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DIGITAL MATURITY OF CLUSTER ENTERPRISES AND THE IMPLEMENTATION OF INDUSTRY 4.0 SOLUTIONS ACCORDING TO THE RESULTS OF SELECTED STUDIES

Irena ŁĄCKA[1*], Przemysław WOJDYŁA[2]

[1] West Pomeranian University of Technology Szczecin; irena.lacka@zut.edu.pl, ORCID: 0000-0003-0762-8856
[2] West Pomeranian Chemical Cluster "Green Chemistry"; przemek@zielonachemia.eu
* Correspondence author

Purpose: This article presents the limitations and opportunities for implementing Industry 4.0 solutions in cluster enterprises in the context of the results of studies of their digital maturity.
Design/Methodology/Approach: The article uses the following research methods: the analysis of domestic and foreign literature on the subject, the analysis of secondary sources (the results of research by other authors, the results of a study of digital maturity of enterprises belonging to several clusters in Poland and enterprises outside the clusters, the data of the Digital Economy and Society Index 2022 report), induction and deductive reasoning.
Findings: Compared to EU countries, companies in Poland (especially SMEs) show a low level of digital maturity necessary to implement Industry 4.0 solutions (including big data technologies, cloud solutions, and artificial intelligence). In fact, this is a solid barrier to improving and maintaining the competitiveness of companies in the conditions of the fourth industrial revolution. Moreover, it stems from certain exo- and endogenous barriers. The research on behalf of the Future Industry Platform among companies participating in clusters revealed that their members show a higher degree of digital maturity than those outside such forms of network cooperation. It indicates more significant opportunities for cluster companies to implement Industry 4.0 solutions. Membership in a cluster represents an opportunity for them to reduce barriers to digitisation. The research results confirm that companies that are members of clusters are more innovative and competitive entities that can function more effectively and efficiently in the digital economy.
Practical implications: The article discusses a unique methodology for measuring the digital maturity of enterprises from several clusters in Poland, which business entities can use and apply for self-assessment. The presented research results and information on the barriers and limitations of digitisation will allow government representatives and other institutions to choose appropriate tools to support enterprises in Poland (especially in the SME sector), facilitating the implementation of Industry 4.0 solutions.
Originality/value: The study presents research results on cluster enterprises' digital maturity using an innovative method. It discusses them in the context of existing limitations in implementing Industry 4.0 solutions in Poland. It highlights the importance of clusters for improving the ability of enterprises to effectively use digital technologies for the success of the enterprise in the conditions of the fourth industrial revolution.

Keywords: digital economy, industry 4.0, digital maturity, enterprise, cluster.

Category of the paper: general review/viewpoint.

1. Introduction

Since the beginning of the 21st century, humanity has been participating in massive civilisational changes under the influence of the fourth industrial revolution, which is marked by advanced digital technologies, artificial intelligence and huge data sets as the most critical factors of production. „This 4th industrial revolution is characterised by a confluence, convergence, and fusion of technologies that is blurring the lines between the physical, digital, and biological spheres" (Hoque, 2019).

They lead to the transformation of the entire world economy and national economies toward the so-called digital economy. K. Schwab notes, "We are witnessing massive changes in all industries; new business models are emerging, disruptive breakthroughs to the existing order are occurring that will revolutionise production, consumption, transportation and delivery systems. On the social front, a paradigm shift is taking place that defines how we work and communicate, as well as how we express ourselves, convey information and seek entertainment. Governments and institutions are being transformed, as well as education, health care, transportation and many other systems. New ways of using technology affect our behaviour and our production and consumption systems [….]" (Schwab, 2018, pp. 17-18). It proves the scale and depth of the observed changes - they cannot be identified only with the sphere of production or service provision. Although one of the names of the fourth industrial revolution is industry 4.0, its essence is not only about changes in manufacturing processes. It is associated with much more profound and broader transformations in society and the economy (Janikowski, 2017; Gagnidze, 2022). They refer to the transformation of markets, production, consumption, labour and globalisation processes (Śledziewska, Włoch, 2020). Unlike the impact of the first three industrial revolutions, the current one is occurring much more rapidly and non-linearly, permeating all socioeconomic systems (the changes are more comprehensive), and new technological solutions are emerging in high-tech and traditional industries.

One aspect of these changes is the transformation in production processes, referred to as Industry 4.0 (Production 4.0). Their basis is the use of information and communication technologies in industry and services to communicate between people and machines to create links between suppliers, producers and customers, i.e. cyber-physical production systems and smart factories (Gajdzik, 2022; Suleiman et al., 2022). For companies, Industry 4.0 creates new development opportunities and offers them the possibility to improve their competitiveness in domestic and international markets through economies of scale and increased efficiency in the use of resources. As a result, it offers excellent opportunities for the growth and economic development of the country, improving the quality of life, and increasing the availability of goods, knowledge and information. Nevertheless, the digital transformation of the economy, causing substantial socioeconomic changes and creating many development opportunities, also raises numerous challenges and risks in micro, macro and mega-economic terms (Schwab, 2018; Harari, 2018; Zervoudi, 2020; Bikse et al., 2022).

The digitisation of the economy and society has, until recently, been advanced primarily in highly developed countries. In 2022, the most digital economies were reported to be: Denmark, the US, Sweden, Singapore, Switzerland, the Netherlands, Finland, South Korea, Hong Kong (SAR), Canada, Taiwan, Norway, and the United Arab Emirates (Statista, 2022; CEDA, 2022).

However, the challenges of the COVID-19 pandemic have greatly accelerated the transformation of socioeconomic systems in less developed countries as well. Limiting interpersonal contacts, the need to maintain social distance, prohibitions on conducting business and other social and economic restrictions have caused negative effects on the economies of all countries (Zhu, Chou, Tsai, 2020; Balcilar, 2020; Mishra, 2020; Kuroda, 2020; Schwab, Zahidi, 2021; Lacka, Supron, 2021). At the same time, they forced a change in the business model of enterprises and accelerated the digital transformation of not only large companies but also those from the SME sector (Almeida, Santos Monteiro, 2020; Szwajca, Rydzewska, 2022). This phenomenon has also been noted in Poland, where the digitisation of the economy had been very slow before the pandemic. Unfortunately, efforts in this area are still insufficient.

Entering the digital economy and achieving adequate competitiveness requires companies to introduce new business models and strategies to integrate all areas of the industry through advanced ICT technologies (ensure digitisation and networking) and to collaborate across the entire value-added chain (from design and research through production, management and logistics, to the distribution of final goods). This chain includes business partners and customers, with cooperation between practically all participants on a peer-to-peer basis. The new operating philosophy of the so-called “smart factory” refers to creating a fully integrated production process enabling mass production of individual products for highly personalised orders. In this case, it is not enough just to automate production; it is still necessary to have cyber-physical systems, Internet of Things (IoT), Industrial Internet of Things (IIOT), Internet of Service (IoS), Big Data analytics, Cloud Computing, horizontal and vertical integration of different levels of management structure, the use of augmented reality and 3D technology, blockchain and cybersecurity. It ensures the complete implementation of an integrated production process, the execution of a virtual design, the production of small batches in response to a personalised order, “automated logistics and production that “learns” and self-optimises” (Gőtz, 2018, p. 387). In this process, the so-called digital twin is used for virtual testing and optimisation of the production line and the final product. The implementation of these pillars of Industry 4.0 requires companies to achieve adequate digital maturity. This name means the state of full readiness and the highest development of an enterprise in the implementation and effective use of digital technologies to achieve its strategic goals in the digital business environment (Deloitte, 2018).

The scale of challenges arising from the implementation of Industry 4.0 solutions in the Polish economy inspired the authors to analyse the results of digital maturity studies of enterprises operating in industrial processing that are part of several national clusters. On this basis, they decided to assess the progress of digitisation in these organisations, determine the limitations and barriers to applying the Industry 4.0 concept in this group of business entities and the chances of improving the digitisation of enterprises thanks to membership in such a cooperation network.

The purpose of this study is to present the limitations and opportunities for implementing Industry 4.0 solutions in cluster enterprises in the context of the results of studies of their digital maturity. Given the adopted objective, the following research questions were formulated:

1. What is the state of digitisation of the Polish economy and its SMEs in the opinion of experts of the European Commission (based on the Digital Economy and Society Index, 2022)?
2. What are the limitations and barriers to digitising the Polish economy and its enterprises?
3. What level of digital maturity is represented by companies in selected clusters (based on the December 2021 survey of cluster companies in Poland)?
4. What are the limitations to improving the digitisation of cluster member companies?
5. What are the possibilities for implementing Industry 4.0 solutions in the surveyed cluster enterprises?
6. How can a cluster improve the digital maturity of its enterprises?

In pursuit of answers to the above questions, various research methods were used, which are discussed later in the paper. The above study fills a certain cognitive gap, as it presents the results of a study of the digital maturity of cluster enterprises (representing, among other things, economic units of industrial processing), which are unknown to a large part of Polish society. At the same time, it highlights the possibilities of clusters (strategic networks operating in dynamically developing industries) in reducing the limitations of implementing the Industry 4.0 concept.

The structure of the article includes the introduction, research methodology, discussion of the theoretical foundations in the field of Industry 4.0, digital maturity and its measurement models, and the impact of clusters on the implementation of Industry 4.0 solutions. The following section presents the results of a study of the digital maturity of cluster enterprises in Poland and the analysis needed to answer the research questions. Subsequently, the authors included a discussion of the results, a summary and a bibliography.

2. Material and Method

The present study is a review based on the analysis of the literature on the subject (domestic and foreign) and secondary sources, both theoretical and empirical. The latter group includes mainly studies of the digital maturity of enterprises belonging to Polish clusters. They were conducted from 22.11.2021-6.12.2021 on a sample of 150 cluster enterprises using a unique tool made available by the Platform of the Future Industry Foundation for self-assessment of the digital maturity of business units (Platforma Przemysłu Przyszłości, 2020). The leader of this research was one of the authors of the article, who was also a representative of one of the clusters. In addition, the study was based on the results of the European Commission's Digital Economy and Society Index 2022 (DESI 2022, 2022). The methods of induction and deductive reasoning were also used, as well as the authors' long experience gained from their activities in the cluster participating in the digital maturity survey.

The tool, as mentioned earlier, the enterprise digital maturity questionnaire, was created considering the most important aspects of enterprise development for the Industry 4.0 concept. It enables an independent identification of the company's development stage in more than a dozen dimensions based on three pillars: Organization, Processes and Technology. Together they form a digital maturity model, with four modules containing complex components in each of these three areas of the company. The entire model consists of three areas (pillars), 12 modules and 20 components. Each component represents a critical aspect of the company's operation, on which management should focus on preparing the organisation to act within the framework of the Industry 4.0 concept. The individual components were assigned a total of 20 questions in the questionnaire. It also includes a demographics section. The detailed design of the digital maturity model is included in Table 1.

A CAWI research technique was used to collect data, and in some cases, the survey was conducted using the CATI technique (in the situation of technical difficulties of entrepreneurs in completing the survey electronically). The authors of the study assumed that a minimum of 150 business units from 5 clusters with at least 30 enterprises would participate. Due to the difficulty of obtaining responses within the relatively short time frame of the survey (22.11.2021-6.12.2021), its organisers decided to target the questionnaire to six clusters. It enabled them to achieve the goal of the research, that is, to determine the level of digital maturity of 150 enterprises operating in clusters. However, the uneven distribution of the survey sample meant that the results obtained could not be aggregated and analysed at the cluster level but only at the level of the entire surveyed population. In the cited study, this and other research limitations are discussed in detail (Wojdyła et al., 2021).

Table 1.
Structure of the Digital Maturity Model of the Future Industry Platform

Pillar	Module	Component	Survey Question Number
Organisation	Cooperation and projects	Project management and collaboration	Q1
	Strategy	Strategy	Q2
	Employees	Training and competence development of employees	Q3
	Leadership	Leadership	Q4
Processes	Internal integration	Planning of resources and production processes	Q5A
	Product lifecycle integration	Product lifecycle management	Q5C
	Integration with the environment	Supply chain fulfilment	Q5B
		Customer collaboration	Q6
	Standardisation	Standardisation of technology purchases	Q7
		Optimisation of energy efficiency	Q8

Cont. table 1.

Technology	Automation	Manufacturing processes (industrial systems and information systems)	Q9A
		Administration and management of the company	Q9B
		Building infrastructure	Q9C
	Connectivity	OT and IT manufacturing processes (industrial and information systems)	Q10A
		Business administration and management	Q10B
		Building infrastructure	Q10C
	Autonomation	OT and IT manufacturing processes (industrial and information systems)	Q11A
		Business administration and management	Q11B
		Building infrastructure	Q11C
	Smart Product	Smart Product	Q12

Source: Wojdyła, Frankowska, Cheba, Ławicka, 2021.

The analysis of the completed questionnaires shows that two clusters - the West Pomeranian Green Chemistry Cluster (bringing together companies cooperating in several thematic platforms, such as bioeconomy, energy and materials recovery, packaging, healthy food, and education and qualification in the chemical sector) and the Metalika Metal Cluster (including companies in the metal and complementary industries) - had the highest participation in the study. Each of them provided more than 40 surveys. They were followed by: Lubuski Metal Cluster and ICT Cluster Western Pomerania. The latter's entities include companies operating in various sectors of the IT industry, such as software, multimedia, telecommunications networks, IT outsourcing, among others. More than 20 surveys were obtained from each of these two clusters. Enterprises in the Southern Wielkopolska Food Cluster (gathering food producers and distributors) and the West Pomeranian Maritime Cluster (which includes manufacturing and service entities operating in the broadly defined maritime economy) were the least involved in the survey, as each of these clusters provided up to 10 surveys. A total of 160 completed surveys were obtained and checked for reliability and completeness. Those that did not meet the required criteria were removed. Finally, for the purposes of the study, responses were collected from 150 companies, which were included in the database.

The data were subjected to statistical analysis. First, a preliminary analysis of the structure of responses to individual questions was carried out, followed by an analysis of the number of responses in each research scope. In the next stage, the average values of the digital maturity index of enterprises were analysed by pillar, module and component. Finally, a ranking of enterprises was created based on average ratings of digital maturity along with the determination of typological groups (clusters) of the surveyed business units. The tool provided by the Future Industry Platform uses a nominal rating scale (ratings from 1-6, with a rating of 1 indicating the lowest level and a rating of 6 indicating the highest). This unique model created by DELab UW (Nosalska et al. 2020) is a modification of the digital maturity model of the so-called Singapore Index (INCIT, 2022, The Smart Industry…, 2022). It was adapted to Polish conditions and expanded to include additional (relevant to Industry 4.0) areas.

On the basis of the information contained in the survey demographics, the surveyed population was also analysed with regard to the year of establishment of the enterprise, the origin of capital, affiliation to the industry and class of business conducted, employment size, the approximate value of turnover and exports in the last year.

Considering the year in which the enterprise was established, entities belonging to the following periods of business start-up were distinguished: up to 1990 under the socialist economy, in 1991-2004 (before Poland entered into the European Union), and then in 2005-2021 (during the time after integration with the Community until the time of the survey). The latter period was further divided into several more, i.e. for the years 2005-2011, 2012-2014, 2015-2018 and 2019-2021.

In the structure of 150 surveyed cluster enterprises, the following distribution can be distinguished: 89 units established in 2005-2021 (59.3%), 49 entities established in 1991-2004 (32.7%) and 12 enterprises with the most extended history, i.e. established before 1991 (8%). Among the largest group of survey participants, companies established between 2005 and 2011 accounted for the largest share. They accounted for 26% of the respondents (39 entities). It was followed by companies established in 2015-2018, with a share of 14.0% (21 units), and companies with the shortest duration (2019-2021), having an 11.3% share (17 companies). The units established in the years 2012-2014 obtained an 8% share among the respondents (12 entities). Most of the participants in the study on the digital maturity of cluster enterprises were fully owned by Polish owners (over 71%), mixed capital represented 17.3% of entities, and 11.3% of the respondents were owned by foreign capital.

Analysing industry affiliation, it was found that 59.3% of business units represented manufacturing (section C), while the rest belonged to another section of the PKD (40.7%). Within the industrial processing enterprises, the largest share was accounted for by those engaged in the manufacture of fabricated metal products, excluding machinery and equipment (26.7%), followed by: the manufacture of machinery and equipment not elsewhere classified (8.0%), manufacture of rubber and chemical products (6.7%), manufacture of chemicals and chemical products (4.7%), other product manufacturing (2.7%), manufacture of computers, electronic and optical products (2.0%), repair, maintenance and installation of machinery and equipment (2.0%), manufacture of other non-metallic mineral products (1.3%). The representatives of the remaining classes of activity in section C accounted for 0.7% of the total volume of industrial processing entities. This group included companies operating in the production of metals, production of motor vehicles, trailers, and semi-trailers, except motorcycles, the production of textile products, production of paper and paper products, production of food products, printing and reproduction of recorded media, the production of clothing, and the production and processing of coke and refined petroleum products.

Cluster companies with different employment figures participated in the survey. Micro-enterprises with up to 9 employees (32.7%), small entities with 10-49 employees (28%) and medium-sized units with 100-250 employees (25.3%) dominated. On the other hand, large entities (over 250 employees) accounted for 7.3% of all units, while the medium-sized ones with employment in the range of 50-99 people accounted for 6.7% of the total population.

The approximate values of turnover and exports in the last year were also important features of the surveyed companies. The largest share of cluster enterprises were entities achieving turnover below PLN 5 million (43.3%) and in the range of PLN 5-50 million (30.0%). Turnover over PLN 100 million was declared by 17.3% of units. The smallest share in this category was obtained by enterprises with a turnover between PLN 50 and 100 million (9.3%).

In the case of the analysis of the structure of the surveyed companies concerning the approximate value of exports, it turned out that as many as 45.3% of the surveyed entities did not receive export revenues in the last year. Among those active in exports, the largest proportion were entities with average export revenue of less than PLN 5 million (23.3% of respondents) and between PLN 5 and 50 million in export revenue (20.0% of respondents). Higher export values in the range of PLN 50-100 million were obtained by 6.7% of cluster enterprises. The highest average export values in the last year of more than PLN 100 million were declared by 4.7% of businesses.

For comparative purposes, information was used from the Future Industry Platform Foundation's (FPPP) database of enterprises that self-assessed their level of digital maturity using a publicly available tool posted on the Foundation's website. They were treated as information from the so-called general base, which included a wide variety of enterprises, often representing different divisions of the Polish Classification of Activities (PKD) at the same time. The questionnaire for the self-assessment of digital maturity did not include the question of cluster membership, so it is difficult to determine whether the 639 businesses in the database included cluster member companies. The FPPP database includes companies and entities that are not typical production enterprises, such as universities, research institutes or business environment institutions. In addition, the Foundation's database of records contained duplicate entries, test entries and information about entities providing an incorrect tax identification number (NIP). Therefore, the research team reviewed the database before using information from this general database. The records with a false NIP, trial or duplicate entries, and related to entities other than manufacturing companies (universities, research institutes and business environment institutions) were removed. Of the initial 639 entities, 489 remained in the created general database of comparative nature.

However, the investigators of the digital maturity survey of cluster enterprises found it impossible to verify the obtained results thoroughly, and the quality of the material they received in relation to the business units in the general base may raise legitimate concerns. They decided that during the analyses, they would calculate only selected descriptive characteristics, including average ratings for pillars, modules and components. Thus, it will be possible to benchmark against the performance of cluster enterprises only in this regard as well, exercising great caution in relying on the results from this part of the study.

3. Theoretical background

3.1. Industry 4.0 and its essence, conditions and barriers to the digitisation of enterprises

Today's extremely rapid, deep and complex technological transformation poses economic, technological, social and cultural challenges for many countries and their economic systems and societies (including Poland). They require a transition to a digital economy, one element of which is Industry 4.0.

In the near future, the competitiveness of the Polish economy in the European and global markets will depend on the pace of implementation of this concept of organising production processes in enterprises. The current drivers of Poland's economic development are diminishing its long-term growth, economic development, and competitiveness (Wieczorek, 2018), as evidenced by the decline in the dynamics of total factor productivity (TFP), which was particularly acute after Russia invaded Ukraine (World Bank, 2022). In this context, only increasing knowledge and innovation in all areas of the economy can stimulate long-term growth and development of the economy. They are supported by the ubiquitous power of information and communication technologies that enable the creation of complex cyber-physical systems.

The concept of Industry 4.0 originated at the beginning of the last decade in Germany. Its creators are German scientists and engineers. They prepared it to answer the government's questions about the strategic directions and conditions for developing the national economy (Kagermann, Wahlster, Helblig, 2013). The term (in German, given as Industrie 4.0) first appeared at the 2011 Hannover Electronics Fair in Hannover, Germany (Grabowska, 2019; Bai et al., 2020). Since 2013, this concept has become extremely popular in highly developed countries. The process of spreading the new manufacturing philosophy accelerated as the global economy recovered from the crisis. Then, the concept of Industry 4.0, with the growing awareness of the digital transformation of the global economy, became recognisable worldwide (Wang et al., 2016). Today, Industry 4.0 is perceived as one of the elements of Economy 4.0 (digital economy) and one of the stages of its creation (He, 2022). The issues of progress in implementing Industry 4.0 solutions, their barriers (Glass et al., 2018; Műller, 2022; Senna et al., 2022; Yűksel, 2022) and the digital maturity of enterprises in various aspects have become an important and current research problem worldwide. It is demonstrated by the review of the global literature and ongoing research in this area contained in the study by M. Flamini and M. Naldi (2022) and the paper by Szász et al. (2021).

The concept of Industry 4.0 defined the driving forces of the new economy (physical, digital and biological megatrends), which over the years, ceased to be merely theoretical (Schwab, 2018). The technologies and socioeconomic phenomena projected for the future were coming into effect rather quickly and transforming the world in all its aspects. Initially, changes were noticed in the manufacturing processes of technologically advanced and traditional industries.

Eventually, they entered many aspects of society, changing socioeconomic relations (e.g., sharing economy, labour market functioning, platformization), public administration, education, and healthcare (Śledziewska, Włoch, 2020). As a result, business units have spearheaded the introduction of disruptive digital technologies into industrial processing following the concept of Industry 4.0, aiming to create so-called smart factories. Subsequently, these solutions permeate many other areas of economic and social life. Over time, this forms the tissue of the new digital economy, the manifestations of which are revealed in all aspects of society and the state - beyond the sphere of production, also in the areas of consumption, distribution, regulation of the social, economic and political system (Schwab, 2018; Schroeder et al., 2019; Tutak, Brodny, 2022). B. Siuta-Tokarska defines this stage of development of the ways of human life and work as "advanced digital transformation of the chains of intertwining horizontal and vertical interconnections of cooperation of units and composite devices, products, services and business models, the key elements of which are: cyber-physical systems, the Internet of Things, the Internet of Services, as well as the so-called smart factories" (Siuta-Tokarska, 2021, p. 6). The statement referred to selected pillars of Industry 4.0, enabling the achievement of the concept's implementation goals. Among them is the ability of business owners to gain better control and understanding of every aspect of business operations. The benefits offered to entrepreneurs after the implementation of this concept also include (Wiesmüller, 2014; Wang et al., 2016; Schwab, 2018; Gajdzik, 2022; Co to jest branża 4.0, 2022):

- the optimisation of manufacturing processes and radical improvement in efficiency and automation through the use of artificial intelligence algorithms – entrepreneurs make data-driven decisions throughout their operations, improve forecast accuracy, support timely delivery, and develop profit-optimised plans;
- the resilience and flexibility of the economic entity thanks to *smart manufacturing* regardless of the market or economic situation; enterprises are shaping their future digital supply chain with modern planning;
- the increase in confidence in discovering new business models and quickly seizing opportunities; thanks to the solutions of the fourth industrial revolution, enterprises reduce costs, increase market efficiency and connect supply chains by sea, land and air;
- the preparation of "green" and sustainable products and technologies without sacrificing profitability; buyers become more efficient and profitable from the supplier's point of view thanks to digitisation, while entrepreneurs achieve their environmental goals without limiting the possibilities of achieving other business goals, such as profitability and scalability;
- the improved individualised response to buyers' needs – automated robotisation and interaction of various technologies create new product opportunities.

As pointed out by Suleiman et al. (2022), Industry 4.0 is based on nine technological pillars, which include: big data (Fei et al., 2019), simulation (Dalenogare et al., 2018), autonomous robots (Bahrin et al., 2016), Internet of Things (Roblek et al., 2016), additive manufacturing (Kang et al., 2016), horizontal and vertical integration (Xu, Xu, Li, 2018; Dalenogare et al., 2018), cloud computing (Liu, Xu, 2017; Alcácer, Cruz-Machado, 2019), cybersecurity (Kamble et al. 2018), augmented reality (Ghobakhloo, 2018).

Using these technologies in the enterprise allows for increased competitiveness, efficiency and productivity, reduces costs and increases the level of security (Tutak, Brodny, 2022). However, it should be borne in mind that many enterprises (especially SMEs), regardless of the country or industry in which they operate, face numerous obstacles and barriers to digital transformation (Vartolomei, Avasilcai, 2019; Styven, Wallstrőm, 2019; Cenamor et al., 2019; Almeida, Santos, Monteiro, 2020; Peter, Vecchia, 2020; Coman et al., 2020; Civelek et al., 2020; Chen et al., 2021; Rupeika-Apoga, Petrovska, 2022). They are also indicated in the paper of D. Szwajca and A. Rydzewska (2022).

Among the many difficulties in the implementation of industry 4.0 solutions and the full digitisation of enterprises, especially of SMEs (a list of which is included in the study by Rupeika-Apoga and Petrovska (2022) among others, the following are most often mentioned: insufficient resources (including financial, human), technical, organisational and cultural barriers, lack of experts, insufficient skills and competences of employees and owners, resistance to change, difficulties in creating effective cooperation in the supply chain, lack of integration, high integration costs, inadequate data quality (lack of information or insufficient data). On the other hand, the OECD report (OECD, 2021) on the digitisation processes of small and medium-sized enterprises listed the following long-term structural barriers (Szwajca, Rydzewska, 2022, p. 296):

- "competence gap preventing managers and employees from identifying digital solution needs and adapting business processes and models,
- financial gap reducing the availability of funds from implementing cutting-edge digital technology,
- infrastructure gap concerning insufficient access to fast broadband connections".

The strength of the indicated barriers is evidenced by the results of the DESI 2022 study for countries in the European Union. In the case of Poland, indicators informing about human capital, connectivity, and integration of digital technologies reveal the occurrence of the obstacles mentioned above in the digitisation not only of businesses but of the entire society. Consequently, this leads to a very distant 24th position in the DESI 2022 ranking. All these limitations and barriers affect the difficulties in implementing Industry 4.0 solutions and the competitiveness of the entire economy and its development opportunities (DESI 2022, 2022; Szwajca, Rydzewska, 2022).

3.2. Digital maturity and its measurement

In order to implement Industry 4.0 solutions in companies, the right level of digital maturity is required, enabling companies to effectively use advanced digital technologies to achieve market success in the new conditions of the digital economy. It requires a company to create an effective business strategy based on using digital solutions to gain a competitive advantage (Jasińska, 2021). "A company's digital maturity is not determined solely by its possession of digital technologies, but, among other things, by how the company designs and offers its products, how it collaborates with customers and business partners, how it manages data, the extent to which it uses autonomous solutions and systems, or how it implements collaboration between partners" (Platforma Przemysłu Przyszłości, 2022).

In recent years, there has been an increase in the number of publications devoted to the digital maturity of enterprises and its impact on the ability of business entities to apply Industry 4.0 technologies. One can also find sources discussing methods for studying digital maturity. A review by the DELab UW team of existing methods to prepare a tool for studying the digital maturity of enterprises in Poland for the Future Industry Platform (Nosalska et al., 2020) showed that there are three strands of maturity assessment in the literature. One of them focuses on technologies and solutions used in production, and the other - on determining maturity in the dimension of organisational change. The latter is a mixed approach. In most of the proposed models for assessing total digital maturity, the phenomenon is first assessed in specific dimensions using partial ratings, and then, by using the arithmetic or weighted average, the assessment of total digital maturity is determined. The proposed maturity models are often closed or semi-open tools. They are offered by consulting companies, which use them to further deepen the digital maturity assessment as part of their commercial services. Most of them require participating in the research of respondents serving in the company as CEO or complementarily as CTO. The available tools do not allow for determining digital maturity in the full range of crucial capabilities for Industry 4.0. To measure digital maturity, interval scales or nominal (five-level) scales describing level-specific scenarios of a given characteristic corresponding to the digital maturity variable are most often used. It is very rare in the publicly available tools to provide a list of recommendations for action to be taken by the company's management to achieve success through the use of digital after conducting a digital maturity assessment. In Table 2, the authors have provided a list of the most important sources dedicated to digital maturity and Industry 4.0.

Table 2.
Publications devoted to the assessment of digital maturity and preparations for the implementation of Industry 4.0 solutions

Author and date of publication	Digital maturity and potential for Industry 4.0 - assessment model
Schuh et al., 2017	The ACATECH Maturity Index
Lichtblau et al., 2015	IMPULS – Industry 4.0 Readiness
McKinsey and Company, 2015	Industry 4.0 How to navigate digitisation of the manufacturing sector
Schumacher, Erol, Sihn, 2016	A maturity approach for assessing Industry 4.0 readiness and maturity of manufacturing enterprises
Leyh et al., 2016	SIMMI 4.0 – A Maturity Model for Classifying the Enterprise-wide IT and Software Landscape Focusing on Industry 4.0
Gokalp, Sener, Eren, 2017	Development of an Assessment Model for Industry 4.0: Industry 4.0
Mittal et al., 2018	DREAMY – Digital Readiness Assessment Maturity Approach
Basil, Doucek, 2019	The Singapore Smart Industry Readiness Index
Pacchini et al., 2019	The degree of readiness for the implementation of Industry 4.0 – a structure based on the Society of Automotive Engineers (SAE) J4000 standard
Corallo, Lazoi, Lezzi, 2020	Assessing Industry 4.0 readiness in manufacturing – based on the PCA method
Dikhanbayeva et al., 2020	Assessment of Industry 4.0 Maturity Models by Design Principles
PWC, 2016	Industry 4.0: Building the digital enterprise
Bierhold, 2018	For a better understanding of Industry 4.0 – An Industry 4.0 maturity model
Nosalska et al., 2020	Support for Industry 4.0 in Poland. Prototype of the tool for assessing the digital maturity of manufacturing enterprises

Source: own elaboration pursuant: Bierhold, 2018; Williams et al., 2019; Tutak, Brodny, 2022.

3.3. Clusters and Industry 4.0

In the modern knowledge-based economy undergoing digital transformation, strengthening innovation and competitiveness in terms of macro, meso, and micro is a significant challenge for the European Union, public authorities in individual countries, business environment institutions, entrepreneurs, research institutions and cluster coordinators. In the literature since the late 1990s, many authors dealing with the issue of clusters and their importance for the economy, the region and businesses have pointed to their pro-innovation impact (e.g. Porter, 1998; Audretsch, Lehmann, 2006; Bernauer et al., 2006; Kowalski, 2013; Fundeanu, Badele, 2014, Bembenek 2017; Łącka, 2018, Bembenek, 2020; McPhillips, 2020; Guimarães, Blanchet and Cimon, 2021). It is a result of the synergy from the cooperation of the two main types of cluster members, i.e., enterprises (primarily SMEs) and units of the scientific and research sector, with the support of business environment institutions and representatives of public administration (Moszkowicz, Bembenek, 2017). This synergy is created by combining the resources, skills and competencies of cluster partners, knowledge and technology transfer and cooperation in innovative processes (Gőtz, 2019, 2020). It is supported by social capital with a high degree of trust between the members of this network organisation. It is of great importance that clusters use the achievements of innovative partners from the R&D sector - entrepreneurial universities and research institutions (Gagnidze, 2022).

In the European Union's strategic documents, clusters are indicated as organisations that can contribute to accelerating the digital transformation in the economy, digitising enterprises, and implementing Industry 4.0 solutions. EU experts emphasise that cluster policy in individual countries should support the building of cross-sector value chains, internalisation, stimulate entrepreneurship and the development of competencies and professional skills (European Commission, 2021a). According to the European Commission, clusters are important for developing Industry 4.0, industrial transformation, innovation and reducing barriers to implementing the smart factory concept. The development of Industry 4.0 is to be based on bottom-up initiatives with favourable state policy, which is to support the development of the digital economy (Iersel, Konstantinou, 2016). In addition, cluster enterprises implementing Industry 4.0 solutions can significantly support the "green" transformation of the European economy and ensure its resilience to the threats of the modern economy (Gagnidze, 2022).

4. Research results

4.1. The state of digitization of the economy in Poland based on the results of DESI 2022

In 2022, the European Commission published another report on the digital economy and society in the European Union member states (DESI 2022, 2022). The study presents their achievements in creating the digital economy in the second year of the COVID-19 pandemic. For this purpose, experts from the European Commission use a synthetic indicator, the so-called Digital Economy and Society Index. This indicator is based on sub-indices relating to the four pillars of the digital economy. They include:

- human capital and its digital skills - Internet user skills and advanced digital skills,
- connectivity and digital infrastructure – demand and coverage of fixed broadband, mobile broadband and the cost of broadband,
- integration of digital technologies in enterprises and e-commerce,
- digital public services, e-government.

In this report, Poland was ranked 24th among EU countries. It was followed only by Greece, Bulgaria and Romania. The position is due to obtaining a synthetic index of 40.5, while the EU average was 52.3. However, looking at Poland's achievements in 2017-2022, which describes the DESI aggregate indicator, one can notice a constant improvement in this indicator. Very slowly but effectively, Poland is managing to narrow the gap with other EU countries in building a digital economy and society. Poland achieves the best results in connectivity, while it performs worst in terms of digital technology integration. The latter aspect is essential for implementing Industry 4.0 solutions in enterprises.

The DESI 2022 Report shows that Poland also has a big problem with human capital. In this category, our country was ranked 24th among the Member States. Only 43% of people aged 16-74 have at least basic digital skills, with the EU average at 54%. Only 57% of people in Poland can create digital content, while the EU average of this indicator is 66% of the population. It indicates an inadequate level of digital competencies that employees of companies operating within a smart factory should be equipped with. Digital competencies are the ability to consciously and responsibly use digital technologies for education, work and social participation. They include skills related to information use, data analysis, communication, collaboration, problem-solving, critical thinking, digital content creation, programming, digital hygiene, ethical online behaviour and cybersecurity (DigitalPoland Foundation, 2022). Their insufficient development among Poles constitutes a substantial limitation of the transformation of the socioeconomic system towards Economy 4.0 and the digital transformation of enterprises.

Digitisation of enterprises and implementation of Industry 4.0 solutions require appropriate quality of human resources, including IT specialists. In Poland, the share of professionals in the field of digital technologies among the working population in 2021 was 16%, with the EU average of 19%. Unfortunately, this is due, among others, to the not very large number of graduates related to information and communication technologies and the digital economy. In 2021, the share of IT graduates in the total number of all graduates was 3.7%, slightly lower than the average rate for the entire EU (3.9%). The DESI 2022 report also shows a slow increase in the number of ICT specialists in the Polish labour market, but their share is approaching the average for the European Union, which is 4.5% of the total workforce. However, this is still not enough concerning the needs of the digital economy. In the countries that are EU leaders in the digital economy, i.e. Sweden and Finland, this indicator is 8% and approximately 7.5%, respectively. The deficit of such specialists in Poland affects the rate companies implement digital technologies.

In Poland, an additional constraint to the digitisation of the economy in human capital is the inadequate IT training of employees in domestic companies. According to the DESI 2022 report, in 2021, only 18% of Polish enterprises provided special IT training to employees. It should be remembered that these data refer to the second year of the COVID-19 pandemic, i.e. a period of acceleration of the processes of digitisation of the economy and implementation of numerous digital solutions worldwide into many spheres of life of societies - including production, service provision, education, health care, commerce, culture, entertainment, etc. It indicates that there are significant barriers to the implementation of digital technologies. They result from various factors, including cost and mentality. The latter aspect is related, among other things, to the attitudes of many owners of micro, small and medium-sized enterprises and a certain proportion of executives, who display a low level of digital competence, are unaware of the changes in the modern economy, display conservative attitudes and an unwillingness to change. It affects the low propensity to invest in both more advanced digital technologies and employee-related training. This problem is complicated to overcome in micro and small businesses when there is increasing uncertainty in the economic situation, the risk of operations and the constant lack of funds for investment.

The integration of digital technologies is another crucial factor for the implementation of industry 4.0 solutions in enterprises. In this category, Poland ranked only 24th among the member states. It indicates that SMEs, compared to the EU average, are far less likely to use digital technologies on at least a basic level. In 2021, there was still a significant distance when using technologies such as social media, big data, cloud solutions, artificial intelligence or e-invoices. The DESI 2022 report also shows that despite these difficulties among Polish entrepreneurs, there is an increase in the tendency to use digital services. In 2021, 19% of enterprises used cloud solutions, and 32% participated in electronic information exchange. However, only 40% of economic entities achieved at least a basic level of digital technology use. The EU average was 55%. Thus, Poland has much catching up to do, given the European Union’s assumption that in 2030 this share of the Community will be 90% (European Commission, 2021b).

Considering Poland’s achievements in the Connectivity pillar, it can be noted that in areas such as the use of fixed broadband of at least 100 Mbps, fibre optic network coverage, and in terms of the broadband price index, Poland performed above the EU average in 2021. On the other hand, in the case of ultra-high-speed network coverage, Poland’s score was in line with the EU average. Unfortunately, Poland appears very far behind the achievements of the EU as a whole in areas related to 5G networks. In this respect, in 2021, Poland was only 25th in this ranking. According to experts from the European Commission, the insufficient development of 5G networks (covering only 34% of populated areas in Poland with an EU average of 66%) is due to the lack of access to the C-band frequency, and this hinders the development of connectivity based on the latest infrastructure and technology. Thus, it is a significant barrier to the digitisation of businesses and the implementation of the Industry 4.0 concept.

4.2. Digital maturity of cluster enterprises

The research on digital maturity in 150 cluster enterprises was conducted in an aggregate manner, i.e. including the analysis of responses in each of the three pillars (organisation, processes, technology). Each time, the analysis was conducted first by the represented level of digital maturity of the enterprise in the pillar using a response scale of 1-6 (1 being the lowest and 6 being the most advanced). Digital maturity was then analysed within each module in the pillar.

Due to the limited framework of this article and its nature, the research results are presented synthetically. The authors focus on providing the most important results of the analysis of the digital maturity of enterprises in each pillar of the assessment model and in relation to individual components in each pillar (Wojdyła et al., 2021).

The average assessments of the cluster companies surveyed in the different pillars of the Digital Maturity Index were as follows. The highest average rating was obtained under the Organisation pillar (3.20). In contrast, the average score obtained for the analyses for the Processes pillar was 2.95. The lowest average score for the level of digital maturity of clustered units was determined for the last pillar, Technology. The average scores in each of the three analysed pillars were less than half of the possible points (median = 3.50).

The assessment of the average maturity of a digital business unit in the first of the analysed pillars: Organization, consisted of scores for four modules. In the case of two of them: Cooperation and Projects and Leadership, the average scores (3.65 and 3.66, respectively) were higher than half of the possible points. However, for the other two modules, Strategy and Employees (training and development of employee competencies), the average ratings (2.96 and 2.51) were below 3.00. In each of these modules, companies were identified in the test sample, characterised by the highest level of maturity with a rating of 6. At the same time, those that achieved the lowest level of digital maturity (rating 1) were found. The established ratings within these modules were also characterised by the highest level of variation. The coefficient of variation has taken respectively: 52.90% and 50.90%.

The analysis of respondents' answers to the evaluation of achievements in the following pillar Processes revealed that none of the analysed modules received average ratings above 3.5. The average ratings of the three modules covering: Internal Integration, Product Lifecycle Integration and Integration with the Environment were of a value above 3. In contrast, the lowest average rating of 2.42 was determined for the module: Standardisation. The rating consisted of the average scores of the surveyed cluster enterprises obtained under two components: Standardisation of technology purchases (average rating of 2.73) and Optimisation of energy efficiency (2.10). The ratings obtained for these two components also had the highest variation. It amounted to, respectively: 43.01% and 46.25%.

In the analysis of the responses of the surveyed companies, it was found that average assessments of less than 3.00 were obtained in each of the analysed modules in the case of the Technology pillar. The average ratings for the modules of this pillar ranged from 2.69 (Automation and Connectivity module) to 2.32 (Intelligent Product module). The average scores for the individual components that comprise the analysed modules were also below 3.00. The research also showed that the assessments obtained by cluster enterprises in these components were characterised by a relatively high level of variation from 36.18% (Component Administration and Management of the Company) to 56.16% (Component Smart Product). The selected descriptive characteristics for the digital maturity index for pillars, modules and components are included in Table 3.

Table 3.

Summary of the most important descriptive characteristics of the digital maturity survey of cluster enterprises

Pillar	Module	Component	Average		Median	Standard deviation	Vs (%)	Min	Max
Organisation	Cooperation and projects	Project management and collaboration	3.20	3.65	3.00	1.40	38.32	1.00	6.00
	Strategy	Strategy		2.96	3.00	1.57	52.90	1.00	6.00
	Employees	Training and competence development of employees		2.51	2.00	1.28	50.90	1.00	6.00
	Leadership	Leadership		3.66	4.00	1.34	36.50	1.00	6.00
Processes	Internal integration	Planning of resources and production processes	2.95	3.09	3.00	1.11	35.87	1.00	5.00
	Product lifecycle integration	Product lifecycle management		3.17	3.00	1.14	35.99	1.00	6.00
	Integration with the environment	Supply chain fulfilment		3.23	3.00	1.17	36.17	1.00	6.00
		Customer collaboration		3.13	3.00	1.11	35.48	1.00	6.00
	Standardisation	Standardisation of technology purchases		2.73	3.00	1.18	43.01	1.00	6.00
		Optimisation of energy efficiency		2.10	2.00	0.97	46.25	1.00	6.00
Technology	Automation	Manufacturing processes (industrial systems OT and information systems IT)	2.56	2.61	3.00	1.09	41.63	1.00	6.00
		Business administration and management		2.97	3.00	1.07	36.18	1.00	6.00
		Building infrastructure		2.48	2.00	1.24	49.87	1.00	6.00
	Connectivity	OT and IT manufacturing processes (industrial and information systems)		2.71	2.00	1.30	48.18	1.00	6.00
		Business administration and management		2.93	3.00	1.22	41.59	1.00	6.00
		Building infrastructure		2.45	2.00	1.37	56.15	1.00	6.00
	Autonomation	OT and IT manufacturing processes (industrial and information systems)		2.61	2.00	1.25	47.75	1.00	6.00
		Business administration and management		2.75	3.00	1.19	43.17	1.00	5.00
		Building infrastructure		2.23	2.00	1.24	55.55	1.00	6.00
	Smart Product	Smart Product		2.32	2.00	1.30	56.16	1.00	6.00

Source: Wojdyła, Frankowska, Cheba, Ławicka, 2021.

In the further part of the digital maturity studies of cluster enterprises, the results obtained by enterprises were subjected to additional analyses using the methods of multivariate statistical analysis (Wojdyła et al., 2021). The average value of the assessments obtained in each of the three analysed pillars was calculated for each company participating in the research. Then all the averages of the individual pillars were summed up by creating a digital maturity index for each surveyed enterprise. On this basis, a ranking of companies was created due to their average level of digital maturity. The surveyed entities were then divided into four clusters. The first two clusters were set up by companies that achieved the digital maturity index at a level above the average determined based on the results of all economic entities. Enterprises with the highest digital maturity index results were classified in cluster one. The following two clusters included entities with digital maturity index results at below-average levels. Cluster four, on the other hand, includes cluster companies with the lowest digital maturity index results. It can be written according to the following breakdown:

- cluster one included entities for which: $Ii \geq \bar{I} + SI$.
- cluster two included enterprises for which: $\bar{I} + SI > Ii \geq \bar{I}$.
- cluster three included enterprises for which: $\bar{I} > Ii \geq \bar{I} - SI$.
- cluster four included enterprises for which: $Ii < \bar{I} - SI$,

where:

Ii – means the value of the digital maturity index determined for each surveyed enterprise,

$\bar{I}$ – means the average value of the digital maturity index determined from the index values obtained by individual enterprises,

SI – means the standard deviation determined based on the values of the indices obtained by individual enterprises.

During the grouping of enterprises by their digital maturity index scores, it was found that the differences in average scores between clusters were relatively significant. The most homogeneous was cluster 2, which included 42 entities. The coefficient of variation for this group was 6.6%. The most significant variation was found for cluster four, which included 25 companies with the lowest scores in the sample. In this case, the coefficient of variation was 11.9%. Table 4 provides the descriptive characteristics of all groups.

The first group included the 25 cluster enterprises with the highest digital maturity index scores in the sample. The minimum average score (the number of points) obtained by the participating entities was 3.8. In contrast, the maximum average score was 5.5. A company with the highest average score in the digital maturity index is a medium-sized entity that employs between 100 and 250 people. It started its industrial processing operations in 2017.

Table 4.
The descriptive characteristics of the concentrations determined for each group

Cluster	Average	Standard deviation	Coefficient of variation	Max	Min	Range
Cluster 1 n = 25	4.4	0.5	10.8	5.5	3.8	1.8
Cluster 2 n = 42	3.2	0.2	6.6	3.7	2.9	0.8
Cluster 3 n = 58	2.6	0.2	8.7	2.8	2.1	0.6
Cluster 4 n = 25	1.7	0.2	11.9	2.0	1.4	0.6
Entire sample n = 150	2.9	0.9	29.9	5.5	1.4	4.1

Source: Wojdyła, Frankowska, Cheba, Ławicka, 2021.

The survey team found that no entity participating in the digital maturity assessment achieved the maximum score in each component. Four companies with varying characteristics achieved the lowest average index score of 1.4. They had different employment figures and started businesses in the following years: 1997, 1999, 2014 and 2019. The group consisted primarily of service companies engaged in providing the following services: information technology, hot-dip galvanising and powder coating, performing the repair, modernisation and investment works of the mechanical industry for the power and heating industries, and carrying out general construction work accompanying the services of this industry. Only one company determined the approximate value of its exports in the last year at the level of PLN 5 to 50 million. The remaining entities were not engaged in export activities.

When comparing the characteristics of all clusters, it can be noted that the differences in the assessments of individual components obtained by the company classified as the highest and the lowest in the created digital maturity ranking are significant. In particular, one notices the inactivity of the company ranked lowest in the built ranking for 15 of the 20 analysed components. They include:

- pillar 1. Organisation - 3 out of 4 components rated at the lowest level, i.e., Strategy, Training and development of employee competencies and Leadership,
- pillar 2. Processes - 5 out of 6 components achieved the lowest ratings, i.e. Supply Chain Execution, Product Lifecycle Management, Customer Collaboration, Technology Purchasing Standardisation and Energy Efficiency Optimization,
- pillar 3. Technology - 7 out of 10 components received the lowest ratings, i.e., Production processes (OT and IT), building infrastructure, production processes (OT and IT), Business administration and management, building infrastructure (in the Automation component), building infrastructure (in the Autonomation component), Smart product.

In the comparative analyses, the focus points noted the similarity of the results obtained by the company classified at the most in the third and fourth clusters. The same result was obtained by the surveyed units from these clusters for the components:

- pillar 2. Processes - Components: Supply Chain Execution, Customer Collaboration, Technology Purchasing Standardisation, Energy Efficiency Optimization,
- pillar 3. Technology - Components: Manufacturing processes (OT and IT), Business Administration and Management, Building Infrastructure, Smart Product.

Attention was also drawn to the similar results achieved by cluster companies ranked highest in clusters two and four. Results at the same level were identified for:

- pillar 1. Organisation - Components: Training and competence development of employees, Leadership,
- pillar 2. Processes- Components: Optimisation of energy efficiency.

Discovered similarities show that the results obtained in various components of the digital maturity index were similar in some of the enterprises, despite relatively significant differences in the level of the index itself.

The demographic criteria of the surveyed entities were also considered when analysing the level of digital maturity of cluster enterprises. One of these characteristics was seniority in the market (year of establishment). Given this criterion, the research team found that enterprises founded in 2005 and later obtained a slightly higher level of the overall digital maturity index compared to entities founded earlier. For this group of entities, evaluations of 4, 5 and 6 for individual components have appeared more frequently than in others. "In most of the analysed cases of companies established after 2005, their digital maturity was assessed at a similar level. On the other hand, a detailed analysis of the responses in the group of the most recently established entities on the market [...] indicated that they mostly rated their maturity level at 3 and 4" (Wojdyła et al., 2021, p. 8).

Considering the employment figures of the surveyed companies, it was noted that micro-enterprises (up to 9 employees) achieved low levels of digital maturity for most components (ratings of 1 or 2). Similar results were recorded for small entities with 10 to 49 employees. In the case of micro-enterprises, digital maturity was rated quite highly only for the Leadership component. The members of this group of respondents gave this component a 4 rating, emphasising that the board has a well-established and full knowledge of the latest solutions but, in their implementation, relies on external experts (N = 16; 32.65%). In the group of entities with 100 to 250 employees, the level of 2 or 3 of the digital maturity assessment was most often declared. The largest business units (over 250 employees) mostly reached level 4 or 5 in digital maturity. For most components, large enterprises rated their digital maturity quite highly. It indicates that there are significant differences compared to the ratings of SMEs. Such differences were noted for the following components: Strategy, Training and Competency Development of Employees, Planning Resources and Production Processes, and Executing the Supply Chain or Standardising Technology Purchases.

Another demographic feature used in the conducted research of business entities was the turnover value. Including this criterion in the analysis of the results of the evaluations of cluster enterprises, it was found that economic entities with the lowest turnover value rated their digital maturity relatively low for most components (more often a rating of 1 or 2 compared to enterprises with other turnover values). They attributed the highest rating (4) to the Leadership component, highlighting the opinion that the board has a well-established and complete knowledge of the latest solutions but, in their implementation, relies on external experts (N = 19; 29.23%). Economic entities representing different turnover values "rated their level of digital maturity in the component: Customer Cooperation at Level 3 - communication with customers is carried out through online and offline channels and is personalised. Enterprises with the highest declared turnover rated their digital maturity at a very low level for the component: Energy efficiency optimisation, indicating level 2 – the company manually measures energy and other media consumption in selected areas (once a month). The company does not have an energy efficiency strategy (N = 18; 69.23%)" (Wojdyła et al., 2021, p. 80).

Analysing the results obtained in this regard, it can be concluded that among companies declaring different values of turnover, there were no significant differences in the assessment of the level of digital maturity.

Considering the value of exports of the surveyed enterprises (possibly no export revenues), it was found that non-exporting entities obtained the lowest digital maturity assessments in the Strategy component (1). At the same time, they indicated that building such a strategy is not considered an important goal in the company's current or future plans (N = 27; 39.71%). However, the same component was rated the highest (at the rating of 5) for those entities that reached the value of exports in the last year of PLN 5-50 million. They often declared that a long-term strategy and a properly adjusted management model are implemented in more than one area of activity (N = 7; 23.33%). That said, it was noted that all groups of companies rated their digital maturity in the Energy Efficiency Optimization component equally low (at level 2). They emphasised that the entity manually measures energy and other utility consumption in selected areas (once a month). The company has no energy efficiency strategy.

The analysis of the research results also established a link between the assessment of the digital maturity of cluster enterprises and the origin of capital and belonging to the industry. The research team found that companies with domestic capital (most represented in the research group) achieved a relatively low level of digital maturity (most often a score 2 or 3). However, foreign-owned entities more often declared level 4 or 5, and even for some components, level 6. It indicates significant differences in the preparedness for the challenges of Industry 4.0 between companies owned by domestic and foreign capital.

Analysing the industry affiliation of the surveyed cluster enterprises, it was noted that entities declaring activities within Manufacturing (section C of the PKD) achieved a higher level of digital maturity than units assigned to other sections of activity.

5. Discussion

The analysis conducted by the authors of the study of Poland's performance in the ranking of the digital economy and digital society index in the latest edition of the DESI 2022 report revealed that against the background of the 27 European Union member states, Poland shows a vast distance from not only the leaders of the digital economy (Finland, Denmark, the Netherlands) but even the other post-socialist countries of the Grouping (Estonia, Lithuania, Latvia, Slovenia, the Czech Republic, Hungary and Slovakia). It ranks only 24th, although it is slowly catching up in laying the groundwork for the digital economy and its digital society. The report cited above reveals the reasons for Poland's weak position in this ranking, classified in terms of all pillars of the digital economy. All of these limitations and deficits significantly impact the ability to implement Industry 4.0 solutions in Polish companies, with the most decisive impact on micro, small and medium-sized entities. In the case of the first pillar, entitled Human Capital, these include:

- insufficient share of people aged 16-74 with digital skills at least at the basic level (only 43% in Poland compared to the EU average of 54%,
- insufficient participation of people aged 16-74 year-olds with basic skills to create digital content (57% against the EU-wide rate of 66%),
- insufficient number of ICT specialists (percentage slightly lower than the EU average),
- the low share of ICT specialists among the working population,
- the low enrolment rate in studies that educate ICT majors,
- a lower share of ICT graduates than in the EU, which has a significant impact on the uptake of digital technologies by businesses,
- a very low share of companies providing special ICT training (only 18%), which, coupled with the low level of digital skills and the low propensity of executives to invest in this area, contributes to the difficulty of Polish companies (especially SMEs) in leveraging the potential of the digital economy.

Considering the next pillar of the digital economy, namely Connectivity, Poland's distance from EU countries is also prominent. Data from the DESI 2022 report indicate that it has been possible to increase the share of households covered by fixed networks with very high capacity (70%, an increase of 5 percentage points over the previous period). However, there are still considerable limitations in developing 5G networks (Poland's 25th place in the EU ranking), which provide significantly higher network speeds and bandwidth than 4G technology. Its advantages are also high reliability and low delays, which is very often crucial in the industry. In addition, its energy efficiency is emphasised. The 5G network can transmit up to 100 times more data using a similar amount of energy than previous generations. The key element of industry 4.0 is wireless communication but at the level of LTE and 5G technologies (Polski przemysł, 2021).

The indicator describing Poland's performance in the third pillar of the digital economy, titled Integration of digital technologies, is very unfavourable. The use of digital technologies in businesses is clearly on the rise. It is evidenced by such data as the share of companies using cloud solutions (19%) and electronic information exchange (32% against an EU rate of 38%). However, EU experts notice Poland's great distance in achieving the goal set by the European Union of a strategy to implement the digitisation of the economy by 2030. It mainly concerns such issues as the use of cloud computing, big data and artificial intelligence. In Poland, in 2021, the use of these technologies ranged from 3% to 19%, compared to the EU target of 75% by 2030. Polish companies' efforts towards further digitisation and their potential in this area should be increased, as only 40% of business entities achieve at least a basic level of digital technology use, against a rate of 55% for the European Union as a whole. The goal of the Digital Decade is to get no less than 90% of SMEs to have "at least a basic level" of digital use in 2030. In the opinion of the authors of the paper, Poland can accelerate its digital transformation and have a more significant impact on the implementation of Industry 4.0 solutions by enterprises by using further incentives to invest in ICT technologies, opening up more opportunities for the development of 5G networks, continuing targeted financial assistance to those implementing these solutions, and supporting enterprises in disadvantaged regions. Measures are also needed to improve the quality of human capital to improve digital skills and competencies.

In Poland, the development of the digital economy and the ability to implement Industry 4.0 solutions in enterprises is adversely affected by the insufficient development of digital public services. It is indicated by the results on digital public services, which are below the EU average. Our country ranks only 22nd in this category. The EU strategy calls for 100% online provision of key public services to EU citizens and businesses by 2030.

The factors presented above that hinder the implementation of Industry 4.0 solutions are diverse and confirm the existence of substantial barriers to the digitisation of domestic companies. In light of these limitations, the results of the digital maturity assessment of cluster enterprises participating in the research using the digital maturity self-assessment tool prepared for the Future industry platform become understandable. They indicate a relatively low level of digital maturity of domestically-owned enterprises (ratings of 2-3 predominated). According to the article's authors, in the studied cluster companies, significant difficulties were noted in connecting individual information technology (IT) systems with *operational technologies (OT)*, i.e. industrial systems. Data generated by sensors installed in industrial machines are rarely connected to a digital database capable of analysing them and drawing conclusions from them on an ongoing basis for decision-making. It constitutes a significant constraint in developing the concept of industry 4.0 in cluster enterprises.

A significantly higher level of digital maturity was demonstrated by foreign-owned entities (scores of 4-5) for most components in the Organization and Process pillars. Cluster enterprises belonging to SMEs, other than large enterprises, non-export entities and companies established before 2005, have significantly worse results in assessing digital maturity. Therefore, these economic units face the most significant barriers to implementing industry 4.0 solutions with various conditions. These are both the competence problems of the owners and their employees, resource constraints (insufficient human, financial, technological, and infrastructure resources), as well as organisational and cultural barriers.

Analysing the results of the digital maturity study, the authors of this paper suspect the existence of communication problems between IT specialists, OT specialists and management in the surveyed companies, which may cause difficulties in developing shared goals for the implementation of the Industry 4.0 concept. After all, the concept is supposed to deliver the goals of the business sphere - reducing costs, increasing revenues, and improving efficiency and productivity indicators. In the case of micro and small companies, probably due to the lack of in-house IT staff, one has to resort to external services, which are most often limited to basic processes. The results of the survey also indicate that some of the owners of enterprises participating in clusters are not ready to change their business model, the need to acquire new competencies, change their approach to the market, and bear the risk of new investments. It demonstrates the share of enterprises that do not include the development of digitisation in their strategic plans.

However, comparing the results obtained by the research team (Wojdyła et al., 2021) for cluster enterprises with the digital maturity assessments obtained by enterprises from the general base, it can be concluded that cluster members obtained higher levels of average digital maturity assessments for the vast majority of components from all pillars (Organisation, Processes, Technology). It indicates that joining a cluster can be an important factor in accelerating a company's digital transformation.

In this type of network, organisations that strongly influence the innovation of their members not only promote the need to respond to the trends and challenges of the modern economy. Educational activities are also underway to raise awareness and knowledge about the transformation of the digital economy and the essence of Industry 4.0. Cluster members can cooperate in research projects, make it easier to use public financial support for projects related to the implementation of industry 4.0 solutions, and benefit from the organisational support of the cluster coordinator during this process. Entities cooperating in the cluster from the sphere of enterprises, science and research, public administration, and business environment institutions can obtain additional value through the possibility of optimising operational activities and reducing transaction costs, establishing solid relationships between cluster members, the occurrence of the network effect and the possibility of fast and effective learning (Frankowska, 2012). Their cooperation creates a so-called value chain in the cluster, which can also be seen in digitisation processes in its enterprises. A cluster's value chain of the digital economy can include business units operating within an ecosystem that will provide digital content and applications, digital services to consumers, businesses, science and research institutions, and government institutions (Kowalski, 2022). Implementing Industry 4.0 solutions across all cluster entities will achieve economies of scale and reduce unit costs. It will also strengthen cooperation between cluster partners and provide a more significant advantage to competitors resulting from using the new business model.

Conclusion

For over a decade, the digital economy and one of its elements, Industry 4.0, have been a significant and current research problem. They are also an important issue for public stakeholders both globally (e.g., The European Commission) and nationally (national governments). In the case of Poland, the government and its ministries and subordinate agencies are tasked with creating appropriate economic policies to support the digital transformation of the country and its business entities, which will condition the level of Poland's competitiveness in the following decades and the possibility for its companies to join global value chains.

The issues of the digital economy and Industry 4.0 have also been of increasing importance to businesses in Poland for several years. Their owners saw the acceleration of the transformation of the fourth industrial revolution in all countries, including those less innovative ones, which have so far benefited from other sources of competitiveness than the implementation of modern technologies in all industries. Due to legal or restrictive industry requirements, some industrial companies in Poland already used specific IT solutions to "track" and analyse information from the production process (companies in the food or chemical industries). These operators have been using some industry 4.0 solutions for a long time. They are now extending them with additional elements while moving toward a new business model.

The second group of economic operators includes those companies that choose digital transformation in a conscious way to increase their competitiveness in international markets. Only by improving efficiency, reducing costs, optimising the use of resources, and personalising their offerings will they be able to compete with foreign competitors.

Some companies see development opportunities in implementing the concept of Industry 4.0 by applying their solutions to improve product quality, better reach buyers, expand their offerings using more data, and then produce personalised mass products. Unfortunately, they do not have sufficient capital for major investments in this direction and a complete change in the business model.

Sadly, the companies in Poland already implementing Industry 4.0 solutions and wishing to introduce them represent a small proportion of business entities. The paper's authors aimed to study the limitations and barriers to developing this concept in domestic enterprises, the possibilities of implementing digital solutions in business entities and the impact of clusters on accelerating the digitisation of business entities in the country.

In this paper, the authors presented the limitations and opportunities for implementing Industry 4.0 technologies in cluster member enterprises in the context of studying their digital maturity and the overall state of development of the digital economy and digital society in Poland. Guided by the posed research questions, they assessed the state of digitisation of the Polish economy and its SMEs based on the data from the European Commission's DESI 2022 report. It provided an opportunity to identify constraints and barriers to the digital transformation process of the Polish economy, society and enterprises, including entities belonging to the SME sector. Using the results of the December 2021 survey of the digital maturity of cluster enterprises in Poland (performed for the Future Industry Platform), they determined the level of digital maturity of business units belonging to several selected clusters.

After analysing the results of this study, they found that cluster enterprises tend to have a low level of digital maturity (average ratings were around 3 on a scale of 1-6). However, their performance is higher than that of the companies in the general base. The results obtained in the digital maturity research prove the existence of strong barriers and obstacles to the digitisation of enterprises in Poland. They result from various external and internal conditions. These factors were revealed by the European Commission's DESI 2022 report and the analysis by the article's authors of the results of a study of the digital maturity of cluster companies. Among them are problems related to the quality of human capital and its digital competencies and skills, the inadequate number of IT specialists in the economy and its entities, and insufficient resources needed to implement the concept of Industry 4.0. In addition, they diagnosed connectivity infrastructure barriers in Poland, regulatory gaps in the digitisation of the economy and its businesses, and insufficient support for the digital transformation of business entities. They also noted organisational and competence limitations to implementing the Industry 4.0 concept in units owned by Polish capital, especially in the case of micro, small and medium-sized enterprises that were not engaged in export activities and had the longest market experience.

However, the authors' research has shown that clusters, on the one hand, bring together business entities that are more innovative, more and more responsive to the challenges of the modern economy, recognising earlier than others the need to digitise their activities in the face of the fourth industrial revolution. On the other hand, joining them increases the opportunities for business entities to implement Industry 4.0 solutions and achieve higher competitiveness in relation to companies outside the cluster. It is due to the numerous benefits offered by this network form of business organisations.

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