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Leveraging technology for enterprise crisis resilience in Industry 5.0

Wykorzystanie technologii w budowaniu odporności przedsiębiorstw na kryzysy w świetle koncepcji Przemysłu 5.0

Abstract: Industry 5.0 is a concept centered on achieving a balance between growth and responsibility toward the environment and society. Enterprises that integrate technological development with effective change and human capital management build crisis resilience and gain a competitive advantage in an era of uncertainty and continuous transformation. This article aims to present the opportunities associated with the use of technology by manufacturing enterprises to build crisis resilience within the framework of the Industry 5.0 concept, as well as to assess the capacity for transformation of Polish enterprises in this regard. The analysis was conducted through a review of scientific and grey literature (including reports from government and industry institutions, publications by enterprise development agencies, and analyses by consulting firms). It was found that Polish enterprises are in the early stages of implementing Industry 4.0 and 5.0 technologies. The results of the analysis of innovation, technological, organizational, and competence readiness of Polish enterprises demonstrate that despite the progressive increase in R&D expenditures and growing innovation activity among enterprises, the progress of digital transformation varies significantly across enterprises, particularly depending on their size and sector of activity. Polish enterprises currently exploit, to a limited extent, the opportunities to leverage technology to build crisis resilience and implement new strategies aligned with the Industry 5.0 concept.

Słowa kluczowe:
przedsiębiorstwo, Przemysł 5.0, technologia, transformacja cyfrowa, humanizacja, zrównoważony rozwój, odporność na kryzysy

Streszczenie: Przemysł 5.0 jest koncepcją polegającą na dążeniu do równowagi między wzrostem a odpowiedzialnością za środowisko i społeczeństwo. Przedsiębiorstwa, które potrafią połączyć rozwój technologiczny z umiejętnym zarządzaniem zmianą i kapitałem ludzkim, budują odporność na kryzysy i zyskują przewagę konkurencyjną w erze niepewności i ciągłych przeobrażeń. Celem artykułu jest przedstawienie szans związanych z wykorzystaniem technologii przez przedsiębiorstwa produkcyjne w budowaniu odporności na kryzysy w świetle koncepcji Przemysłu 5.0 oraz ocena zdolności transformacji polskich przedsiębiorstw w tym zakresie. Wnioskowanie przeprowadzono na podstawie wyników przeglądu literatury naukowej i literatury szarej (m.in. raportów instytucji państwowych i branżowych, opracowań agencji rozwoju przedsiębiorczości oraz analiz firm konsultingowych). Stwierdzono, że polskie przedsiębiorstwa znajdują się we wczesnej fazie wdrażania rozwiązań technologicznych Przemysłu 4.0 i 5.0. Wyniki analizy gotowości innowacyjnej, technologicznej, organizacyjnej i kompetencyjnej polskich przedsiębiorstw dowodzą, że mimo postępującego wzrostu nakładów na B+R oraz rosnącej aktywności innowacyjnej przedsiębiorstw, postęp transformacji cyfrowej znacząco różnicuje się wśród przedsiębiorstw, zwłaszcza w zależności od ich wielkości i sektora działalności. Polskie przedsiębiorstwa w marginalnym zakresie wykorzystują obecnie szanse związane z wykorzystaniem technologii w budowaniu odporności na kryzysy i wdrażają nowe strategie zgodne z koncepcją Przemysłu 5.0.

JEL:
M11, M14, M15, Q01, Q55, Q56

Introduction

The second and third decades of the 21st century represent a period replete with threats and new challenges arising from both long-term megatrends (including the planetary crisis, demographic changes, and the advancement of digitalization) and sudden, often unpredictable events that affect the entire world (including geopolitical tensions, armed conflicts, and pandemics). Manufacturing enterprises face challenges related to, among others, climate change, diminishing resources, economic inequalities, depopulation, and the accelerated pace of digitalization. All of these factors contribute to increased uncertainty and risk in the business environment, leading to adverse situations in enterprise operations, such as supply chain disruptions, rising production costs, or resource availability constraints.

The Industry 5.0 concept, announced by the European Commission in 2021, constitutes a response to emerging challenges. It represents a new vision that extends beyond

production elements related to building efficiency and effectiveness through technology, directing attention toward the human being (human-centric approach), toward respect for human values and the satisfaction of significant social needs. Industry 5.0 emphasizes the well-being of workers, along with other values that comprise the human component of production processes [Huang et al., 2021]. Simultaneously, respect for sustainability principles is central to the Industry 5.0 concept. Resilience is also a pillar of Industry 5.0, referring to an enterprise's capacity to survive, recover, improve, and grow during and after a crisis.

The European Commission [2021, p. 14] defined the essence of the Industry 5.0 concept as "the power of industry to achieve societal goals beyond jobs and growth to become a resilient provider of prosperity, by making production respect the boundaries of our planet and placing the well-being of the industry worker at the centre of the production process." Modern solutions applied in industry strengthen stability during crises, enable earlier problem detection, improve decision-making, and enhance resource utilization and cost control. Simultaneously, they enhance operational security and transparency, which facilitates faster responses to disruptions. Digital technologies employed in Industry 5.0 are also present in Industry 4.0; however, in Industry 5.0, they provide additional value in resilience, sustainable development, and a human-centric approach [Ivanov, 2022].

This article aims to present the opportunities associated with the use of technology by manufacturing enterprises to build crisis resilience within the framework of the Industry 5.0 concept, as well as to assess the capacity for transformation of Polish enterprises in this regard.

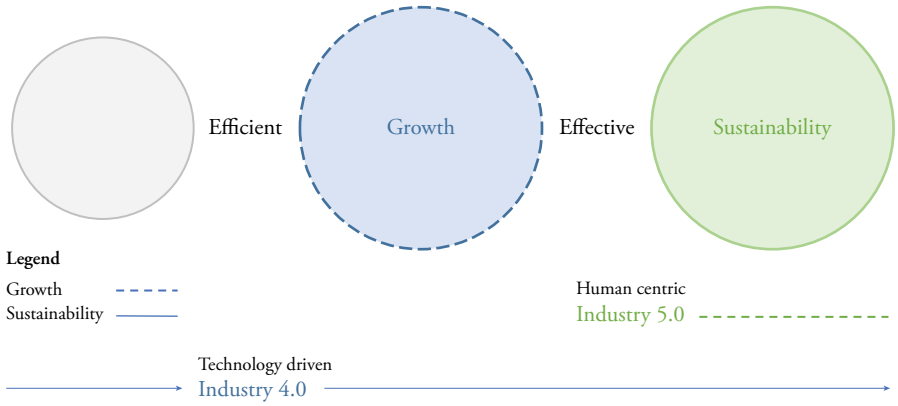
The research method employed by the authors is secondary data analysis (desk research). The analysis was conducted based on a review of scientific literature from domestic and international online databases, as well as grey literature, including reports from governmental and industry institutions, publications by enterprise development agencies, and analyses by consulting firms, incorporating sources published by APA Group [2024], BGK [2024], GUS [2023], NCBiR [2025], NTT DATA Business Solutions [2021], PARP [2024], and Siemens [2024]. Considering that the analyzed reports pertain to heterogeneous and partly selective enterprise populations – including manufacturing firms, medium-sized and large entities, as well as the SME sector – the extent to which the findings can be generalized to the entire population of enterprises in Poland is inherently limited.

The subsequent section of the article presents the assumptions of Industry 5.0. This is followed by a discussion of the impact of technology on enterprise crisis resilience within the framework of Industry 5.0. An assessment of the propensity and readiness of enterprises operating in Poland to utilize technology is undertaken. The summary presents the main conclusions and identifies the direction of the next stage of research.

The Industry 5.0 Concept

The assumptions of the Industry 5.0 concept focus on creating a balance between growth and responsibility toward the environment and society (Figure 1). Industry 5.0 embraces the value of new technologies, ensuring social well-being and economic growth while respecting sustainability principles and placing the prosperity and well-being of the industrial worker at the center of the production process [European Commission, 2021]. It differs from the Industry 4.0 concept, which primarily aims at growth through the implementation of technological innovations, but shows insufficient concern for sustainable development and human beings.

Figure 1. Evolution of approaches within the Industry 4.0 and Industry 5.0 concepts



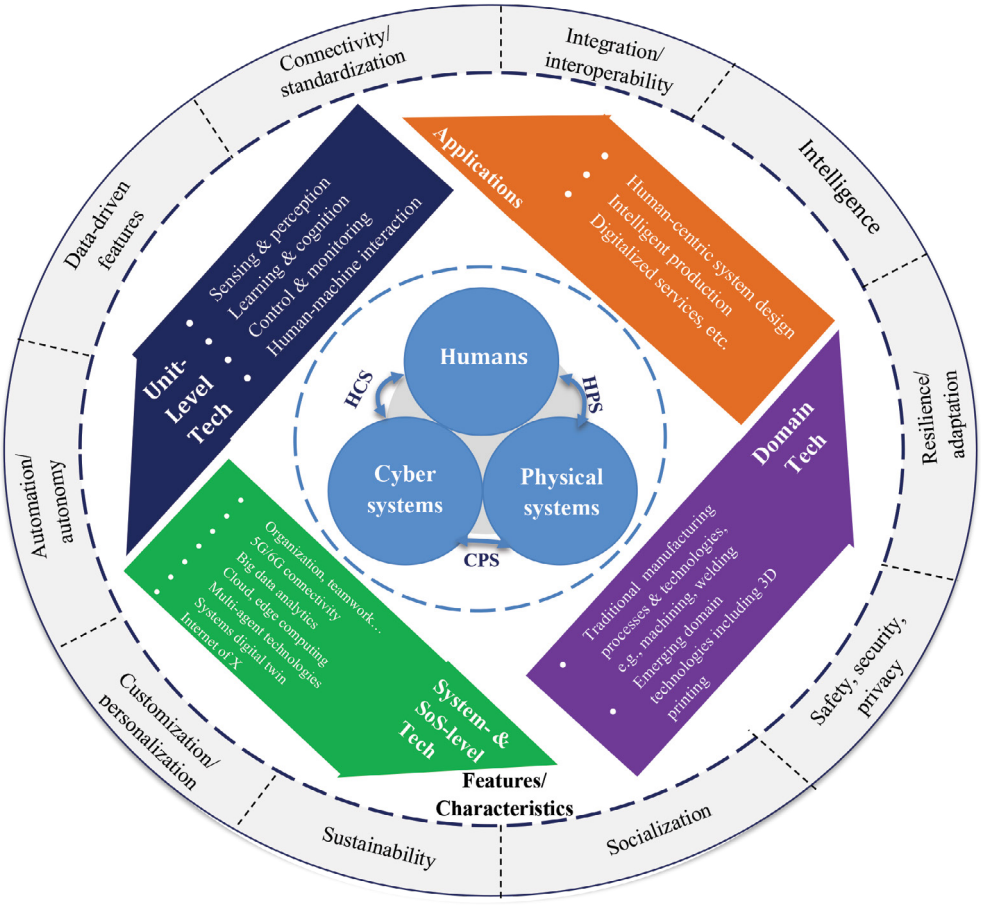
Source: Aheleroff et al. [2021].

The role of the human factor in the development of Industry 5.0 is aptly captured by system models of the HCPS (Human-Cyber-Physical Systems) type. The elements of HCPS are presented in Figure 2. The structure and operation of the system are based on understanding how different elements interact within Industry 5.0. At the central point of the model are humans, physical systems, and digital systems. The inclusion of human interactions distinguishes this model from the standard Industry 4.0 approach.

The outer zones of the central arrangement indicate various aspects and characteristics of systems. The blue zone encompasses sensing and perception technology, i.e., processes for collecting data on the physical state of systems and their environment, as well as machine learning and pattern recognition tools, indicating the application of artificial intelligence for real-time data analysis. The orange zone addresses various applications, such as human-centric systems and intelligent manufacturing, which are directed toward satisfying human needs. It also encompasses one of the most important

aspects of Industry 5.0 – personalization, i.e., adapting technological solutions to individual human needs. The purple zone encompasses various domain technologies, such as 3D printing, and newer technologies such as digital manufacturing. The green zone encompasses technological aspects of systems and infrastructure, such as information and communication technologies and cloud computing. Reference to personalized technological solutions is also found here, which is crucial for adaptive systems. The outermost part of the model indicates key values that guide the evolution of industrial production within the Industry 5.0 concept.

Figure 2. Components of the HCPS system model



Source: Wang et al. [2022].

It encompasses the following key aspects:

- **Personalization and autonomy of solutions** – indicates the adaptation of systems to individual user needs. In the context of HCPS, this means technology should be flexible and adaptable to various conditions and preferences.
- **Sustainable development** – all systems utilized by Industry 5.0 must be designed with their environmental impact in mind, minimizing resource consumption and limiting negative consequences for our planet. Sustainable development within HCPS is strongly associated with building energy efficiency and recycling.
- **Community** – this aspect concerns the integration of technology into social life and its impact on this domain. In the HCPS model, it is important that technology aligns with social values and helps solve human problems.
- **Security, privacy, and adaptation** – refer to protection against external and internal threats that may affect the operation of cyber-physical systems. Privacy is a crucial element, especially when computer systems collect large amounts of data. Adaptation is the ability of systems to adjust to new or changing environmental or technological conditions.
- **Intelligence** – in the context of HCPS, refers to the application of artificial intelligence (AI), machine learning, or analytical algorithms to enable cyber-physical systems to learn, predict, and make decisions based on datasets.
- **Resilience** – concerns the ability of systems to adapt to new situations and changing conditions, which is crucial in dynamic technological environments.

Technology and Enterprise Crisis Resilience in Industry 5.0

Factors conducive to implementing Industry 5.0 from a crisis-resilience perspective are closely related to the challenges in the practical development of Industry 4.0. Industry 5.0 built on its foundations while emphasizing human-centricity, sustainable development, and crisis resilience. On the one hand, previous achievements, for example in technology, allow for further development and enable change. On the other hand, the role of observed problems requiring urgent solutions is clearly marked.

One of the most important catalysts for change is the lack of stability and resilience in existing systems. Industry 4.0 is associated with many challenges that threaten system stability [Khan et al., 2023], rendering it less resilient to crises. Its excessive focus on "outcomes" is frequently criticized, with insufficient emphasis on the impact on humans. Today, however, in production and logistics, the need to focus on socioeconomic systems is increasingly recognized. Resilience requires the coexistence of humans and technology. So-called human-technology interaction influences various human factors (perceptual requirements, cognitive requirements, physical requirements, psy-

chosocial environment) that determine the outcomes of the entity and the system as a whole [Grosse et al., 2023]. Through the focus on humans, placing them at the center of attention and integrating humans into production processes, technology acceptance is expected to increase, the risk of social exclusion to decrease, and social resilience to increase [Adel, 2022; Mourtzis et al., 2022].

At the same time, as mentioned, previous achievements motivate further changes – digital technologies employed in Industry 5.0 are also present in Industry 4.0; however, here they provide additional value from the perspectives of resilience, sustainable development, and a human-centric approach [Ivanov, 2022]. Modern solutions applied in industry strengthen its stability in crises, enable earlier problem detection, improve decision-making, and enhance resource utilization and cost control. Simultaneously, they enhance operational security and transparency, which facilitates faster responses to disruptions. Key examples of technologies for building resilience include [Khan et al., 2023; Ivanov, 2022; Maddikunta et al., 2022; Sindhwani et al., 2022]:

- Predictive maintenance – enables early detection of failures and planning of service activities, which increases production resilience to disruptions and crises.
- Cyber-Physical Cognitive Systems – improve human decision-making and increase trust between humans and machines.
- Edge computing – enhances cybersecurity and reduces latency.
- Big Data Analysis – is significant for improving decision-making, real-time forecasting, etc.
- Internet of Everything – allows for cost reduction, increases resource productivity, and enables efficient supply chain management.
- Digital twins – allow for cost reduction, prediction of future failures, and the possibility of avoidance.
- Artificial intelligence (AI) – increases efficiency, improves quality control, and enables rapid decision-making.
- Blockchain technologies – help improve resilience through supply chain mapping.

Analysis of available technologies utilized in Industry 5.0 (including solutions in the field of bionics, green computing, Big Data, digital twins, smart materials, and holography) shows that they have a significant impact on building enterprise resilience by enabling them to create more flexible and resilient production and management systems [Sindhwani et al., 2022]. Through advanced automation, enterprises can significantly increase operational efficiency, enabling faster adaptation to changing market conditions, such as demand fluctuations or supply chain disruptions.

Furthermore, Industry 5.0 technologies enable advanced data analysis, allowing for the prediction of potential threats and failures before they occur. As a result, enterprises can undertake appropriate corrective or adaptive actions, minimizing downtime and losses. These transformations also contribute to sustainable development, which

is of key importance for long-term enterprise resilience to changes in environmental regulations and resource markets [Sindhwani et al., 2022]. Industry 5.0 technologies support organizational flexibility, enabling rapid responses to changing external conditions, such as economic or technological changes, through real-time monitoring systems. Moreover, Industry 5.0 promotes innovation, allowing companies to experiment with new products and solutions that are more resilient to changing consumer needs. Technologies such as the Internet of Things and artificial intelligence also enable continuous process monitoring, enhancing security and enabling faster detection of physical and cyber threats (both of which affect the well-being of the organization's employees).

Propensity and Readiness of Enterprises in Poland to Utilize Technology

In the context of the presented Industry 5.0 concept, which emphasizes the importance of synergy between technology, human potential, and organizational resilience, it is essential to assess the extent to which enterprises operating in Poland are prepared to undertake digital transformation, thereby enabling the implementation of more advanced solutions in the future. Due to the lack of mature implementations of the full Industry 5.0 paradigm, the analysis of domestic entities' readiness was based on an assessment of their advancement in technologies and practices characteristic of Industry 4.0, which constitute the base layer for further evolution. Accordingly, the analysis encompassed four complementary dimensions of readiness: innovation, technological, organizational, and competence, which reflect the resources conditioning both the effectiveness of digital transformation and the ability of enterprises to build future technological-organizational resilience.

Innovation Readiness of Enterprises in Light of R&D Expenditures and Innovation Activity

Innovation readiness is understood as the capacity of enterprises to finance research and development activities and to create, absorb, and implement innovations that enhance enterprise productivity and competitiveness. In determining the level of innovation readiness of Polish enterprises, the intensity of research and development expenditures, measured by the GERD (Gross Domestic Expenditures on Research and Development) and BERD (Business Expenditures on Research and Development) indicators, was analyzed, as well as the prevalence of innovation practices in the industrial and service sectors.

In the last two decades, Poland has recorded an almost twelvefold increase in nominal research and development expenditures, which has significantly strengthened enterprise innovation readiness. Between 2003 and 2023, R&D expenditures increased from PLN 4.5 billion to PLN 53.1 billion, and the share of R&D expenditures in GDP (GERD) increased from 0.54% to over 1.5%, indicating the economy's growing capacity to absorb and generate innovation [NCBiR, 2025]. Although R&D intensity still remains lower than in the most developed European economies, Poland exceeds many Southern European economies in this respect.

During the period analyzed, expenditures on research and development financed by the business sector (BERD) grew particularly rapidly. Their level increased from 0.13% of GDP to 1.01% of GDP, representing a significant reduction in the gap relative to the EU average (1.48% of GDP) [NCBiR, 2025]. The increase in R&D expenditures is also reflected in the level of innovation activity: in 2020–2022, innovations were implemented by 32.2% of enterprises, with the highest activity characterizing large entities (72.1% in industry and 62.3% in services) [PARP, 2024, p. 46].

Innovation readiness remains strongly differentiated by sector. In industry, the highest activity in this regard was exhibited by technologically advanced industries, including the pharmaceutical, refining, and electronics sectors, while in the service sector, knowledge-based industries such as insurance, R&D activities, and media [PARP, 2024, p. 47]. The structure of innovation expenditures also differentiates between the two sectors: in 2022, enterprises allocated a total of PLN 55.7 billion to innovation activities, with R&D expenditures dominating in services (55%) and investments in fixed assets in industry (40%) [PARP, 2024, p. 51]. These differences reflect different mechanisms for building innovation potential – from the predominance of competence-organizational components in services to infrastructural and technological investments in industry.

Technological Readiness of Enterprises in Light of Process Digitalization and Digital Intensity

Technological readiness is an essential dimension of enterprise digital transformation, and its profile is shaped by both infrastructural factors and organizational maturity in the use of Information and Communication Technologies (ICT) and the automation of operational processes. Technological readiness of enterprises refers to the organization's capacity to effectively implement and scale digital technologies in key business processes, encompassing: access to and utilization of ICT infrastructure (broadband internet, cloud resources), adoption of business software (ERP, CRM, Business Intelligence) and data analytics practices, application of advanced technologies (AI) in decision-making and operational functions, integration of IT/OT systems and automation of production and operational activities, as well as digital security and mature data management.

Research confirms that the foundation of technological readiness in Poland is a very high level of internet infrastructure accessibility – broadband internet access is possessed by almost all enterprises [PARP, 2024, p. 70]. At the same time, high infrastructure availability does not directly translate into deep digitalization, particularly among micro and small enterprises. Differences are already evident in basic digital tools, such as websites and digital communication, where disparities between large and small enterprises are significant [PARP, 2024, p. 70; BGK, 2024, pp. 8–9].

The greatest differentiation is observed in the area of utilization of business systems ERP, CRM, and analytical tools. ERP systems are used by fewer than 36% of enterprises, CRM by 28.5%, while Business Intelligence class tools are used marginally (10.5%) [GUS, 2023, p. 89]. The level of data analytics utilization is also limited (only 18%), which confirms the low percentage of enterprises making data-based decisions [GUS, 2023, p. 93]. This means that many entities remain at the stage of operational digitalization, lacking advanced data-driven information transformation.

An even more pronounced technological gap appears in the realm of advanced technologies, such as artificial intelligence. AI solutions are utilized by only a small fraction of enterprises, primarily large ones operating in knowledge-based sectors [GUS, 2023, p. 101]. Functions that automate administrative processes and support decision-making dominate, while more advanced applications, such as autonomous robotics, are marginal. These data confirm that AI utilization remains in a very early stage of development in Poland.

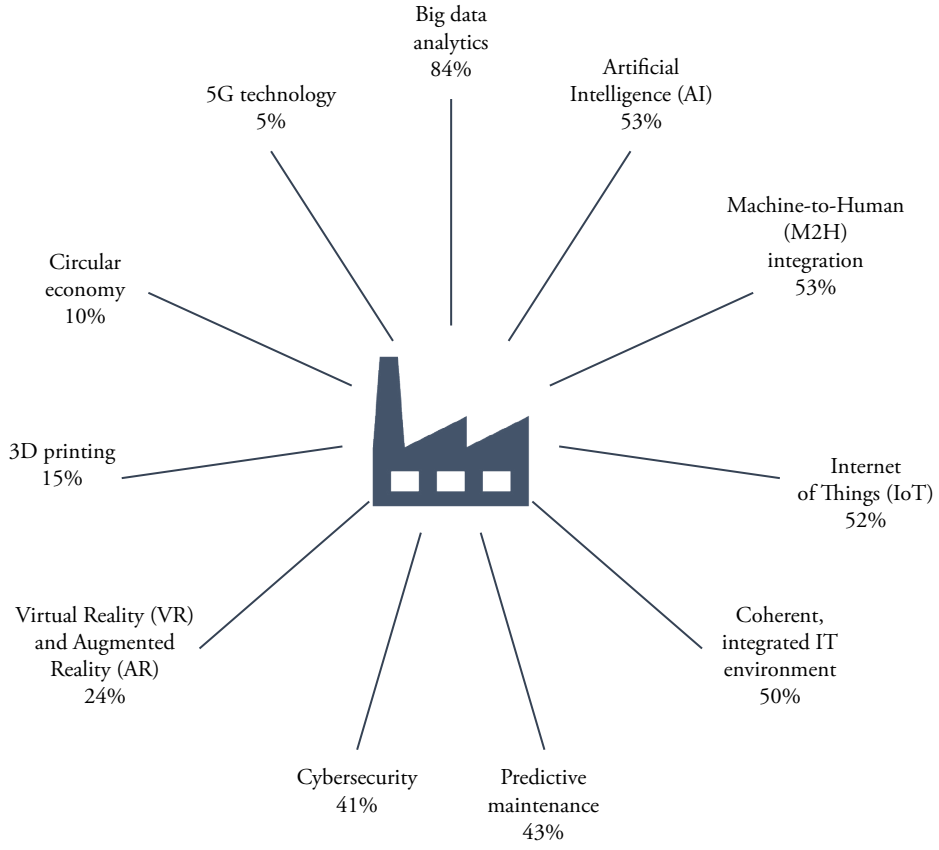
The diagnosis of technological readiness is reinforced by Eurostat's digital intensity index, which classifies more than three-quarters of Polish enterprises as having low or very low digital intensity [GUS, 2023, p. 110]. This result places Poland slightly below the EU average, yet above some Southern European economies [GUS, 2023, p. 112]. This means that, despite gradual improvement, the technological maturity of enterprises remains relatively low compared with more digitally advanced member states.

Additional context is provided by industry research. The Digi Index 2024 report by Siemens indicated that most Polish manufacturing enterprises are in the early stages of digital transformation, despite rising levels of digitalization and automation of production processes, and increasingly frequent integration of IT and OT systems [Siemens, 2024, pp. 21–22, 38–39]. Similar conclusions emerge from reports by APA Group and NTT DATA Business Solutions, which draw attention to the growing importance of ERP systems, cloud computing, and automation, while noting the very limited adoption of AI, Big Data, and predictive technologies – domains mainly of large enterprises and high-technology sectors [APA Group, 2024, p. 6; NTT DATA, 2021, p. 15].

In summary, the technological readiness of Polish enterprises is characterized by a high level of digital infrastructure availability but low maturity in the use of advanced systems, data analytics, and artificial intelligence. The gap between the infrastructural

level and the level of technology utilization significantly limits the pace of digital transformation. In the context of the future factory concept (Figure 3), which is based on Big Data, AI, IoT, and full IT/OT integration, the current level of technological readiness should be assessed as insufficient, indicating the need to intensify modernization activities toward advanced, data-driven digitalization.

Figure 3. Elements constituting the foundation of the future factory concept



Source: NTT DATA Business Solutions [2021].

Organizational Readiness of Enterprises in Light of Strategic, Structural, and Implementation Conditions

Organizational readiness constitutes an important dimension of digital transformation, complementary to innovation and technological readiness. It encompasses the capacity of enterprises to create strategic, structural, and implementation conditions,

enabling the effective execution of digital changes and the accompanying adaptation of business models. In this approach, organizational readiness means the capacity to coherently conduct transformation, encompassing strategy formalization, the development of structures that coordinate the change process, technology implementation, and the capacity for deep reconfiguration of the mode of operation.

Research indicates that in many medium- and large-sized enterprises, digitalization processes remain fragmented and are implemented as a collection of unrelated initiatives. A holistic approach to transformation is declared by only a small proportion of enterprises (23% of large and 34% of medium), and a significant percentage of entities operate without a formal digitalization strategy or do not plan to develop one [Siemens, 2024, pp. 19, 36]. Similarly, the level of formal transformation budgeting, which limits the ability to coordinate activities and manage change over the long term [Siemens, 2024, pp. 23, 42]. These data confirm that many enterprises in Poland are in the early stages of building the foundations of a systemic approach to digitalization.

Clear differences between medium and large enterprises are also evident in organizational structures and staffing preparation. Large entities more frequently have dedicated units responsible for digital transformation and implement comprehensive competence development programs covering all managerial and operational staff. In medium-sized enterprises, such solutions are less common, and a significant proportion of entities do not plan to implement them [Siemens, 2024, pp. 20, 37]. This indicates limited structural readiness of many entities and the absence of conditions for conducting consistent implementation activities.

In implementing Industry 4.0 solutions, organizational readiness varies and largely depends on available resources. One-fifth of enterprises report increased interest in developing implementation strategies and conducting pilots; however, only a small percentage proceed to the technology scaling stage, indicating limited operational readiness [APA Group, 2024, pp. 11, 18]. A higher level of advancement characterizes large entities, whereas SMEs exercise greater caution and focus primarily on strategic planning [APA Group, 2024, pp. 11–12].

A key component of organizational readiness is the capacity for business model transformation, which measures deep enterprise adaptability. Research shows, however, that fundamental business model modifications in 2020–2022 were undertaken by only a small proportion of entities (8%) [PARP, 2024, p. 49]. These changes required a comprehensive reconfiguration of the method for creating and delivering value, a restructuring of operational processes, and the implementation of new relationships with partners. The low percentage of enterprises undertaking such transformations indicates significant challenges in structural adaptation, employee competence development, and organizational culture.

Competence Readiness of Enterprises in the Digital Transformation Process

Competence readiness constitutes a key element of enterprise preparation for digital transformation, determining their capacity to utilize modern technologies through an appropriate level of knowledge, skills, and attitudes of employees. It encompasses both technical and digital competences, as well as analytical, organizational, legal, ethical, and cultural competences, and also the readiness of personnel for learning, cooperation, and adaptation to technological changes.

Report results confirm that competence readiness is one of the least developed dimensions of Polish enterprises' preparation for digitalization. Despite growing awareness of the importance of transformation, most entities struggle with knowledge and skill gaps that clearly limit the pace and scope of implementation. The research results in the Digi Index 2024 report highlight insufficient digital and analytical competences, including difficulties in data collection and utilization, a lack of strategy development skills, and low proficiency in cross-departmental cooperation [Siemens, 2024, p. 23]. These gaps hinder the transition to a data-driven model, which constitutes the foundation of the enterprise of the future.

A significant area of deficits also includes legal and ethical competencies. Enterprises report doubts regarding data protection, privacy, and responsibility related to automation and artificial intelligence, as confirmed by GUS research [GUS, 2023, p. 104]. These problems become particularly important in the context of AI's growing role in decision-making, where issues of responsibility, regulatory compliance, and data security are fundamental.

A major challenge remains the shortage of IT specialists, data analysts, and engineers responsible for developing and maintaining advanced industrial solutions. Industry reports indicate that the shortage of technical staff, reinforced by employee resistance to change and an immature organizational culture, significantly hinders the scaling of implementations and the execution of digitalization projects [APA Group, 2024, p. 23].

In summary, competence readiness remains one of the main factors limiting the depth and dynamics of the digital transformation of Polish enterprises. Competence deficits in technical, analytical, legal, ethical, and managerial knowledge create a multidimensional barrier that hinders the full realization of the potential of digital technologies. As a result, many organizations stop at early stages of digitalization, focusing on operational solutions, without reaching the stage of strategic transformation and changes in the business model.

Conclusion

Industry 5.0 is a concept of technological and organizational transformation in which technology ceases to be an end in itself and becomes a tool for building a more sustainable, flexible, and human-centric production model. Key importance is gained by solutions such as the Internet of Things, AI, digital twins, automation, augmented reality, and HCPS-type systems, which connect machines, data, and people into a single integrated ecosystem. Thanks to them, it is possible to increase efficiency, shorten response times to market and environmental changes, and personalize products and services. At the center of this approach is the human being – not as a passive observer, but as an active participant and beneficiary of technological transformation. In unstable environments – health, climate, political, and economic crises – the ability to respond quickly, adapt, and recover becomes a key competence for enterprises. Industry 5.0 strengthens organizational resilience through, among other things, more effective risk management, automated detection of disruptions, scenario planning, and real-time process integration. Technologies such as big data and artificial intelligence enable predicting problems before they occur, and digital tools enable rapid testing and implementation of solutions without disrupting operational activities.

Polish enterprises are at an early stage of implementing Industry 4.0 and 5.0 solutions. Although digital transformation accelerated due to the COVID-19 pandemic, its level still varies significantly by enterprise size and sector. Data indicate that medium and large enterprises implement modern technologies much more frequently than micro-enterprises. In Poland, despite growing technological awareness, many companies – particularly from the SME sector – still remain at the initial stage of adapting modern solutions. Poor utilization of AI, big data analytics, or integrated ERP/CRM systems continues to limit their resilience and ability to compete in a dynamically changing environment.

The analysis in the article demonstrates that the propensity and readiness of Polish enterprises to implement Industry 4.0 technologies and practices, which constitute the base layer for further evolution, are strongly differentiated and remain conditioned by multidimensional factors. The comparison of four dimensions of readiness – innovation, technological, organizational, and competence – shows that despite the progressive increase in R&D expenditures and growing innovation activity of enterprises, the digital transformation process does not proceed uniformly. High availability of ICT infrastructure contrasts with the low scale of utilization of advanced technologies, particularly AI, data analytics, or IT/OT system integration. In the organizational dimension, enterprises are still characterized by a low level of formalization of digital strategies, limited coordination of activities, and low readiness for deep restructuring of business models. However, the greatest developmental barrier remains competence readiness,

encompassing deficits in digital, analytical, legal, and technical knowledge, as well as a limited culture of innovation and low levels of employees' adaptive skills.

These conclusions lead to the finding that effective digital transformation of enterprises requires not only technological investments but, above all, the parallel strengthening of competence resources, the development of organizational structures, and a strategic vision for technology utilization. Only complementary strengthening of these areas will allow the full exploitation of Industry 4.0's potential and open the path to Industry 5.0, in which the synergy of technology, employee competencies, and organizational maturity can translate into greater enterprise resilience.

Against this background, the need to identify factors influencing the implementation of the Industry 5.0 concept is particularly important. For this reason, in the next stage of research, the authors of the article will undertake the identification of factors facilitating and inhibiting the implementation of technology in relation to crisis resilience and will prepare a publication in this area to provide enterprises and other stakeholders with desired recommendations for the development of strategies, models, and business practices oriented toward a change in the management paradigm focused on the human being, sustainable development, and crisis resilience.

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