Factory technologies of the future—automation and digitalization of production in the aspect of Industry 4.0 concept

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Abstract: The purpose of this article is to present the reader the concept of Industry 4.0 as a modern idea introducing the company into a new era of computerization and robotics. This concept applies to different areas of the organization as a whole, supported by intelligent systems facilitating decision making and automation that improves productivity and quality of work. The idea of Industry 4.0 is an emerging concept, which is why there are many concerns about whether it is an opportunity for businesses or maybe it is rather a threat. The following paper presents the assumptions of the Industry 4.0 concept, and the results of a questionnaire regarding the state of awareness and preparation of the enterprise for the implementation of the Industry 4.0 concept were developed. The purpose of the survey was to recognize the approach to the new concept in enterprises located in Wielkopolska. The survey indicated the size of companies participating in the survey and the type of industry to which they belong. Next, according to these companies, the factors that influence the development of innovations and the ways of their implementation in enterprises were presented. It is also very important to identify barriers to growth in the company. Based on the results of the survey, it can be stated that the motivating factor for actions towards development are above all customer expectations. However, the most important resource in which enterprises want to invest are people whose knowledge and experience is irreplaceable.

Key words: Industry 4.0, smart factory, cyber-physical systems, the Internet of things

1. Introduction

A high level of production efficiency with low costs, assuring the right quality and variety of the assortment, the ability to easily change the production profile are the main goals pursued by manufacturing companies. To achieve these goals, enterprises should constantly increase the quality of their products by offering products produced in flexible production systems/ lines and, above all, by lowering production costs (mainly through the implementation of lean manufacturing rules). Investments in the production industry focused on in-

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formation technology are now gaining importance and are included in the general concept of Industry 4.0.

The history of the industry has been created from the beginning thanks to innovative technical solutions. Many of them initiated a revolution in industry, causing also cultural, economic and social changes. The first revolution took place at the end of the eighteenth century and was related to the use of water energy, the invention of a steam engine and work mechanization. The second revolution took place at the beginning of the twentieth century and was characterized by the use of electricity, the introduction of mass production techniques. The third revolution was initiated in the 1970s and was the result of the introduction of systems as well as information technologies that enabled the automation of production processes. Inventions have shaped the industry and, above all, relieved employees, while increasing productivity and production speed, minimizing its costs. As a result, mass production has become possible. After important technical revolutions there was a new phase of development that has a significant impact on production. This phase is called the fourth technical revolution—Industry 4.0 (Jaworowska and Piątek, 2016; Sąsiadek and Basl, 2018).

2. Essence of Industry 4.0

2.1. Concept

The Industry 4.0 concept is a modern idea introducing enterprises into a new era of robotization and digitization through optimal control of all production processes. This trend applies to all areas of the organization as a whole and is supported by intelligent systems that facilitate not only quick decision making, but also support automation that improves productivity and quality of work (Godlewski, 2016).

The concept of Industry 4.0 appeared for the first time in 2011 in Germany. It was assumed then that in the area of Industry 4.0, the company's production system will consist of an information system and numerically controlled machines that will operate autonomously and exhibit elements of artificial intelligence. The Industry 4.0 is currently one of the most-discussed topics among practitioners and scientists, making it a priority for many research centres and enterprises (Lee, 2013).

> Undoubtedly, the final result of this most complex industrial revolution is to become an intelligent factory, otherwise known as Smart Factory. In such an innovative factory, intelligent networks are seamlessly connected with each other by machines, products, processes, customer networks and suppliers. As a result, it will be possible to further deepen automation in companies, continuous optimization of products/ services and their processes, as well as the collection and processing of large amounts of data in real time and preventive maintenance of machines and devices, enabling quick adaptation to market changes (Schwab, 2016, pp. 57–58).

The idea of Industry 4.0 was created not only thanks to the possibilities offered by modern technologies, but also from the need to adapt production methods to market orientations on the part of consumers wanting a diverse offer, giving the possibility of free and individual

choice. The challenge is, therefore, to meet increasingly more personalized customer needs. In addition, constantly changing promotional campaigns as well as new marketing strategies of sellers have resulted in a shorter product life. In general, the idea is to replace mass production with mass customization. This is to be made possible by the factory in version 4.0 (Jaworowska and Piątek, 2017; Maślanek, 2014).

2.2. Technologies

The digitization of the industry based on nine very advanced technologies plays a key role in the development of the fourth industrial revolution. As a result of transformations 4.0, all sensors, machines, workpieces and IT systems will be merged into a value chain (Figure 1).

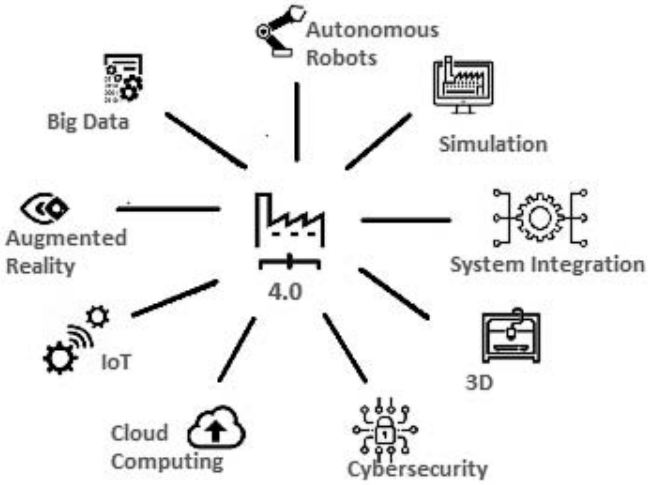

Figure 1. New technologies of Industry 4.0

S o u r c e: Authors' own elaboration based on Jaworowska and Piątek, 2017.

The most important, according to some sources, are two elements, namely the Internet of Things and CPS cybernetic and physical systems integrated in information and technical systems. One of the assumptions of the fourth industrial revolution is the strict integration of physical objects with the information network. Therefore, it can be concluded that Industry 4.0 is the digitization of production infrastructure controlled by systems in the Internet of Things environment, where, additionally, there is a smooth and collision-free penetration of the real world with virtual reality. Cyber-physical systems integrate computational and physical processes. Built-in computers connected in networks monitor and control physical processes, usually with feedback, where physical processes affect calculations and vice versa—the results of calculations are used to shape physical processes (Gontarz, 2015; Deloitte, 2015).

Today, widely used in factory halls, automated workstations will be turned into integrated systems that exchange information constantly. We can, therefore, confidently say that we will deal not so much with automated production lines, but with intelligent and

> robotic factories. An element of this integrated environment are also supposed to be people who cooperate with special 'social' robots by jointly performing tasks. Together, they consist of more effective activities in the production process, the course of which will depend on the results of the ongoing analysis of information (Schwab, 2016, p. 78).

A lot of modern technologies and solutions will be needed for the future factory to function efficiently, which is why special programmes for the so-called digital production—digital manufacturing exist. They give the opportunity not only to model the parameters of individual products, but also to test the behaviour of the entire production line in a virtual environment. Thanks to this, it is possible to simulate various variants of production, taking into account selected factors and parameters, starting from the influence of stresses and pressures in individual components, or noise level of designed mechanisms, to the effects of applying legal regulations, for example related to environmental protection (Dmowski et al., 2016).

The prospect of integrating digital production systems with ERP class systems will allow verification of loads and parameters on the production line depending on the market situation, for example—seasonal changes to the demand for manufactured goods or forms of cooperation with contractors. Then, it will be possible to test numerous models of the factory's operation and indicate the optimal variant (Iwański and Gracel, 2016).

It is worth noting that autonomous robots, able to perform tasks entrusted to them, and what is important, learn new skills, also from a human, will become more and more important. They will not work, as before, only on independent, individual workstations, but also in integrated systems and configurations created for the needs of a specific order. It will be possible thanks to advanced computer solutions allowing for quick reprogramming of both individual robots and entire networks (Jaworowska and Piątek, 2017).

An important issue without which it would not be possible to develop Smart Factory is Information Technology (IT), which is the whole of issues, methods, measures and activities related to information processing. It combines applications of information technology and telecommunications, also includes computer hardware and software, as well as tools and other techniques related to the collection, processing, transmission, storage, security and presentation of information. It provides the user with tools through which he can obtain information, select it, analyze it, process it, collect it, manage it and transfer it to other people (Schöning, 2018, p. 121).

All IT systems operating in Smart Factory will be integrated. At the same time, all applications will be linked to support for production processes, management and business operations, contacts with customers and contractors. Subsequent data processed in them will be simultaneously analyzed, including also based on Big Data solutions. As a result of connection with digital simulation it will allow to test the settings of the production apparatus before the actual changes in its software have already been made (Jaworowska and Piątek, 2017).

The access to many data will be possible thanks to the use of a very large number of sensors in the IIoT Industrial Internet of Things network. These sensors will be used, among others, for efficient communication between manufactured components and robots involved in their processing, and as a result for controlling production processes. Information from sensors controlling real-time work of individual parts and subassemblies will ensure even better use

of the potential of production machines. The possibility of predicting any damage or failure will help to reduce downtime on the production line (Gontarz, 2015).

In Smart Factory, the so-called systems of augmented reality will also find application. In the future, they will help employees find the right parts in the warehouse and make the anticipated repairs. The machine manual will be able to be sent via mobile devices or displayed directly on the subassemblies of the repaired device. Undoubtedly, it will facilitate and accelerate decision making and will streamline all procedures related to the performance of appropriate activities. In order to shorten the machine downtime, service teams will be able to use on-site 3D printers to perform some spare parts. These printers can also be used in the manufacturing process to produce products with more complex shapes or complex connections, thus reducing their mass (Gontarz, 2015).

The technologies and solutions used will allow for the production of very small batches of products or a series of the same products, distinguishing themselves between individual elements and ultimately even individual products for individual customer orders. The intelligent factory will provide the ability to quickly change the configuration of the production line in such a way that you can produce different, changing products on the same machines, following the changing needs and preferences of customers (Jaworowska and Piątek, 2017).

Ultimately, the individual components of the intelligent factory will mutually determine the best path to the production process by analyzing, exchanging and coordinating information between many components connected to the cloud (Cloud Computing), starting with the design, production machine, through digital design and production management systems, until for systems supporting logistic support and business analytics. This will ensure greater flexibility of production processes and the ability to quickly adapt them to the changing market realities, expectations of contractors and cooperators as well as individualized consumer needs. Finally, it is to enable the transition to a new economic formula, based on the calculation of customer satisfaction, and not just a calculation based on profit from the sale of goods (Dmowski et al., 2016).

2.3. Chances and dangers

Table 1 presents the opportunities and dangers posed by the introduction of the Industry 4.0 concept in enterprises in Poland.

Table 1. Opportunities and threats for the implementation of the concept Industry 4.0 in Poland

Chances	Threats
Better meet consumer needs	Reduction of jobs
Increase in productivity	Incorrect staff qualifications
New jobs with high added value	The outflow of parts of the industry from Poland
Innovative economy	Reducing the competitiveness of Polish companies
Attractiveness for investors	The advantage of foreign solutions providers 4.0
The development of new industries	The disappearance of thriving companies
Decrease in production costs	Large investment costs
Efficient use of materials and energy	Digital exclusion of numerous groups of people

S o u r c e: Authors' own elaboration.

Certainly, it should be admitted that the factories of the future will bring real benefits in various areas of the company's operation, allowing for better use of assets, even by reducing downtimes, which will translate into increased productivity. At the same time, it will ensure the optimization of production costs thanks to monitoring the condition of machines and the costs incurred. The use of intelligent devices, digitally connected together, will allow for ongoing tracking of production processes and production of personalized products, in accordance with the requirements of customers, thus translating into greater market competitiveness. Apart from non-productive aspects, it is worth mentioning even faster adaptation to changing market requirements, shortening the time of designing and introducing new products to the market (Chrzanowski and Głażewska, 2016).

Failure to participate in building Industry 4.0 will deprive Poland of the opportunities it brings and at the same time can strengthen the threats it generates. The development of Smart Factory in developed countries may result in the relocation of a part of production back, for example to Western Europe, because Poland will no longer have a significant advantage of labour costs. Negative consequences may be caused by the lack of action at the level of the whole country. For example, new, well-paid jobs in an intelligent factory will require completely different competences than those jobs that will be reduced. The lack of a properly tailored education system poses a risk of many vacancies with structural unemployment (Brandt, 2016).

> The Smart Factory concept is based on integrated processes which should improve both flexibility and efficiency. Additionally, the idea of a smart production centre is very often presented as an opportunity to improve sustainability. These goals, as well as the successful implementation of the concept, may be accomplished thanks to vertical integration of the participants within an enterprise, horizontal integration with external participants and End-To-End Integration consisting of, amongst others, customers' requirements, design and product development and production engineering which facilitates product re-use at each stage (Wang, Wan, Li and Zhang, 2016).

It is worth noting that along with the proliferation of communication and the use of standard communication protocols originating from Industry 4.0, the threat against cyber attacks is also growing, which is why the need for security of key systems and production lines will be so important. As a consequence, the assumption of cyber security will be the reliability of communication and advanced user identification systems that grant or deny access to devices.

Effective implementation of the Industry 4.0 concept can bring benefits for the entire economy and individual regions, which can be a strong development impulse for companies.

3. Survey research

The purpose of the survey was to identify the approach to the concept of Industry 4.0 in enterprises located in Wielkopolska. The study carried out in electronic form was quantitative and qualitative. The survey conducted in the period from November 18 to November 26, 2018, involved 40 companies (including 17 with foreign capital and 23 with Polish capital).

Only three plants have never dealt with the Industry 4.0 concept. Figure 2 presents information about the size of the surveyed enterprises due to the number of employees. The research involved 19 large, 8 medium, 6 small and 7 micro plants.

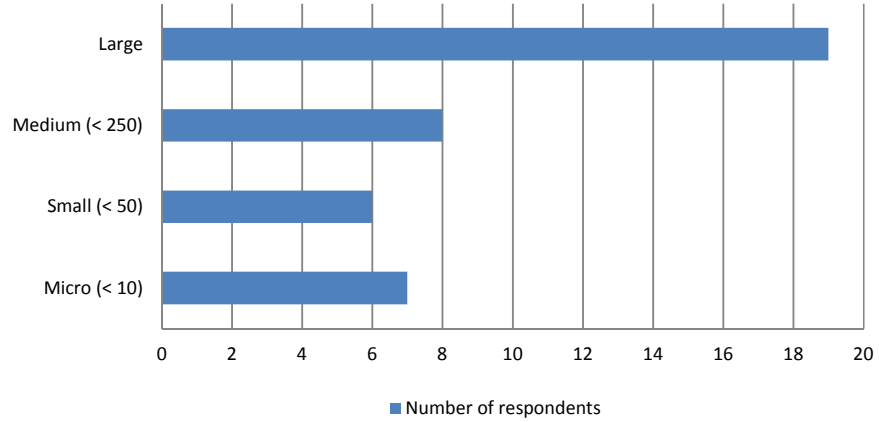

Figure 2. Size of companies participating in the survey

S o u r c e: Authors' own elaboration based on surveys.

In the next question, the type of industry to which the surveyed companies belong (Figure 3) was defined. The largest number of enterprises, as many as 20 represented the electromechanical industry, 3 light, food and chemical industries, 1 wood and paper industry, and 10 other industry (IT, services, and education).

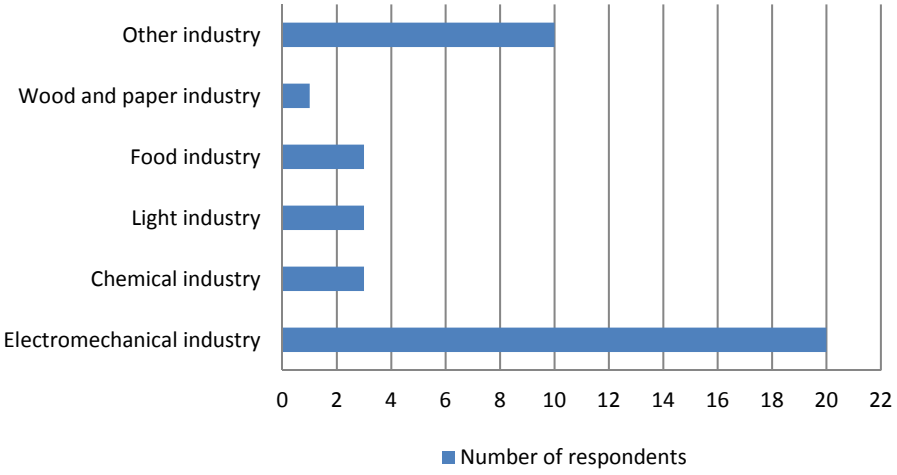

Figure 3. The type of industry of enterprises participating in the survey

S o u r c e: Authors' own elaboration based on surveys.

For 35 enterprises, Industry 4.0 is a very important issue, which is why in the next question the entrepreneurs were asked whether they connect their future with the development of the technology of the discussed concept. The same number of surveyed companies (35) associates their future with the development of technology, 3 do not plan to develop, while 2 large enterprises have not yet determined whether there will be a development process in this direction.

Using the Chi square test, it was noticed that there is a significant relationship between the company size and the assessment of the perception of the Industry 4.0 impact. The dependence is statistically significant at the significance level of 0.05. This relationship exists even for p=0.02. The strength of this compound was also determined by using the Cramer coefficient. With a 2% error, it can be assumed that the relationship is statistically significant and is shaped at the medium level.

In the further questionnaire survey companies were asked who have implemented the Industry 4.0 concept or plan to do it about the most important factors affecting the implementation of innovation. To the most important premises, the respondents ranked the clients' expectations (77%) and the internal policy/ mission of the company (60%). The third very important factor is the threat to the market position (41%), and then the possibility of receiving subsidies (21%). The indicated answers are shown in Figure 4.

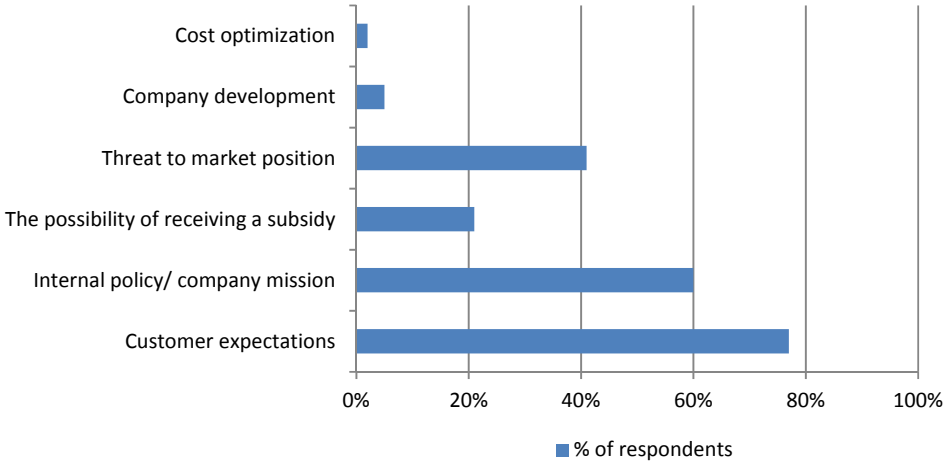

Figure 4. Factors influencing the implementation of innovation

S o u r c e: Authors' own elaboration based on surveys.

In the final phase of the survey, the most common activities applied to implement product innovations were asked. And among 40 companies surveyed, the main activity was indicated by investments in new or significantly improved machines, devices or software. The second very important activity is the improvement of employees' competences through trainings (Figure 5).

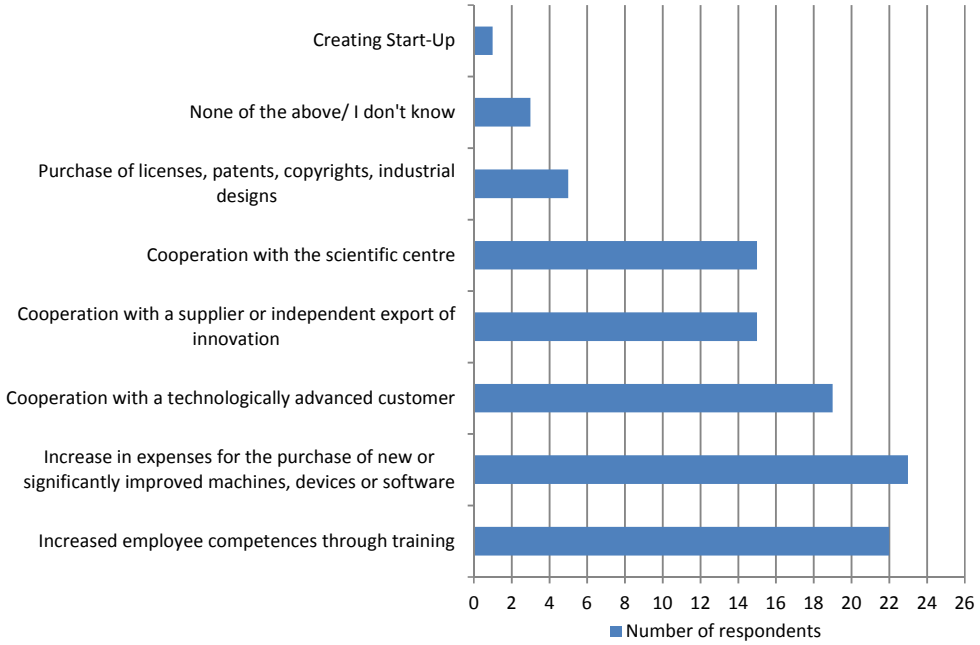

Figure 5. Ways of implementing product innovations by enterprises participating in the survey

S o u r c e: Authors' own elaboration based on surveys.

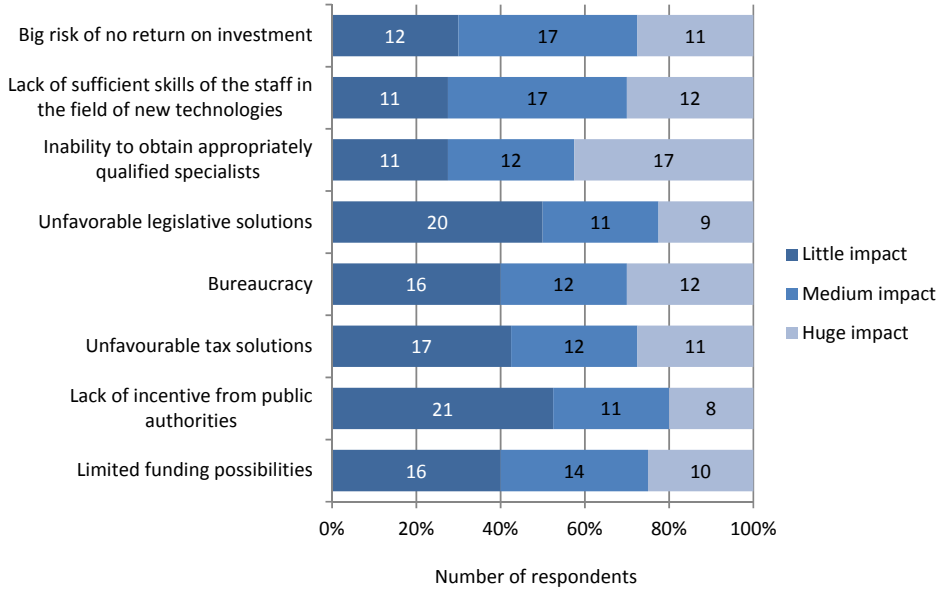

Figure 6. The degree of influence of factors inhibiting the development of new technologies

S o u r c e: Authors' own elaboration based on surveys.

The last question that has been asked to the respondents concerned barriers to growth in the company and their significance (Figure 6). The most important factor is the inability to acquire qualified specialists. The average impact is the fear of the risk of losing the money invested and the lack of sufficient competence of the staff. Negative legislative solutions and the lack of incentives from public authorities are of minor importance.

4. Conclusions

Taking into account the overall survey results, it can be concluded that the Industry 4.0 concept is not a foreign topic for Wielkopolska entrepreneurs. The idea of the concept begins to gain significance in both large and micro companies. Entrepreneurs realize that if they want to exist on the market, they must constantly evolve towards automation and digitization. It should be noted that the main factor behind the introduction of the Industry 4.0 concept is the response to customer expectations. Among the ways of implementing innovations, the funds were exchanged for new or significantly improved machines, devices or software, as well as for improving employees' competences through training. When analyzing factors hampering development, attention should be paid to the answers indicating the lack of sufficiently educated employees.

On the basis of the study, it can be stated that people are the most important resource that modern enterprises have. Highly qualified specialists nowadays are the highest good.

References

Brandt, M. (2016). *Automatisierung bedroht Millionen Arbeitsplätze* [online, accessed: 2018-12-20]. Retrieved from: http://ap-verlag.de/automatisierung-bedroht-millionen-arbeitsplaetze/23457/.

Chrzanowski, A., Głażewska, I. (2016). Wpływ rewolucji technologicznej na ewolucję strategicznych paradygmatów zarządzania przedsiębiorstwem. *Kwartalnik Naukowy Uczelni Vistula*, *2* (48), 5–34.

Deloitte. (2015). *Industry 4.0: Challenges and solutions for the digital transformation and use of exponential technologies* [online, accessed: 2018-12-20]. Geneva: Deloitte. Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf.

Dmowski, J., Iwasieczko, M., Kowalska, I., Libucha, J., Owerczuk, M., Pławik, K., Suffczyńska-Hałabuz, N. (2016). *Przemysł 4.0 PL. Szansa czy zagrożenie dla rozwoju innowacyjnej gospodarki?* Warszawa: The Boston Consulting Group.

Godlewski, A. (2016). *Rewolucja przemysłowa 4.0 po niemiecku* [online, accessed: 2018-12-20]. Warszawa: ObserwatorFinansowy.pl. Retrieved from: https://www.obserwatorfinansowy.pl/tematyka/makroekonomia/rewolucja-przemyslowa-niemcy-produkcja/.

Gontarz, A. (2015). *Przemysł 4.0, czyli jedność fizyczna i cybernetyczna* [online, accessed: 2019-01-20]. Warszawa: ITwiz Media Group. Retrieved from: https://itwiz.pl/przemysl-4-0-czyli-jednosc-fizyczna-cybernetyczna/.

Iwański, T., Gracel, J. (2016). *Przemysł 4.0. Rewolucja już tu jest. Co o niej wiesz?* [online, accessed: 2018--12-20]. Kraków: Astor. Retrieved from: https://www.astor.com.pl/images/Industry_4-0_Przemysl_4-0/ASTOR_przemysl4_whitepaper.pdf.

Jaworowska, M., Piątek, Z. (2017). *Przemysł 4.0 – technologie przyszłości* [online, accessed: 2018-12-20]. AutomatykaB2B.pl. Warszawa: AVT-Korporacja Sp. z o.o. Retrieved from: https://automatykab2b.pl/temat-miesiaca/47534-przemysl-4-0-technologie-przyszlosci.

Lee, J. (2013). Industry 4.0 in Big Data Environment. *German Harting Magazine*, *13* (1), 8–10.

Maślanek, J. (2014). *Przemysł 4.0 – rewolucja czy ewolucja?* [online, accessed: 2018-12-20]. Raport Specjalny 2014. Katowice: Portal Gospodarczy wnp.pl. Retrieved from: https://www.wnp.pl/artykuly/przemysl-4-0-rewolucja-czy-ewolucja,236764.html.

Sąsiadek, M., Basl, J. (2018). Świadomość i poziom wdrożenia koncepcji Przemysł 4.0 w wybranych polskich i czeskich przedsiębiorstwach. In: R. Knosala (ed.). *Innowacje w zarządzaniu i inżynierii produkcji*. Vol. 2 (pp. 189–198). Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją. ISBN 9788394128128.

Schöning, H. (2018). Industry 4.0 [online, accessed: 2018-12-20]. *it – Information Technology. Methods and Applications of Informatics and Information Technology*, *60* (3), 121–123, Retrieved from: https://www.degruyter.com/downloadpdf/j/itit.2018.60.issue-3/itit-2018-0015/itit-2018-0015.pdf.

Schwab, K. (2016). *The Fourth Industrial Revolution*. Geneva: World Economic Forum. ISBN 9781524758875.

Wang, S., Wan, J., Li, D., Zhang, Ch. (2016). Implementing smart factory of Industrie 4.0: An outlook. *International Journal of Distributed Sensor Networks*, *16* (7), 3–10.

Technologie fabryki przyszłości – automatyzacja i cyfryzacja produkcji w aspekcie koncepcji Przemysłu 4.0

Abstrakt: Celem niniejszego artykułu jest zaprezentowanie czytelnikowi koncepcji Przemysłu 4.0 jako nowoczesnej idei wprowadzającej przedsiębiorstwa w nową erę informatyzacji i robotyzacji. Koncepcja ta dotyczy różnych obszarów funkcjonowania organizacji jako całości, wspomaganych inteligentnymi systemami ułatwiającymi podejmowanie decyzji oraz automatyzacją poprawiającą wydajność i jakość pracy. Idea Przemysłu 4.0 jest koncepcją wyłaniającą się, dlatego istnieje wiele obaw dotyczących tego, czy stanowi ona szansę dla przedsiębiorstw, czy być może jest raczej zagrożeniem. W poniższej pracy przedstawiono założenia koncepcji Przemysłu 4.0 oraz opracowano wyniki badania ankietowego odnośnie do stanu świadomości i przygotowania przedsiębiorstwa do wdrożenia koncepcji Przemysłu 4.0. Celem badania ankietowego było rozpoznanie podejścia do nowej koncepcji w przedsiębiorstwach zlokalizowanych na terenie Wielkopolski. W ankiecie wskazano wielkość firm biorących udział w badaniu oraz rodzaj przemysłu, do którego one należą. Następnie zaprezentowano, jakie zdaniem tych firm istnieją czynniki wpływające na rozwój innowacji oraz sposoby ich wdrożenia w przedsiębiorstwach. Bardzo istotne jest również wskazanie realnych barier hamujących rozwój w firmie oraz wielkość ich wpływu. Na podstawie uzyskanych wyników badania ankietowego można stwierdzić, że czynnikiem motywującym do działań w kierunku rozwoju są przede wszystkim oczekiwania klientów oraz chęć dalszego istnienia na rynku. Natomiast najważniejszym zasobem, w który przedsiębiorstwa chcą inwestować, są ludzie, których wiedza i doświadczenie są niezastąpione przez maszyny.

Słowa kluczowe: Przemysł 4.0, smart factory, systemy cyber-fizyczne, internet rzeczy