and thus to IT-related processes.
- Cyber-physical system (CPS)-related processes: The third technology field takes into account the near real-time production control system, the automation of logistics and the digital data exchange with suppliers and customers. These technologies already had production elements in cyber-physical systems and are therefore considered to be among the advanced I4.0 technologies.

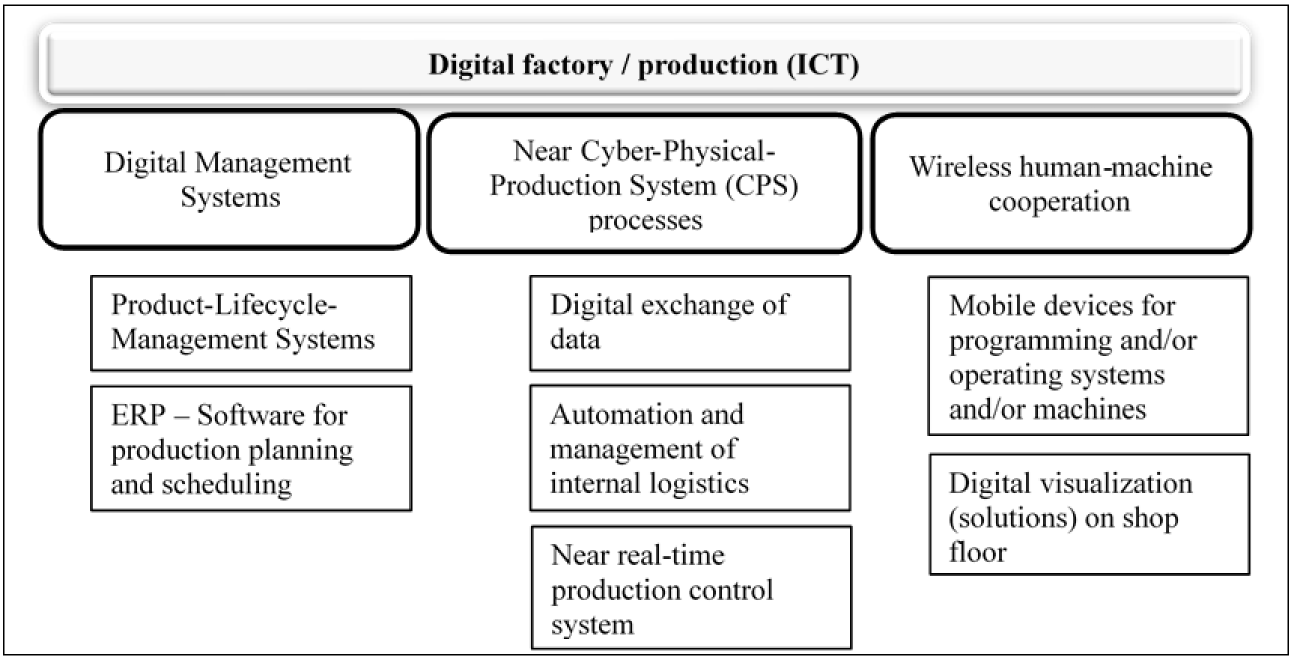

Fig. 4. Industry 4.0 readiness index with selected digital technologies

Table 5 present characteristics of selected digital technology in our Industry 4.0 readiness index. We asked manufacturing companies about their first implementation of technology, planned use of specific technology in the period 2019-2021, and upgrade of the existing technologies in the period from 2016 to 2018. We can observe that the majority of technologies is upgraded continuously, on average, from 30 to 55% of implementation cases. Especially, technologies from the “Digital factory” group are very frequently subject to follow-up investments / upgrades.

The share of companies planning to invest in technologies in the next 3 years has risen dramatically, compared to our previous research rounds. The column "Planned use" presents the share of companies that do not possess a specific technology but are planning to introduce it in the period from 2019 to 2021. A third of companies, currently without any ERP system, digital solutions to provide info directly on the shop floor, near real-time production control systems and mobile/wireless devices in production, are planning to implement these technologies in the following years.

Digital factory technology	Use [%]	Planned use [%]	Year of first use	Upgrade [%]
Mobile/wireless devices	32,2	30,0	2011	55,3
Digital solutions to provide info directly on the shop floor	54,2	33,3	2010	37,5
ERP system	62,7	34,1	2008	43,2
Digital Exchange of data with suppliers	51,7	22,8	2011	29,5
Near real-time production control system	39,8	28,2	2011	51,1
Systems for automation and management of internal logistics	20,3	23,4	2014	33,3
Product Lifecycle Management, Product Data Management	19,5	15,8	2012	30,4

Tab. 5. Characteristics of digital factory technologies in Slovenian manufacturing companies

Figure 5 depicts the distribution of all six described Industry 4.0 readiness levels for Slovenian manufacturing companies. A fairly high proportion, around 17% of all companies have so far not implemented any digital technologies in production. Around 57% of all companies already have IT-related processes in their production and form the basic levels. However, this group covers a big share of companies (nearly two thirds). This basic users group includes the group of beginners who only use technologies from one field (almost 20%; level 1), the advanced beginners who operate in two technology fields (almost 24%; level 2), but also the already advanced companies that are combining technologies from all three technology fields (almost 14%; level 3). In the two highest levels 4 and 5, this top group consist of a total of 26,3% of all companies. About every fourth company is consequently active in all three technology fields, and not only uses IT-related processes, but also several CPS-related processes simultaneously. Levels 4 and 5 have very similar share of companies. A look at Slovenian manufacturing sector shows that there is still a certain share of companies that heavily relies on traditional production processes (non-users). The main group of Slovenian manufacturing companies has slowly started to use IT-related processes, but there is a big difference between beginners and advanced users. The former are clearly closer to the non-users in terms of the type of production processes, the advanced companies are slowly preparing to enter the top group. The top group is not only active in each of the three technology fields, but also uses several CPS-related processes. There is a certain readiness to digitize their production, where the level 5 companies (13,6%) in particular seem to be preparing for Industry 4.0 related production or are already trying to implement it.

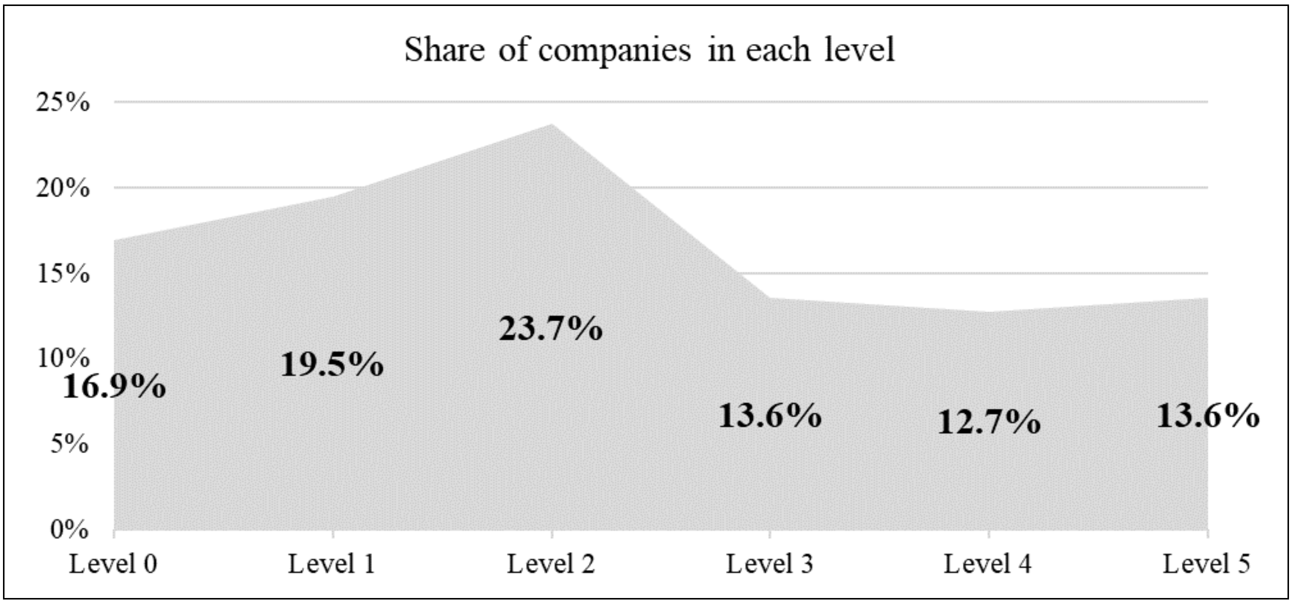

Fig. 5. Industry 4.0 readiness index in Slovenian manufacturing companies

5. Discussion and conclusion

In this chapter we have explored several Industry 4.0 readiness and maturity models and introduced a selected Industry 4.0 readiness model/index. Existing readiness and maturity model quite differ, what we attribute to researchers having different understanding and perception of Industry 4.0 and that there is a lack of standardized definition of Industry 4.0 concept. Since readiness models are country and industry specific, in the future we propose more general models that would be more widely applicable. Up to this date (to the best of our knowledge), no article has been published which compares the reliability and usability of existing models.

As is the case with all research, some issues must be taken into account when considering the reliability, significance, and general use of the obtained results. First, the data from Slovenia contains 118 companies in the EMS 2018 round. Although the sample is not small, further research should go towards the direction of a larger sample of more countries. The chapter present latest results of our research with the use of simple descriptive statistics. Our findings will be tested in the future with the use of advanced regression models.

We will also make more in depth analysis regarding the use of technologies where we will consider company size, technological intensity of the industry they belong to, their status as the final producer for consumers or business customers (OEM) or supplier (system supplier or supplier of parts or components). We will also look into the relationship between introduced technologies and specific characteristics, such as product complexity, production type and ability to introduce new products.

This research also has practical and managerial implications. Our results on the adoption of technologies indicate the current state of technology implementation in Slovenian manufacturing companies, which can serve managers as a roadmap for future investments. Similar with Industry 4.0 readiness index managers can on one hand get familiar with one of the possible models to measure company readiness for Industry 4.0 and on the other hand compare their company to Slovenian average Industry 4.0 readiness.

6. Acknowledgements

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