ARE SLOVENIAN MANUFACTURING COMPANIES READY FOR INDUSTRY 4.0?

IZTOK PALČIČ, KLEMEN KOVIČ
University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
iztok.palcic@um.si, klemen.kovic@um.si

Abstract This paper focuses on the diffusion of digital technologies in Slovenian manufacturing companies with respect to the concept of Industry 4.0. We present an Industry 4.0 readiness index and assess the Industry 4.0 readiness of Slovenian manufacturing companies. This index focuses on the use of selected digital technologies and their distribution within specific technology fields. The results are based on a sample of 141 Slovenian manufacturing companies whose data was collected as part of the latest edition of the European Manufacturing Survey 2022. The results show that the use of included digital technologies differs between companies and that the majority of manufacturing companies is still far away from the highest Industry 4.0 readiness levels.

Keywords:
manufacturing company, digital technology, Industry 4.0, Readiness Index, European manufacturing survey

JEL:
L60

University of Maribor Press

DOI https://doi.org/10.18690/um.epf.3.2023.38
ISBN 978-961-286-736-2

1 Introduction

Industry 4.0 can be briefly defined as the digitalization of production and services. The general understanding of the Industry 4.0 concept includes fully automated physical systems, but it should also be considered as automated and intelligent decision-making systems, not only automated physical systems (Elibal & Oezceylan, 2021). Industry 4.0 is characterized by sophisticated automation and digitalization processes and the use of electronics and information technologies in production and services (Yang, 2017). Digitization refers to the diverse sociotechnical phenomena and processes of adopting and using (digital) technologies in broader individual, organizational, and societal contexts (Legner et al., 2017). The adoption of digital technologies (DT) affects almost all areas of modern businesses, including manufacturing/production processes (Plekhanov et al., 2002). To determine the prevalence of different DTs, we analyzed selected technologies from the "digital factory" field. Therefore, our research presents use of seven selected DTs characteristic of the Industry 4.0 era in the Slovenian manufacturing industry. In addition to analyzing the diffusion of these technologies, this paper also presents an Industry 4.0 readiness index and assesses the Industry 4.0 readiness of Slovenian manufacturing companies.

This paper is organized as follows: First, the concept of Industry 4.0 readiness and maturity models in general are presented, followed by the Industry 4.0 readiness index that we used in our research. In the methodology section, we explain the characteristics of the European Manufacturing Survey (EMS). Then we present the use of selected DTs in Slovenian manufacturing companies and the results obtained using the Industry 4.0 readiness model. Finally, we conclude with a discussion of the results and some implications for business management, limitations of the research, and directions for future research.

2 Industry 4.0 readiness & Maturity Models

With the emergence of the Industry 4.0 concept, both scholars and practitioners face the challenge of determining the current maturity and readiness of companies for Industry 4.0 concepts (Elibal & Oezceylan, 2021). To perform better, industry and academia have continuously sought to develop and refine self-assessment models that can be used to assess companies' Industry 4.0 readiness (Hizam-Hanafiah et al., 2020). Identifying these Industry 4.0 readiness models is also of great importance as

they allow companies to measure antecedents and preconditions in the digital transformation process, which can then lead to organizational transformation (Canetta et al., 2018).

The Industry 4.0 readiness model attempts to represent how ready a company is to implement advanced technologies and concepts. Some authors define the readiness model as "the degree to which organizations can take advantage of Industry 4.0 technologies" (Hizam-Hanafiah et al., 2020), while others define it as "a tool to conceptualize and measure the baseline situation and initialize the development process" (Schumacher et al., 2016). To successfully master Industry 4.0 readiness, researchers from academia and industry have developed a variety of Industry 4.0 readiness models in recent years.

Schumacher et al. (2016) developed a maturity model to assess the Industry 4.0 readiness and maturity of manufacturing companies. Their main goal was to extend the prevailing technology focus by including organizational aspects. De Carolis et al. (2017) developed a maturity assessment method to measure the digital readiness of manufacturing companies. Using different dimensions, they assess 5 areas in which key manufacturing processes can be grouped: 1) design and engineering, 2) production management, 3) quality management, 4) maintenance management, and 5) logistics management. Canetta et al. (2016) proposed a digitalization readiness model to assess the state of a company's journey towards Industry 4.0, taking into account five dimensions: 'strategy', 'processes', 'technologies', 'products and services', and 'people'. Pacchini et al. (2019) proposed a model that includes eight technological enablers that are most relevant based on existing literature: Big Data, Internet of Things (IoT), cloud computing, autonomous robots, additive manufacturing, cyber-physical systems, augmented reality, and artificial intelligence.

3 Industry 4.0 Readiness Index

Our proposed Industry 4.0 readiness index was developed by Fraunhofer ISI to analyze the data collected in our research: EMS (Lerch et al., 2016). The logic of the Fraunhofer Industry 4.0 Readiness Index is shown in Figure 1 and is based on the selected DTs. Since the different technologies are highly process and operation dependent and come from different technology fields, a simple enumeration of the technologies used is not sufficient for an Industry 4.0 Readiness Index. Therefore, these DTs 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 to Industry 4.0, the technology field CPS already contains initial approaches to networked/digital production and can therefore be classified as closer to Industry 4.0 than the other two technology fields (Lerch et al., 2016).

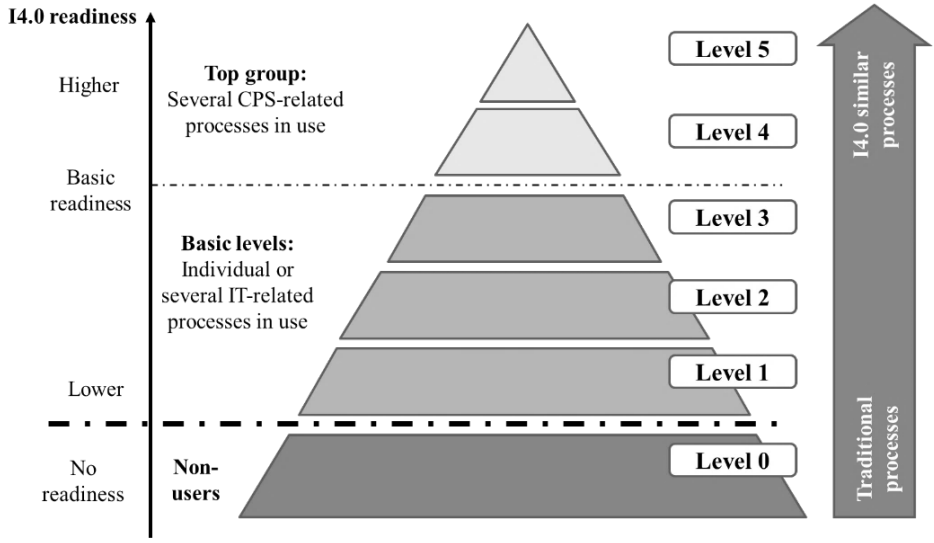

Figure 1: Industry 4.0 readiness index

Source:(Lerch et al. (2016)

With this grouping, companies can be classified as Industry 4.0-related companies that, 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, the Industry 4.0 readiness index results in 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.

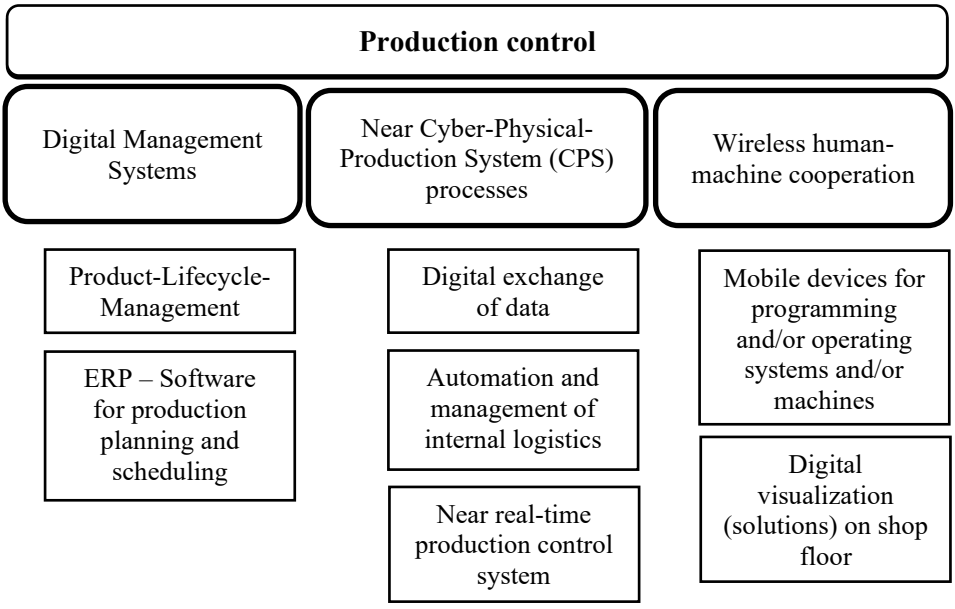

Figure 2: Industry 4.0 readiness index with selected DT
Source: Lerch et al. (2016)

With each level, the status of Industry 4.0 maturity increases or the distance to networked production decreases. While there is no readiness for Industry 4.0 in stage 0, companies in stages 1 to 5 have a basic readiness. However, companies that already use IT-related processes (levels 1 and 2) have a greater distance to Industry 4.0 than companies in levels 3 to 5 that are already implementing the first elements of networked production. But even at levels 4 and 5, it cannot be assumed that the

threshold to Industry 4.0 has been crossed. Rather, the distance to networked production has merely decreased. This Industry 4.0 readiness index can be used to map the change from traditional production to Industry 4.0-related production. Companies with a higher level have already made the transition to a greater extent than companies with a lower level (Lerch et al., 2016). Figure 2 shows all three technology fields in the Industry 4.0 Readiness Index with the associated DTs.

4 Methodology

The research data was collected as part of EMS, coordinated by the Fraunhofer Institute for Systems and Innovation Research – ISI, which is the largest European survey of manufacturing. The survey' questions address manufacturing strategies, the use of innovative organizational and technological concepts in production, cooperation issues, production offshoring and backshoring, servitization, and workforce deployment and skills issues. Data is also collected on performance indicators such as productivity, flexibility, quality and return on investment. In the last round of the survey EMS, we added questions on digital elements of products, new business models, artificial intelligence, circular economy, etc. The survey takes place every three years. In most countries, EMS is organized as a paper-based survey at the company level (the core questionnaire is six pages long). The people contacted to fill in the questionnaires are the production managers or the general managers of the manufacturing companies. The responding companies represent a cross-section of the major manufacturing industries. These include manufacturers of rubber and plastics, the metal industry, mechanical engineering and the electrical industry.

The survey is administered to manufacturing companies (NACE revision 2 codes from 22 to 32) with at least 20 employees. The main objectives of the EMS project are to find out more about the use of production and information technologies, new organizational approaches in manufacturing and the implementation of best management practices. Our research is based on data from EMS from a Slovenian subsample from 2022. We received 141 responses – a response rate of 16%. We divided manufacturing companies into three classes based on the number of employees. The largest share of respondents came from medium-sized companies (around 49%), followed by small companies (31%) and large companies (20%).

5 Results

The analysis shows (Table 1) that digital solutions for providing drawings, routings, or work instructions directly on the store floor and software for production planning and control (e.g., ERP or APS systems) are the most commonly used technologies, installed in about two-thirds of Slovenian manufacturing companies. Mobile/wireless devices for programming and controlling machines and/or equipment and digital exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI) are also catching up and are installed in almost 50% of Slovenian manufacturing companies.

Table 1: DT adoption in Slovenian manufacturing companies

Digital technology	Share [%]
Mobile/wireless devices for programming and controlling machinery and/or facilities	47.5%
Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor	64.5%
Software for production planning and scheduling (e.g. ERP or APS system)	63.8%
Techniques for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	27.7%
Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI)	44.0%
Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	17.7%
Near real-time production control system (e.g. Systems of centralized operating and machine data acquisition, MES)	33.3%

Using these DTs helped us develop Industry 4.0 readiness levels for Slovenian manufacturing companies. Figure 3 shows the distribution of all six Industry 4.0 readiness levels described. Around 14% of all companies have not yet installed any DTs in production. A little under 60% of all companies already have IT-related processes in their production and form the basic levels. This group of basic users includes the group of beginners that only use technologies from one area (almost 18%; level 1), the advanced beginners that are active in two technology areas (almost 24%; level 2), but also the already advanced companies that combine technologies from all three technology areas (over 16%; level 3). In the two highest levels, 4 and 5, this top group consists of a total of 28.4% of all companies. Accordingly, around one in four companies is active in all three technology areas and uses not only IT-related processes but also several CPS-related processes simultaneously. Levels 4 and 5 have a very similar proportion of companies.

A look at the Slovenian manufacturing sector shows that there is still a certain proportion of companies that rely heavily 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 closer to the non-users in terms of the type of manufacturing processes, and the advanced companies are slowly preparing to join the top group. The top group is not only active in each of the three technology areas, but also uses several CPS-related processes. There is some willingness to digitize their production, with level 5 companies in particular (14.9%) appearing to be preparing for or already trying to implement Industry 4.

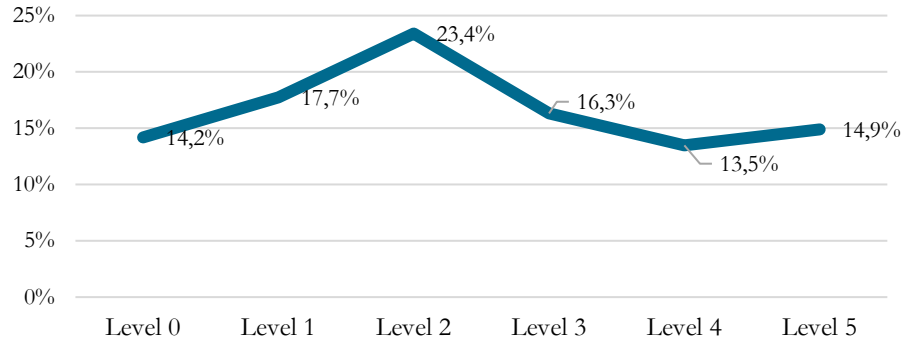

Figure 3: Industry 4.0 readiness index in Slovenian manufacturing companies
Source: Authors' calculations.

6 Discussion and Conclusion

Our results show that the use of DT in Slovenian manufacturing companies depends on the type of technology and the characteristics of the manufacturing company. Not surprisingly, not all selected DT are equally suitable for all manufacturing companies in the included industries. Nevertheless, some of the included DT are beneficial or even absolutely necessary in all manufacturing companies (e.g. ERP or real-time data collection) but are still not present in all companies. The absence of DT is several manufacturing companies is also evident from Industry 4.0 readiness assessment. Almost 50% of manufacturing companies use only from 0 to 2 DTs.

Our research has several limitations and consequently several future research agendas. For this research, we only considered the general distribution of the selected DTs, regardless of company characteristics such as size, OEM or supplier status, technological intensity of the industry to which they belong, etc. We have also

neglected some other specific characteristics, such as product complexity, production type and innovation capability. Another limitation is that we observed only one country and the number of cases was limited. In our future research, we will conduct a multinational study with a much larger sample of manufacturing companies. Our future research will also look more deeply into the combinations and relationships between DTs and their effects on firm performance.

Our findings have some initial implications for business management. The presented Industry 4.0 readiness index can serve as a simple tool for managers to assess which DT and the nature of its structural distribution contribute to the determination of the basic Industry 4.0 readiness index. It also enables managers to compare the level of Industry 4.0 readiness of their company with that of other Slovenian manufacturing companies from their industry.

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