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INDUSTRY 4.0 IN POLAND – SELECTED ASPECTS OF ITS IMPLEMENTATION

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Abstract: Nowadays, Industry 4.0 is leading manufacturing companies into the era where processes and all their resources – including human resources – are being optimised in real time. It covers all areas of operations that, supported by intelligent decision-making systems, improve productivity, quality of work and safety. The paper makes an attempt to evaluate the existing state of research in literature and implementation of Industry 4.0 in Poland. The first part of the paper reviews scientific and research achievements related to Industry 4.0, covering as well best practices. Further, the paper presents changes in information systems in the Polish economy as well as in industrial companies, related to the implementation of the concept of Industry 4.0.

Keywords: Industry 4.0, digitalisation, information systems, megatrends, optimisation.

1. Introduction

By enabling devices to be connected within digital business ecosystems, the fourth industrial revolution is contributing to a deeper integration within horizontal and vertical value chains. In the economy, these challenges are related to new jobs with high added value centred around automation, to increased competition with innovative international economy, to more efficient use of energy and materials. The scientific literature classifies them as challenges related to (i) leadership in organisation, (ii) market, (iii) business ecosystem, (iv) value creation process (Bharadwaj, 2013b; Peppard, and Ward, 2016). According to K. Schwab, their attractiveness for investors is perceived by the creation of a favourable feedback loop between the development of competence and the inflow of capital (Schwab, 2018). Under the influence of new technological solutions, the fourth industrial revolution has significantly changed the function of the production. Its contemporary version cannot be this simplified version consisting of two or even three inputs, as defined by the classical economy, namely labour (L) and land (Z), or capital (K) included in the capitalist economy. Nowadays, information and knowledge about hardly measurable values and their high amplitude of changes becomes crucial, and the production function, which takes into account additional values, takes the form of a complex relation with a general formula Y = f(L, K, Z, KL, HK), where: L – labour, K – capital (financial), Z – land (ground where a plant or raw materials are located), KL – human capital (knowledge, abilities, know-how), HK – social capital (good law, good institutions) (Olender-Skorek, 2017). In this context, Industry 4.0 means new behaviours of the companies and changing their perception of competition and competitiveness. This is a consequence of implementing new key technologies used in the Industry 4.0 concept as shown in Figure 1.

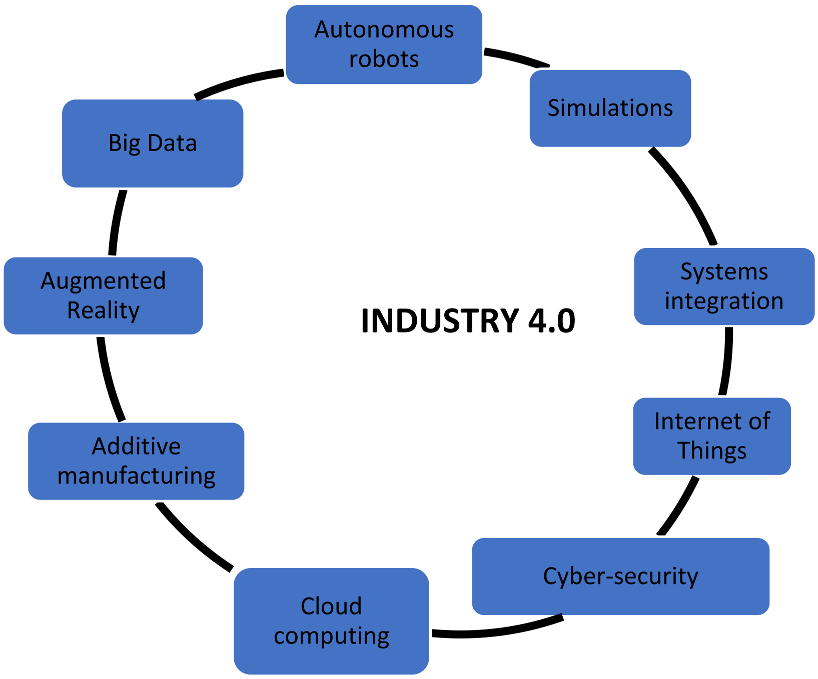

Figure 1. Key components of the Industry 4.0 concept. Source: author's own study.

What has been observed is a new shape of architecture of production management systems and a transition from linear processes and a traditional pyramid of production management systems to the network of connections and non-linear production. Combining these innovations with new artificial intelligence capabilities leads to a revolutionary change in manufacturing management where systems operate in a highly autonomous manner, dynamically changing their structure and functions within an organisation. Many researchers agree that Industry 4.0 is part of a larger megatrend which is a digital transformation affecting a number of industries (Miśkiewicz, 2019; Juszczyk, 2017; Gracel, 2016; Chrzanowski, and Głażewska, 2016; Saniuk, S., and Saniuk, A., 2017).

The purpose of the paper is to update Polish and international scientific and research achievements related to the concept of Industry 4.0 in Poland. To achieve this, the author used a qualitative descriptive method referring to a critical analysis of domestic and foreign studies on the subject as well as exemplary implementations of certain solutions in the industrial companies.

2. Review of scientific and research achievements related to Industry 4.0

Scientific literature related to the fields of economics and management and technical sciences provides a number of arguments relating to the essence of Industry 4.0. The authors Hermann M., Pentek T., and Otto B. made an attempt to identify and structure these arguments in their work *Design Principles for Industrie 4.0 Scenarios: A Literature Review.* They noticed that in today's global activities competition manifests itself in all spheres of business activity of companies. Hence the need for more extensive use of knowledge and – on the basis of this knowledge – for professional management of changes in the company (Herman, et al., 2015; Szulewski, 2018; Furanek, 2018; Miśkiewicz, 2018). Business massive personalisation and additive manufacturing may in the near future, as K. Liczmańska, M. Kuczyńska pointed out (Liczmańska, and Kuczyńska, 2016), contribute to a creation of a new business model. Digitalisation of the production process and artificial intelligence are determining the directions of contemporary industrial developments and are placing it in the architecture of a new market economy (Zhong, et al., 2017). The common features of available models, and the emerging similarities in their behaviour were analysed, for instance, by M. Kardas, B. W. Wirtz, A. Pistoia, S. Ullrich, W. Gottel, A. Osterwalder and Y. Pigneur, K. Nosalska and G. Mazurek, D. Ibarra, J. Ganzarain, J.I. Igartua. The results of their research became the basis for distinguishing general schemes of business models (Kardas, 2016; Wirtz, et al., 2016; Osterwalder, and Pigneur, 2013; Zott, and Amit, 2013; Nosalska, and Mazurek, 2018; Ibarra, et al., 2018). These included, i.a. (i) unbundling into separate but complementary modules relating to infrastructure management, product innovation and customer relations (e.g. mobile operators); (ii) 'long tail' - a new or additional value proposition targeted at a large number of niche customer segments that together generate a significant profit (e.g. when reaching them via e-commerce platforms), although it would not be profitable to serve only one of them; (iii) multilateral platforms providing customers with a value that "provides access"; (iv) the "FREE" concept where paying customers subsidise a segment by using a free offer. Open business models based on external sources of research and development results are becoming important. H. Chesbrough, E.G. Popkova, Y.V. Ragulina, A.V. Bogoviz (Chesbrough, 2017; Popkova, et al., 2019; Czakon, et al., 2015) and others pointed out that intellectual property is now becoming a new type of asset capable of generating additional benefits for a company, which is part of the concept of Industry 4.0. Since 2016, also in Poland this strategy has been the subject of many studies, reports and analyses concerning the whole economy or its selected industries. They reveal the conviction that the scale of economic innovations is confirmed by the level of R&D expenditure as compared to GDP. Poland has relatively low indicators in this respect in comparison to other EU economies. In 2014, for instance, 0.94% of GDP (GERD/GDP) was earmarked for this purpose while according to the Polish Central Statistical Office (GUS) in 2017 this indicator was 1.03%. The highest value of internal expenditure on scientific research and development was recorded in the enterprise sector. It has allocated nearly PLN 13.3 billion to R&D, which is over 12% higher compared to 2016 (currently they are spending 64.5% of the outlays). In 2017 the Business Expenditure on R&D (BERD) was 0.67% of GDP. There has been a significant improvement compared to 2010 when the BERD/GDP ratio was only 0.19%. It also shapes the Summary Innovation Index which in 2016 was 54.8% and generally classified Poland, in the ranking based on this indicator, on 25th position out of 28 in Europe. Although in terms of GERD and BERD in relation to GDP Poland clearly stands out in minus from the EU average (amounting to 2.07% and 1.36% respectively), but is systematically closing the gap (GUS, 2018). The entrepreneurs are also increasingly aware of the need to invest in R&D and are expecting the resulting benefits. The results concerning the R&D activity in Poland, presented successively by GUS, PARP, and other bodies, indicate positive changes in law as regards the economic activity, which reduces their investment risk (Mikołajczyk, 2016; European, Commission, 2016). The reports of ASTOR, DELOITTE, PWC, PARP and PWC also confirm high requirements that Polish companies should meet. Interesting in this respect is the analytical material contained in the report published in 2014 by Roland Berger Strategy Consultants *Industry 4.0. The new industrial revolution – how Europe will succeed.* It shows that Poland is among the hesitating countries with a low index of readiness for the implementation of Industry 4.0, and with an average industrial base. Moreover, ASTOR and PWC reports indicate that only 15% of the Polish companies are fully automated, and 76% need partial automation of their company (Astor, 2016; PWC, 2017). More optimistic are the synthetic research outcomes contained in the MarketsandMarkets report "Manufacturing Execution System Market by Deployment Type (On-Premises, On-Demand, and Hybrid), Offering (Software and Services), Process Industry (Food & Beverages, Oil & Gas), Discrete Industry (Automotive, Medical Devices) – Global Forecast to 2022". In 2014 in Poland, for instance, the value of investments in the Internet of Things was $2 billion, and in 2018 exceeded $3.7 billion; however, in the 2020 perspective, these expenditures will oscillate around $5.4 billion (Report, 2017). Some other problems were highlighted in the latest report published in 2019 by Control Engineering Polska *Towards the Economy 4.0*. The analysis of the data contained in the report shows that companies on the Polish market lack not only the strategy of action, but also transformation leaders and the ability to use Industry 4.0 tools, i.e. new technologies, innovations or R&D. It has also been found that only 14% of companies have a strategic transformation plan for activities within the Economy 4.0 concept and have started to implement it. Almost half (48%) declare that activities related to digitalisation of manufacturing processes are not supported by the company's strategy, although smaller projects are carried out in this area. What is even most worrying – more than every fourth company (27%) does not intend to carry out any activity related to the broadly understood Economy 4.0 (Report, 2019; PARP, 2019). All-Poland research related to Industry 4.0 is successively supplemented by regional scientific institutions or individual industrial companies. Projects implemented in the metallurgical industry may serve as examples:

Optimisation of key areas of the company's business activity in terms of monitoring the location of resources and supervision of the casting process in real time (Vizum Factory) (Project No ReA-1/8/2018); *Launching the technology of manufacturing high precision cast iron castings for the automotive sector with the use of INDUSTRY 4.0 methodology; Development and exemplification of a method of using CPS and IoT in the process of a modern method of manufacturing metallurgical products* (Project No POIR.01.01.01-00-0804/17) (Miśkiewicz, 2019). Other industries, such as automotive, mechanical, furniture and glass, also have pilot studies on IT applications and their application in businesses (Sąsiadek, and Basl, 2018; Fischer, 2018). Others, relating to computer modernisation and robotisation of the operation of companies, to the directions of development for logistics systems, indicate methodological solutions that will facilitate decision-making and improve work efficiency and quality (Stadnicka, et al., 2017, Bujak, 2017). In recent years, we have also seen intensified activities undertaken in Polish regions which are aimed at preparing their economies to the implementation of the Industry 4.0 concept (Szum, and Magruk, 2018). They are developing on the basis of EU law and funds, but it is worth noting at this point that Polish strategic documents also contain a direct reference to Industry 4.0; these are *Responsible Development Plan*, in the area of "Reindustrialisation" (Strategy, 2017), *Future Industry Platform*, *The Initiative for Polish Industry 4.0, Industry 4.0 Incubators,* and *Industry 4.0 Competence Centres* (Walicki, 2018). The latter are stimulating the activity of innovative regions and the competitiveness of their industrial companies (Guliński, 2019). As legislative and institutional solutions are gradually appearing, they reinforce the legitimacy of implementing the concept of Industry 4.0 in the economy. These are, for example, government programmes, Polish Digital Platform or Industry 4.0 Implementation Monitoring Centres (Bal-Woźniak, 2012; Orłowski, 2013; Act, 2016; Broński, and Tylman, 2017).

3. Changes in Industry 4.0 information systems

Significant changes taking place nowadays in Industry 4.0 information systems have been indicated by ACATECH, A. Whitmore, L. Agarwal, X. Da. These systems are supported by global networks, including machines, storage systems, and production facilities, in the form of cyber-physical solutions (ACATECH 2016; Whitmore, Agarwal, Da, 2015). The authors G. Bartoszewicz and G. Mazurek (Bartoszewicz, 2017; Mazurek, 2018) also pointed out to their complex architecture and referred to their Internet infrastructure, global network of intranets with its multimedia services, PLC (Programmable Logic Controller) with built-in microprocessor systems necessary to control manufacturing devices, Wireless Sensor Networks (WSN) consisting of sensors communicating with each other, used to monitor the condition of devices and production lines. In Poland, an important segment of CPS, the ERP 2.0 systems, is a fact, and their development is analysed, for instance, by Ch. Bartodziej, J. Badurek, Ch. Hu, B. Golińska, J. Kapania, who suggest that these systems support the implementation of the fourth industrial revolution as they include real time systems used in Logistics 4.0 processes related to GPS and RFID technologies. They control just-in-time (JIT) production and supply, perform Autonomic Computing (AC) based on self-managing computer systems which are self-configuring, self-protecting, self-healing, self-optimising, and process and analyse Big Data. Subsequently, they present information in the form of intelligent reports and management dashboards in BI (Business Intelligence) modules (Bartodziej, 2016; Badurek, 2015; Hu, 2013; Golińska, and Kapania, 2016). They are shaping a new model of modern business and production, which has been defined and modelled by J. Lee, E. Lapira, B. Bagheri, H. Kao as a 5M system in the context of Industry 4.0. On the one hand, it is integrated with the infrastructure based on a functional model 5C, and on the other hand, it is integrated with completely new paradigms based on innovative trends and megatrends understood as directions of social, economic, environmental, political, cultural and legal transformations (Magruk, 2017; Lee, et al., 2013; Weyer, et al., 2015).

The digitalisation of product and service offerings, the integration of value-added chain leads to the implementation of a number of their functions in Industry 4.0. These include (i) horizontal integration through value networks; (ii) digital integration of engineering processes throughout the entire value chain; (iii) vertical integration; and (iv) networked manufacturing systems. This leads to a fusion of IT strategy and business strategy on the basis of which a digital business strategy is being created and developed (Olszak, 2015; Stańczyk-Hugiet, 2015; Wolniak, and Hąbek, 2016). In the industrial companies, IT systems offer new opportunities to centralise certain global functions related to accounting or R&D by creating global virtual teams, or refusing to a single headquarters. Taking into account trends in automation and standardisation based on product models, they enable the customer's access to industrial production through digital platforms. Poland is also an emerging market with accelerating pace of robot installation, especially since 2014. Our market is particularly attractive when it comes to applying robots in the automotive, chemical, metal and machine industries. However, the number of robots per 10,000 employees is still lower compared to the Czech Republic, Slovakia and Hungary – 36 units (in the automotive industry 165 units per 10,000 employees, other industries: 24). In 2017, the annual sales of robots in Poland increased by 16% and reached 1,891 units. The total number of robots installed in Poland is estimated by IFR at approximately 11,400 units (data as at the end of 2017). According to IFR analysts, if the European economy continues to experience growth, it is very likely that between 2018 and 2021 the number of robots installed in Poland will grow by 15%-20% (IFR, 2017, Gracel, 2016).

Conclusion

The analysis of already vast Polish, German and English literature as well as the analysis of the findings of available scientific research show that the factors determining the development of Industry 4.0 in Poland, its regions or individual companies are already known. The scope of changes related to its development regards not only production and technology, but also social, economic, political and ecological aspects. Therefore, it is necessary to update the legislation related, for example, to the Responsible Development Plan or Regional Innovation Strategies in order to rationally use financial resources for the implementation of Industry 4.0 key technologies in the economy. Hence the practical proposal to move quickly from the analysis of the problem to its direct implementation in Poland.

Being at the heart of Industry 4.0, technological progress offers a number of benefits to companies; however, it can also create real risks which have been identified and referred to as social, technical and technological, economic, environmental, and legal risks. In order to eliminate them, it has been necessary for individuals involved in the process of digital transformation – every entity from the science, business and public administration sectors – to jointly expand the technological sphere of Industry 4.0 as well as the 'soft sphere' related to competences.

According to the aforementioned reports, within Industry 4.0 in Poland, a list of several megatrends, technological driving forces have been identified, which, in the coming years, will have a significant impact on the development of new business models and digital business strategies of companies.

Cyber-physical systems (CPS) and the Internet of Things (IoT) provide rational premises for building own internal communication solutions in manufacturing companies. For example, the steel company ReAlloys has implemented active monitoring devices Vizum Box – based on Raspberry Pi + Arduino architecture – and server software written with the use of NETcore technology, which allows to embed server software in any cloud computing.

IT in management becomes not only a technical and supportive tool, but also a source of organisational solutions. The implementation of Industry 4.0 in companies also requires the implementation of next-generation tools to design or modify organisational structures. This new research thread indicates the need to build a learning enterprise, improve the capabilities of an organisation as a whole, and implement systemic thinking as a resource of knowledge and tools that allow to explain and influence complex phenomena. Changes to companies' organisational structures, caused by the dynamic development of digital technologies, allow companies to globalise in a more "lean" way, and digital tools facilitate remote collaboration and rapid communication.

On the basis of the *Polish Digital Platform* and regional *Industry 4.0 Implementation Monitoring Centres*, it would be worthwhile to create an institution similar to the German

Fraunhofer-Institute which focuses on innovation and new technologies. This poses challenges to the Polish economy, the organisation and quality management science in terms of revaluation of research methods and tools related to Industry 4.0. These existing quantitative and qualitative descriptive and mixed methods, referring to a critical analysis of domestic and foreign sources, should be replaced by new methods such as TQM (Total Quality Management), Lean, Six Sigma, Statistical Process Control (SPC), or Theory of Constraints (TOC).

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