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ANALYSIS OF THE FOURTH INDUSTRIAL REVOLUTION IN THE CONTEXT OF INNOVATION AND THE IDEA OF TECHNOLOGY DEVELOPMENT

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Purpose: The purpose of the study was to analyze the phenomena occurring in the industrial area as a result of the penetration and spread of new technologies and innovations within the framework of Industry 4.0, taking into account the possible forms and areas of their application in practice.
Design/methodology/approach: The research method was an analysis of the literature on the Fourth Industrial Revolution and our own observation of the changes occurring in the industrial area in the context of new technologies.
Findings: Currently, the industrial area and its innovative potential is conditioned by new technologies, which are increasingly (directly and indirectly) influencing production processes and manufactured products, while implying their continuous evolution. The study reveals a research gap regarding the lack of systematic research - analysis in the field of the degree and depth of the changes that have occurred, in which the products of the fourth industrial revolution affect the achievement of the adopted goals within the industrial sector and sustainable development.
Research limitations/implications: Future research directions will concern the scope of implications of Industry 4.0 creations in the industrial and service sectors and their impact on the operation of business entities. Another direction of research will be the question of the validity of the division of economic sectors in view of the significant interpenetration of the material, product and service spheres.
Practical implications: The results of the research indicate the possibilities of implication of Industry 4.0 creations (such as, but not limited to: advanced human-machine interfaces, Internet of Things platforms, intelligent sensors, cloud computing, 3D printing, mobile devices, data analytics and advanced algorithms, multifaceted customer interactions and their profiling) in order to increase the efficiency of processes implemented in manufacturing companies and increase their level of competitiveness.

Originality/value: Filling the research gap in the analysis of creations and improvements in the industrial area resulting from the diffusion of new technologies and innovations under Industry 4.0 and the possibilities of their implications. The research is addressed to the management of business entities.

Keywords: Industry 4.0, industrial revolutions, new technologies, management and quality.

Category of the paper: Research paper.

1. Introduction

Advances in the visualization of business models, advanced information and communication technologies, as well as information technology are the result of changes in existing customer expectations and preferences (Bembenek, 2017). These types of activities indicate the level of competitiveness of business entities, for this reason, it is noticeable that companies are striving to increase the area of investment projects. These activities determine the implementation of changes within the organizational structure, development strategy or introduction of changes within the implemented production processes. The aim of the undertaken improvements is to maintain a stable market position by maintaining the current number of customers and acquiring new ones, and ultimately to achieve an increase in profits from the sale of products and services provided (Kraszewska, Pujer, 2017; Pacana, Czerwińska, 2020).

The literature on the subject presents numerous studies relating to modern, process-based enterprise models. These models are distinguished by greater or lesser detail. It can be noted, however, that all models are based on the definition of the process, which is defined as a set of activities processing products of a similar nature and at the same time referring to a clearly defined range of knowledge. The enterprise model according to Deming is based on the pursuit of a high level of quality, whereas the prior model operating in the Taylor era was oriented towards ensuring productivity. Silvestro's model, on the other hand, is mainly oriented toward a quality management system (Silvestro, 1998). Zaskórski and Warszewski, on the other hand, proposed a process management model using modern tools currently implied in the solutions used in the fourth industrial revolution. In the framework of activities related to Industry 4.0, in which the integration of process activities within the information and decision-making plane and the dynamic cooperation of business entities focused on shared value, guided by decision-makers of decision-making processes, is crucial (Zaskórski, Warszewski, 2015).

A key component of the competitiveness of business entities is also the effective acquisition, collection of information resources and then their interpretation and processing into useful knowledge, which can increase the quality of the implemented processes, ensure their stability and reduce their execution time (Sobinska, 2016; Czerwinska et al., 2020). This creates the possibility of producing products adequate to individual customer demand and means optimizing the level of reputational risk. The risk refers to the possibility of dissatisfaction with the operation of products, the production of products that have non-conformities and, ultimately, their withdrawal from the sale or the obligation to cover repair costs (Szwajca et al., 2014; Szwajca, 2017; Pacana et al., 2020). Therefore, in the context of the development of manufacturing enterprises, it is important to expand the analytical and IT infrastructure, including from the implementation of such tools as cloud computing, Big Data, Internet of Things, as well as highly developed information systems (Smart Industry Poland Report, 2018). Efficient acquisition, processing and transfer of information in real-time make it possible to integrate the various planes operating within the company and adjust the company's offerings to the prevailing needs in the market while taking into account the predispositions and production capabilities of the organization (Kieltyka, 2017; Olender-Skorek, 2017; Czerwińska, Pacana, 2020).

The article is devoted to the fourth industrial revolution and innovation in the industrial sector. The purpose of the study was to analyze the phenomena occurring in the industrial field as a result of the penetration and spread of new technologies and innovations within the framework of Industry 4.0, taking into account the possible forms and areas of their application in practice.

2. Industrial revolutions

Over the past several hundred years, the development of civilization (and especially the economy) has proceeded in stages. The beginning of each stage was characterized by transformations resulting in significant changes in three main areas: economic, cultural and social life. Within the economic domain, the transformations were called industrial revolutions. So far, four such transformations have been identified. So far, the industrial revolutions have brought breakthroughs in production processes, mainly enabling the growth of efficient yet mass production of goods and provision of services. We are currently in the midst of the fourth industrial revolution (Gracel et al., 2017; Michalski, 2017). The main features of the four industrial revolutions are shown in Table 1.

Table 1.
Key features of industrial revolutions and technological breakthroughs

Key features			
Industry 1.0	**Industry 2.0**	**Industry 3.0**	**Industry 4.0**
- Mechanization - invention of the steam engine, - The introduction of production into the era of industrialization - the transition from manufactures and craftsmen to mechanized production	- Era of mass production - manufacturing identical products on production lines in large batches, - Electrification - replacement of steam engines, - Application of the concept of division of labor, - Specialized machinery and moving assembly lines, - Manufacturer develops product and produces it, assuming existing demand, - Reduction of the unit cost of the product, lowering prices, making the market offer more attractive and increasing demand for the product	- Digitization - made it possible to control machines with software, - Automation of machines - greater efficiency and flexibility, - Mass customization, i.e. meeting the needs of more customers, - Variation of products based on their modularity	- New information technologies - systems integration and networking, - Integration of man with machine, with the process, - Increased product traceability, - Smart products or services, - Value paradigm shift, - Transfer of decision-making processes to the virtual world, - Personalizing production - the customer becomes an active participant in the design of the product or service

Source: own compilation based on: (Wodnicka, 2021).

The beginning of first industrial revolution took place at the end of the 18th century. The main changes were identified within three levels. The first was a technical breakthrough within industrial production. This breakthrough was based on mechanization, i.e., a shift away from manual labor toward work done through a machine. The key invention in this period turned out to be the steam engine, which began the era of industrialization. At that time, water pores and water began to be used as the driving force for machinery. The steam engine found a wide range of applications, and was used in steam stagecoaches, steam locomotive structures, steam hammers for forging metals, tractors and printing machines, among others. The second was related to the economic breakthrough based on changes in production organization and economic calculation. The third, on the other hand, was related to social structure - lifestyle changes. Urban society began to change into an industrial one, and there was intellectual development of society (Michalski, 2017; Janikowski, 2017).

The start of the second industrial revolution is indicated in the second half of the 19th century and the beginning of the 19th century. This revolution was associated with the popularization of electricity and the final development of electrification, lighting and the emergence of a significant number of technical solutions, such as the method of oil ratification (1852), the kerosene lamp (1853), the light bulb (1879), the telephone (1879), the internal combustion engine (1897), dynamite (1867) (Michalski, 2017).

The beginning of the third industrial revolution took place in the 1960s/70s. This revolution mainly concerned the scientific and technical areas. The third revolution is identified with computerization, the implementation of new IT solutions, the digitization of production and the use of new sources of energy generation. The development of high technology, automation of work, as well as the development of telecommunications and transportation are also features of this revolution. The third revolution saw the widespread use of IT systems for production planning and control, as well as robots cooperating with humans. The result of this revolution was also a boom in online services, the possibility of e-purchasing and other online activities was created (Rifkin, 2012; Michalski, 2017).

Industry 4.0 is a concept based on technologies enabling the integration of people, machines and processes. It refers to the exchange of information between systems, equipment and management, providing convenient access to processed information at any time and from anywhere. The Fourth Industrial Revolution points to the process of integrating smart solutions that relate to new roles taken by available human resources, new ways of working, and IT systems and devices (Schwaba, 2016; Pietraszek et al., 2020). It focuses attention on a relational approach concerning human-machine interfaces, i.e. both horizontal and vertical integration of production systems, which is determined by the exchange of user data in real-time, and a flexible production system adequate to customer needs and prevailing market conditions. A number of solutions used within the framework of Industry 4.0 are presented in the literature (Poplawski, Bajczuk, 2019; Li et al., 2017; Ustundag, Cevikcan, 2017).

3. The fourth industrial evolution in the context of the development of technology

Technology has accompanied humans since they consciously began using tools to achieve their goals. It is worth considering more broadly the human labor view. Human labor should be understood as socially realized labor, assuming that the birth of the individual is at the same time the birth of human society, since the two variables cannot be separated. Referring to human labor, technology can be understood as a tool for shaping reality. Taking the presented view of the essence of technology for human development and labor, the necessity of a rational effort to look at the entire development of technology based on the plane of true value becomes important. As part of this, it is important to pay attention to the changes bearing the name of revolutionary within the framework of industrial development (Peterson, Schaefer, 2014; Quina et al. 2016).

Figure 1 captures the most significant inventions whose emergence revolutionized industry from a historical perspective. After the stage of mechanical production (Industry 1.0 - mechanization), through mass production (Industry 2.0 - electrification) and computer-controlled production (Industry 3.0 - digitization), there was a period of a homogeneous cyber-physical system, which means the unification of the real functioning of machines with the virtual world of the Internet and information technology and people. The factors starting each industrial revolution and at the same time triggering changes in production and management processes and the products and services themselves are disruptive technological innovations.

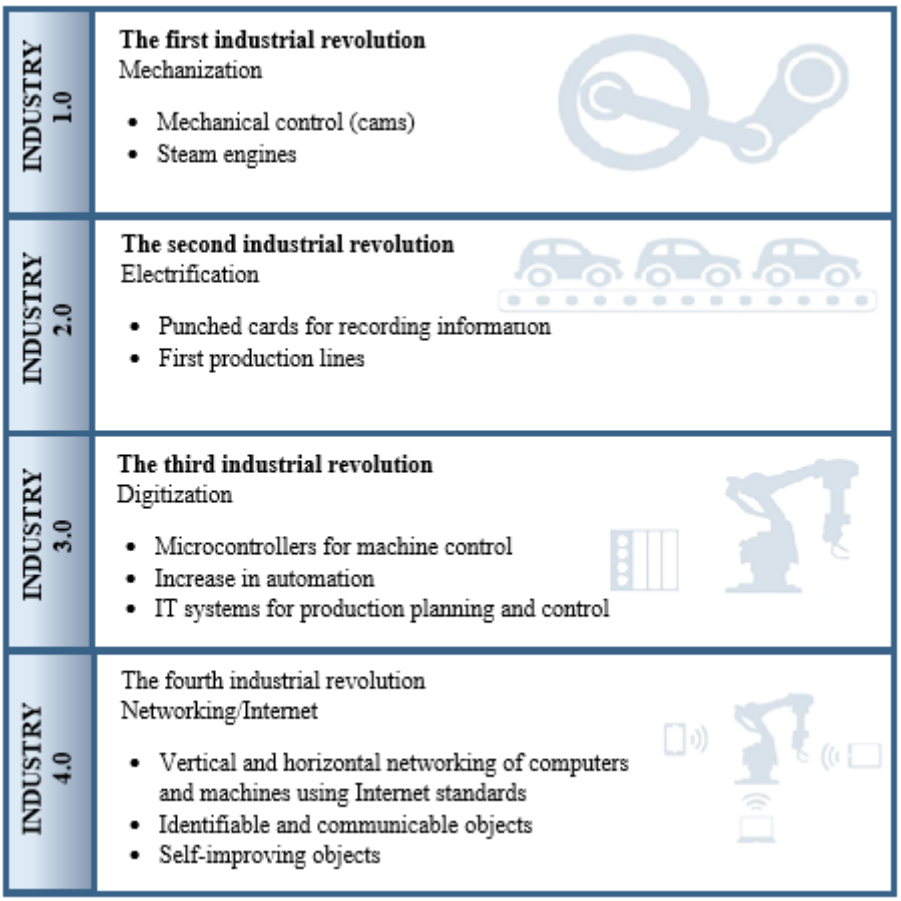

Figure 1. Summary of the most important achievements of the industrial revolutions. Source: own compilation based on: (Strcuła et al., 2018).

So far, industrial revolutions, that is, up to and including the Third Revolution, have been exhaustively described in the literature in the context of the changes and consequences that were associated with their emergence of changes and consequences that were associated with their occurrence (Melnyk et al., 2019; Pozdnyakova et al., 2019; Ratajczak, Wozniak-Jêchorek, 2020; Zamorska, 2020). For this reason, the changes conditioned by the current revolution - Industry 4.0 - deserve special attention.

About technology, the fourth revolution is associated with the creation of (Mączyńska, 2011; Hahn, 2020; Xu et al., 2018):

- a new method of communication that does not only involve people, but also devices and machines,
- highly developed interfaces that function between man and machine and machine and man,
- internet cloud computing, whose reaction dynamics siege milliseconds,
- techniques for simulating the operation of real objects in a virtual mapping environment, thus making it possible to verify and optimize manufacturing processes before implementing real adjustments.

The technical advances of Industry 4.0 outlined have contributed to (Götz, Gracel, 2017; Furmanek, 2018; Skilton, Hovsepian, 2018), among other things:

- integrating available digital and physical resources,
- changes in the area of communication and the work of individuals,
- the emergence of new philosophies and business models in the management of contemporary economic entities,
- implementation of innovations contributing to efficiency leaps in specific manufacturing areas,
- 24/7 access of societies to products, goods, services, and thus to consumption,
- personalization of production through increased individualization and expansion of the importance of consumers,
- changes in transportation, education, health systems and other areas of the economy,
- visualizing changes in the global labor market - the impact of the processes of platformization and digitization of work, especially in terms of: labor demand and new hiring patterns, increased labor mobility of workers.

In the context of the indicated effects of the Fourth Industrial Revolution, the term Industry 4.0 can be defined as a highly developed digital transformation of chains with vertical and horizontal linkages in terms of units, combined equipment and machines, manufactured products, provided services and business models, whose main links are the Internet of things, Internet of services, cyber-physical systems and so-called smart factories (Figure 2) (Furmanek, 2018).

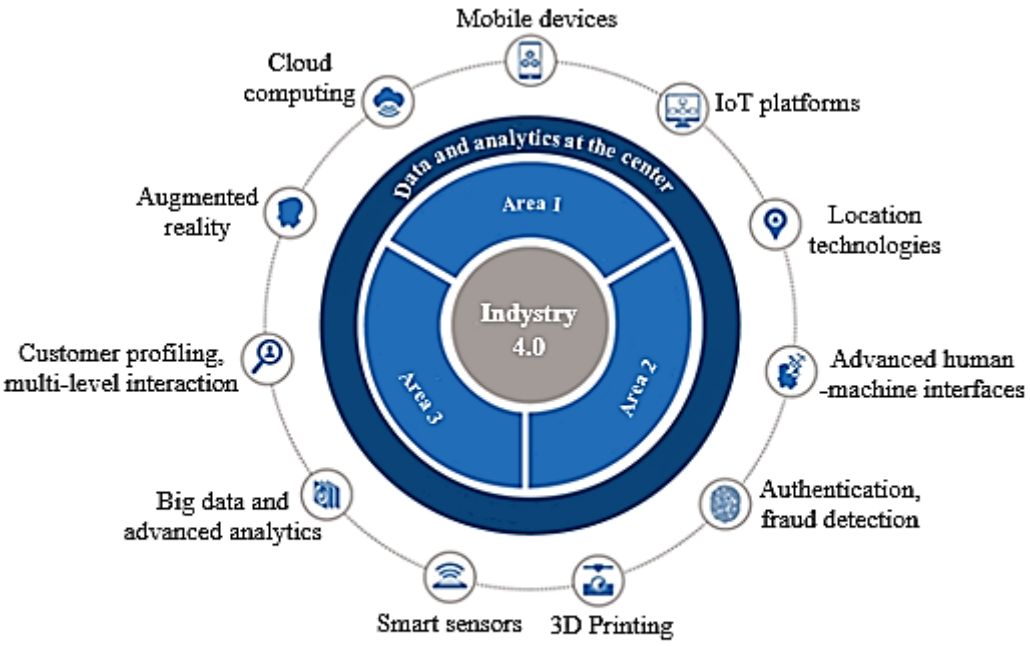

Figure 1. Industry 4.0 basics Source: *Przemysł 4.0, czyli wyzwania współczesnej produkcji* (2017). Warszawa: PWC.

Figure 2 provides a graphic depiction of the essence of Industry 4.0 in the context of the development of technology, as a combination of digitization processes and 21st-century human activity products, such as advanced human-machine interfaces, Internet of Things platforms, smart sensors, cloud computing, 3D printing, mobile devices, data analytics and advanced algorithms, multi-faceted customer interactions and their profiling. The products of Industry 4.0 promote cost reduction for manufacturing companies and improve their efficiency. They contribute to shortening production processes and testing phases. They make it possible to extend the life and usefulness of products, while ensuring flexible response and supplier substitutability thanks to a cohesive network. In addition, it enables the production of individual pieces of products without limiting profitability to mass production (Miśkiewicz and Wolniak, 2020). Industry 4.0 is expected to be a guarantee of maintaining competitiveness by enabling business entities to adapt their offerings to the ever-changing needs of customers and the market, as well as expectations of high quality. However, before manufacturing companies can take full advantage of the application opportunities created by Industry 4.0, which will begin to have positive effects on the economy, it becomes important to both adequately ensure network security and data transmission quality. It is likely that the efficiency of Internet connections will determine the success of the idea of smart factories (Wolniak, Skotnicka-Zasadzień, 2014; Ingaldi, Ulewicz, 2019).

When considering the results of the Fourth Industrial Revolution in terms of the development of technology, including the inventions and discoveries that took place as part of Industry 4.0, it is also worth noting a particular challenge from the area of the modern knowledge economy - artificial intelligence. Many scientists are seeking answers to questions such as how human knowledge is built and how it can be applied to action and problem-solving. The research conducted on the mechanisms of human intelligence has contributed to the emergence of a field of science called "artificial intelligence." Within the framework of this science, there are activities related to the construction and modeling of systems that provide support and even replace creative and rational human actions (King et al., 2017). In its experimental stream, artificial intelligence (applied artificial intelligence) is treated as a branch of computer science (including divisions: expert systems, systems with a knowledge base, natural language processing, theorem proving and inference, games, simulation, robotics and others), while in its theoretical stream, artificial intelligence integrates relevant issues from electronics, computer science, neurophysiology, mathematics, as well as psychology, anthropology and philosophy (Tegmark, 2017; Denning, Denning 2020; Homes et al., 2021).

In the future, industrial production will be performed by integrally connected technological systems. The Fourth Industrial Revolution is a step in the context of the development of the economy, while for manufacturing companies it means the emergence of a new business model. It implies the need to engage new technologies and innovations for the provision of public goods (Götz, 2018).

4. Conclusions

Currently, one of the criteria for increasing the level of innovation within the industrial sector and the processes implemented in manufacturing companies is both the development of new technologies and the rate of their absorption by organizations. Industry 4.0 makes it possible to create new innovative technologies, as well as to improve and modify existing ones.

The purpose of the study was to analyze the phenomena occurring in the industrial area as a result of the penetration and spread of new technologies and innovations within Industry 4.0, taking into account the possible forms and areas of their application in practice.

As a result of the analysis of available scientific studies, it was found that currently the industrial area and its innovative potential are conditioned by new technologies, which increasingly (directly and indirectly) affect production processes and manufactured products, at the same time implying their continuous evolution. It is worth noting that most of the literature is focused on the general discussion of the concepts and theories of Industry 4.0. There is a noticeable lack of systematic research on the industrial sector, specifically, established information on possible applications in this sector, the actual use of Industry 4.0

creations and their benefits. This will require systematic and in-depth research. The study also reveals a research gap relating to the lack of analysis on the extent and depth of the changes that have occurred, to which the creations of Industry 4.0 affect the achievement of the adopted goals within the industrial sector and sustainable development.

Analysis of the most relevant phenomena describing Industry 4.0 facilitates the direction of further development of production systems. For this reason, future research directions will concern the extent of the implications of Industry 4.0 creations in the industrial and service sectors and their impact on the functioning of business entities. Another direction of research will be the question of the validity of the division of economic sectors given the significant interpenetration of the material, product and service spheres. The research is addressed to the management of manufacturing business entities.

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