VIRTUAL ECONOMICS

ISSN 2657-4047 *(online)*

2019 Volume 2 Number 2 (April)

CHALLENGES FACING MANAGEMENT PRACTICE IN THE LIGHT OF INDUSTRY 4.0: THE EXAMPLE OF POLAND

Radosław Miśkiewicz

Abstract. The article outlines selected challenges brought by Industry 4.0 as well as consequences for Polish businesses in the modern process of their management. The concept is based on a close connection between physical objects and information network. Sophisticated networks of businesses are being created, connected with smart resources communicating via the Internet. This means cooperation within implemented cyber-physical systems affecting a company's environment, its production model, value-added chain of business processes and organisational structure.
Keywords: industry 4.0, cyber-physical systems (CPS), robotisation
JEL Classification: F6, L26, O32

Author(s):

Radosław Miśkiewicz
Silesian University of Technology, 26, Roosevelta Street, Zabrze, Poland, 41-800
E-mail: radoslaw.miskiewicz@polsl.pl
https://orcid.org/0000-0003-2370-4783

Citation: Miśkiewicz, R. (2019). Challenges facing management practice in the light of Industry 4.0: The example of Poland. *Virtual Economics, 2*(2), 37-46. https://doi.org/10.34021/ve.2019.02.02(2)

Received: November 28, 2018. Revised: December 29, 2018. Accepted: March 7, 2019.

1. Introduction

Today, the fourth industrial revolution which enables devices to be interconnected within digital ecosystems is contributing to deeper integration within horizontal and vertical value chains. In the economy, the challenges will include new jobs with high added value concentrated around automation, increased competition with an innovative international economy, more efficient use of energy and materials. As K. Schwab writes, attractiveness for investors will be perceived through building a positive feedback loop between competence development and capital inflow (Schwab, 2018). Under the influence of new technological solutions, the fourth industrial revolution has affected the shape of production functions. Today's production cannot limit itself to a simplified version consisting of two or even three factors, such as those defined by classical economics, i.e. labour (N) and land (L), and capital (K) included in the capitalist economy. At present, the key factor is information and knowledge about values that are difficult to measure and characterised by high amplitude of changes; so the production function taking into account additional values will take the form of a complex equation, with a general formula $Y = f(N, K, L, SK, HK)$, where: N - labour, K - capital (financial), L - land (land on which the factory stands, natural resources), HK - human capital (knowledge, skills, know-how), SK - social capital (good law, good institutions) (Olender-Skorek, 2017). In this context, Industry 4.0 means new market models, new behaviour of businesses, a different perspective on competition and competitiveness.

Industry 4.0 encompasses a range of new technologies such as the Internet of Things, cloud computing, Big Data analysis, artificial intelligence, as well as additive printing, augmented reality and collaborative robots. This means significant changes in production management, business operations and value creation chain. A new architecture of production management systems is also being shaped, moving from linear processes and the traditional pyramid of production management systems to a network of connections and non-linear production. The combination of these innovations with new artificial intelligence capabilities should lead to a revolutionary change in manufacturing management systems which will operate in a highly autonomous way, dynamically changing their structure and functions within an organisation. Industry 4.0 is part of a larger megatrend of digital transformation, encompassing a wide range of industries, the financial and logistics sectors in particular (Miśkiewicz, 2019).

2. Literature review

Scientific literature in economics and management sciences provides a number of arguments relating to the substance of Industry 4.0. An attempt to identify them was made by Hermann M., Pentek T. and Otto B. in their work Design Principles for Industrie 4.0 Scenarios: A Literature Review. They noted that in modern global activities the competition manifests itself in all spheres of business activity of enterprises. This necessitates the need to make more extensive use of knowledge and on its basis professionally manage the changes in a company (Herman et al., 2015). Mass customisation in the business area as well as additive manufacturing may, as K. Liczmańska and M. Kuczyńska emphasise (Liczmańska &

Kuczyńska, 2016), further contribute to the development of a business model. Taking into account the theory proposed by J. Bis, it is the factor which, unlike product and service, is much more difficult to copy. This fact seems to be confirmed by the experience of businesses that have achieved a competitive advantage by changing and continuously adapting their business model to new possibilities and operating conditions in the face of dynamic technological development (Bis, 2013). Common features of available models and emerging similarities in terms of their behaviour have been analysed by M. Kardas, B. W. Wirtz, A. Pistoia, S. Ullrich, W. Gottel, A. Osterwalder and Y. Pigneur, to name a few, and their research results have become the basis for distinguishing five general business model schemes (Kardas, 2016; Kwilinski, 2018a, 2018b, 2018c; Osterwalder & Pigneur, 2013; Pająk et al., 2016; Wirtz et al., 2015). These included (i) unbundling into separate but complementary modules relating to infrastructure management; (ii) product innovation and customer relationships management (e.g. mobile operators); (iii) long tail - a new or additional value proposal addressed to a large number of niche customer segments that together generate a significant profit (e.g. if reached via an e-commerce platform), although it would not be profitable to operate only one of them; (iv) multilateral platforms providing customers with values 'ensuring the access'; (v) the FREE concept where customers who pay subsidise the segment that uses the free offer. Of importance are open business models based, for instance, on research and development results obtained from external sources.

The main aim of the article is to provide the reader with an insight into the current topic of the fourth generation industry still poorly explored and researched, and to identify the challenges facing the Polish economy and manufacturing companies. Consequently, it has been possible to present the state of advancement in the implementation of solutions resulting from the Industry 4.0 concept.

3. Methodology

In writing this article, the author made use of a qualitative descriptive method referring to a critical analysis of national and foreign studies on the fourth industrial revolution and Industry 4.0 and, on the basis of collected materials, made a short review of selected theoretical approaches constituting challenges that countries, economy and businesses are faced with as a consequence of the implementation of Industry 4.0.

Acatech, A. Whitmore, L. Agarwal, X. Da. point out significant changes taking place in IT systems. These modern ones are supported by global networks consisting of machines, storage systems and production plants in the form of cyber-physical solutions (ACATECH; Whitmore et al., 2015). Their complex architecture is also emphasised by G. Bartoszewicz, G. Mazurek (Bartoszewicz, 2017; Mazurek, 2018) who refer it to the Internet infrastructure, global intranets with their multimedia services, Programmable Logic Controllers (PLC) with embedded microprocessor systems, necessary to control manufacturing devices, Wireless Sensor Network (WSN) consisting of sensors communicating with each other, used to monitor the condition of equipment and production lines. An important segment of cyber physical systems (CPS) - ERP 2.0 - is indicated by Ch. Bartodziej, J. Badurek, Ch. S. Hu. These systems support the implementation of Industry 4.0 as they include: real time systems used in the processes of Logistics 4.0 and concerning GPS and RFID technologies, they control just-in-time production and supply, carry out Autonomic Computing (AC) based on self-managing computer systems with the following characteristics: self-configuring, self-protecting, self-healing, self-optimising, processing and analysing Big Data. As a result, they present information in the form of smart reports and management cockpits in Business Intelligence (BI) modules. (Bartodziej, 2016; Badurek, 2015; Hu, 2013) These challenges shape a new model of modern business and production, defined 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 infrastructure based on the 5C functional model, and on the other hand, on completely new paradigms created on the basis of innovative trends and megatrends understood as directions of social, economic, environmental, political, cultural and legal changes as presented in *Fig. 1*.

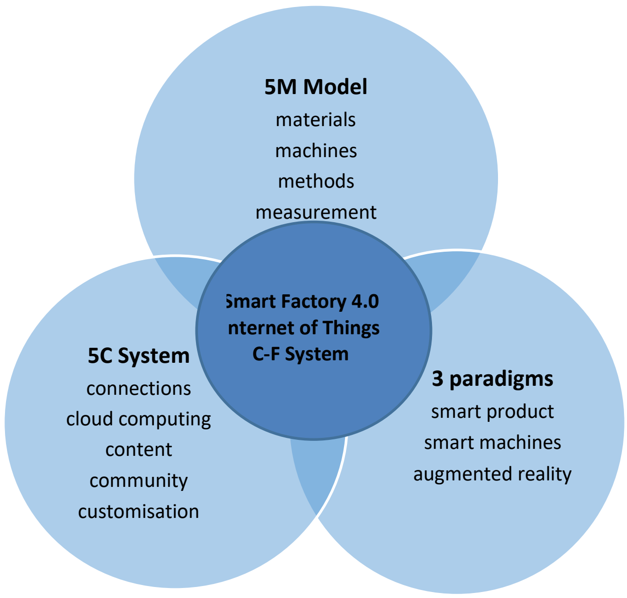

Figure 1. Components of Industry 4.0
Source: (Magruk, 2017; Lee et al., 2013; Weyer et al., 2015).

The digitisation of product and service offer, the integration of value-added chain are shaping a new model of modern businesses. This means the mass customisation of products resulting in the implementation of the following functions in Industry 4.0 and relating to: horizontal integration through value networks; digital integration of engineering processes throughout the value chain, vertical integration and integration of networked production systems. The implementation of Industry 4.0 in businesses also requires the implementation of next-generation tools for the design or modification of organisational structures. This new research thread is undertaken by the author (Miśkiewicz, 2019) who points to the need to build a learning enterprise, improve the possibilities of an organisation as a whole and implement systemic thinking as a resource of knowledge and tools that allow to explain complex phenomena and influence them. Changes in business organisational structures caused by the dynamic development of digital technologies allow companies to globalise in a more "lean" way. Digital tools, as emphasised by M. Frankowska, M. Malinowska, A. Rzeczycki, enable remote cooperation and instant communication (Frankowska et al., 2017). They create new opportunities for centralising some global functions related to accounting or R&D, creating virtual global teams or completely resigning from the existence of a single headquarters. Taking into account automation and standardisation trends based on product models, they enable customers to access industrial production through digital platforms. An important challenge facing modern management practice is the development of human capital, analysed in various contexts by M. Wosiek, A. Butkiewicz-Schodowska, M. Kocór, J. Pieregud or R. Geissbauer, J. Vedso, S. Schrauf. These contexts refer to the ability to think in a systemic way, to operate in a multicultural environment and a globalised economy, as well as to the constant expansion of competences and readiness to accept new ideas, technologies and economic practices. They influence the working environment and its modern management (Wosiek, 2015a, 2015b; Butkiewicz-Schodowska, 2015; Kocór, 2015; Pieregud, 2016; Geissbauer et al., 2015).

4. Results

Analysis of available literature and published reports indicates that Industry 4.0 is already a global fact. Its importance is evidenced by the fact that the search for its terminological reference in online databases has increased a hundredfold in the last five years. The leading slogans are production, business, politics, technology (ASD Consulting, 2018). The digitalisation of industry with the production brought to a completely new level is a great opportunity for economies. According to the Capgemini Report, it is estimated that by 2020, the 4.0 companies will bring an added value of 500 billion dollars to the global economy. This will happen mainly by adapting modern technological solutions streamlining production processes in the smart manufacturing market with the use of automation, Internet of Things or Artificial Intelligence. It is also an opportunity for Poland, because thanks to the digital revolution in the industrial sector we can get richer by nearly 5 billion dollars. The report "Digitalisation Productivity Bonus: Sector Insights" points to the need to implement specific investments in the areas of engineering, automotive, printing and plastics industries. In the former, the transition to digital technology could generate productivity gains of between $1.4 bn and $2.1 bn. The implementation of smart packaging with embedded RFID chips, print technology to monitor the flow of goods or cloud links between the customer and the manufacturer will result in digitisation bonuses in the printing, packaging and paper industries in the range of $0.5 bn. to $0.8 bn. In the plastics industry it will amount to around $0.7-1.1 bn. In the automotive industry, taking into account the electromobility megatrend and the use of new technologies such as AGV, the productivity bonus could be in the range of $0.5-0.8 bn. (Siemens, 2017) Digital transformation of production requires appropriate IT systems, e.g. Manufacturing Execution System (MES). Unfortunately, the report "Industry 4.0. The new industrial revolution - how Europe will succeed" published in 2014 by Roland Berger Strategy Consultants places Poland among hesitating countries with a low index of readiness to implement Industry 4.0 and an average industrial base. According to the

 ISSN 2657-4047 (online)

Marketsand Markets 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", and research conducted by Astor, only 15% of Polish companies are fully automated and 76% show partial automation of their company (Astor, 2017b).

In the global economy, automation of production is becoming more and more common. Based on available data included in the report of the International Federation of Robotics (IFR), it appears that in 2017 the number of installed robots worldwide exceeded 2 million robots; there are almost 498,000 in Europe and about 52,863 in Central and Eastern Europe. Poland is an emerging market with an accelerating pace of robot installations, especially since 2014. Our market is particularly attractive for production in the automotive, chemical, metal and machinery industries. Robot density is constantly increasing, but the number of robots per 10,000 employees is still lower than in the Czech Republic, Slovakia and Hungary - 36 units (in the automotive industry 165 units per 10,000 employees, other industries: 24). In 2017, annual sales of robots in Poland increased by 16% and reached a number of 1,891 units. IFR estimates the total number of robots installed in Poland at about 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 robot installations in Poland will grow by 15%-20% (IFR, 2017; Gracel, 2016). Smart machines are most commonly used in welding, palletising and handling operations, i.e. feeding, moving, preparatory operations or machine operation. Polish entrepreneurs faced with the requirement to improve the quality of products are increasingly "employing" robots also for quality control (International Federation of Robotics, 2018).

Another challenge facing management practice is the implementation of the Internet of Things concept and global access to Big Data in Polish companies. In the global economy, the costs of digitisation are currently being reduced and the concept of a smart factory is being implemented, which has a direct impact on data generation. For example, in 1992 it was 100 GB/per day, in 2013 it was 28,875 GB/per second, and in 2018 already 50,000 GB/per second. At the same time, the cost of data storage was reduced from 10,000 USD/year (1995) for 1 GB, and nowadays it is about 3 cents for 1 GB/year. Meanwhile, according to ASTOR research (Astor, 2017), 59% of Polish companies enter data manually into the system, 36% do so automatically and 16% manually on paper. It is essential to develop physical, digital and biological clusters in megatrends affecting the development of the economy and entrepreneurship globally and in Poland, such as: Industry 4.0, closed-loop economy, sustainable finance, eco-investment, flexible labour market and electromobility promotion (Schwab, 2016). It is also worth noting that in the United States, the digitisation index is 18%, in Western Europe 12%, and in Poland 8%. This means that the degree of digitisation of Polish companies is on average 34% lower than in Western Europe (Astor, 2017).

5. Conclusions

The basis for conducting various industrial operations is an efficient, reliable and real-time data exchange between individual components of the system. The increasing amount of data to be transferred and/or processed has forced the development of new standards for industrial networks. Of importance too is that modern production control and management systems have to communicate with the company's reporting modules, and this raises some problems. It is also a good thing if they work with design support software in construction offices. This means that industrial networks can no longer exist for themselves, but must also communicate with the entire company's infrastructure, either directly or via bridges. IT networks are usually built on Ethernet, which in comparison with other networks within a company occupies 52% (increase by 22% year on year), Fieldbus 42% (annual growth 6%) and wireless 6% (annual growth 32%) (Pieriegud, 2016).

The most important challenges for business practice will be:

- expanding the activities of the Polish digital platform with the task of integrating and coordinating the activities of many entities, including public administration, businesses, educational and scientific-research institutions carried out for the benefit of industry digital transformation;
- developing physical clusters, autonomous vehicles, advanced robotics, 3D printing and new materials such as graphene, self-cleaning clothes, ceramics turning pressure into energy and digital clusters built on the Internet, availability of computing power, data collection and processing, mobile devices;
- implementing new technical competencies and specialisations of the managerial staff as the most important for the development of Industry 4.0, but also broadening them with soft skills related to communication and leadership.

The effects of the fourth industrial revolution will mean transformations of entire market structures, changes in business models, organization and management of the company, the creation of added value, the functioning of labor markets, and the conduct of a number of public policies. Hence the need for more research dynamics in this area. Unfortunately, existing studies draw attention to the technical and engineering perspective, while omitting international issues, for example, trade and investment relations. In Polish scientific literature, this process has not been analyzed in an international context. Its development in research can provide arguments for changes in the models of a modern enterprise, define new requirements in relation to planning and management in it. The scientific analysis should cover the economic policy of Poland implementing the concept of Industry 4.0, for example with an expanded research area regarding working conditions in an intelligent factory, in which organizational boundaries disappear, where flexible working time and distance work are preferred.

References

ASD Consulting. (2018). *Wyzwania polskich przedsiębiorstw w erze Industry 4.0 [Challenges of Polish enterprises in the era of Industry 4.0].* Retrieved from https://asdconsulting.pl/wp-content/uploads/2018/06/Raport-ASD-06-2018.pdf [in Polish].

ASTOR. (2016). *Przemysl 4.0. Rewolucja już tu jest. Co o niej wiesz?* Retrieved from https://www.astor.com.pl/images/Industry_4-0_Przemysl_4-0/ASTOR_przemysl4_whitepaper.pdf [in Polish].

ASTOR. (2017a). *Inżynierowie Przemysłu 4.0 [Engineers of Industry 4.0].* Kraków:, Poland: ASTOR Publishing. Retrieved from https://www.astor.com.pl/images/Industry_4-0_Przemysl_4-0/ASTOR_Inzynierowie_4.0_whitepaper.pdf [in Polish].

ASTOR. (2017b). *W jakie technologie inwestują firmy produkcyjne w Polsce?* Retrieved from https://polskiprzemysl.com.pl/wp-content/uploads/Raport-ASTOR-2017.-W-jakie-technologie-inwe stuj%C4%85-firmy-produkcyjne-w-Pol....pdf[in Polish].

Badurek, J. (2015). *Przedsiębiorstwo informacyjne. Systemy produkcyjne nowej generacji [Information company. New generation production systems].* Gdańsk, Poland: Wydawnictwo Politechniki Gdańskiej [in Polish].

Bartodziej, Ch. J., (2016). *The Concept Industry 4.0: An Empirical Analysis of Technologies and Applications in Production Logistics.* Wiesbaden, Germany: Springer Gabler, Springer Fachmedien Wiesbaden GmbH.

Bartoszewicz, G. (2017). Wykorzystanie metod zarządzania procesowego BPM w celu zwiększenia efektywności złożonych procesów logistyki 4.0 w systemach ERP 2.0 [The use of BPM process management methods to increase the efficiency of complex logistics processes 4.0 in ERP 2.0 systems]. In P. Cyplik and M. Adamczak (Eds.), *Wybrane problemy współczesnej logistyki w świetle badań naukowych i praktyki biznesowe [Selected problems of modern logistics in the light of scientific research and business practice]* (pp.12-31). Poznań, Poland: Wydawnictwo Wyższej Szkoły Logistyki. Retrieved from http://wsl.com.pl/tl_files/wydawnictwo/publikacje/WSL_Forum_2017/1. pdf [in Polish].

Bis, J. (2013). Innowacyjny model biznesowy – sposób na zwiększenie przewagi konkurencyjnej [Business Model Innovation – a way to increase competitive advantage]. *Przedsiębiorczość i Zarządzanie. Modele Biznesowe [Entrepreneurship and Management. Business Models] XIV*(13), Part 2, 53-64. Retrieved from http://piz.san.edu.pl/docs/e-XIV-13-2.pdf [in Polish].

Frankowska, M., Malinowska, M., & Rzeczycki, A. (2017), Kształtowanie modeli biznesu w erze Industry 4.0 [Developing New Business Models for the Industry 4.0 Concept]. , [in:] R. Matwiejczuk, L. Pisz (eds.) Logistyka w naukach o zarządzaniu. *Przedsiębiorczość i Zarządzanie. Logistyka w Naukach o Zarządzaniu [Entrepreneurship and Management. Logistics in Management Sciences],* XVIII(8), Part 1, 97-109. http://piz.san.edu.pl/docs/e-XVIII-8-1.pdf [in Polish].

Geissbauer, R., Vedso, J., & Schrauf, S. (2015, September). *Industry 4.0: Building the digital enterprise.* Global Industry 4.0. PWC. Retrieved from https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

Gracel, J. (2016). Industry 4.0 – kluczowe pytania i odpowiedzi [Industry 4.0 - Key Questions and Answers]. *Automatyka. Podzespoły. Aplikacje [Automation. Components. Apps], 6*(10), 36-39.

Hermann, M., Pentek, T., Otto, B. (2015). *Design Principles for Industrie 4.0 Scenarios: A Literature Review. Working Paper No 01.* Germany: Technische Universität Dortmund Fakultät Maschinenbau. Audi Stiftungslehrstuhl Supply Net Order Management. Retrieved from https://moodle.ufsc.br/pluginfile.php/2759968/mod_folder/content/0/Design-Principles-for-Indu strie-4_0-Scenarios.pdf?forcedownload=1

Hu, Ch. S. (2013). *A New Measure for Health Consciousness: Development of A Health Consciousness Conceptual Model.* Retrieved from https://www.researchgate.net/publication/299484743_A_New_ Measure_for_Health_Consciousness_Development_of_A_Health_Consciousness_Conceptual_Model

Gausemeier, J., & Klocke, F. (Eds.). (2016). *Industrie 4.0 International Benchmark, Options for the Future and Recommendations for Manufacturing Research.* Paderborn: Aachen. Retrieved from https://en.acatech.de/publication/industrie-4-0-international-benchmark-options-for-the-future-and-recommendations-for-manufacturing-research/

International Federation of Robotics. (2018). *Robot density rises globally.* Frankfurt: IFR. Retrieved from https://ifr.org/ifr-press-releases/news/robot-density-rises-globally.

Kardas, M. (2016). Pojęcia i typy modeli biznesu [Concepts and types of business models]. In K. Klincewicz (Ed.), *Zarządzanie, organizacje i organizowanie - przegląd perspektyw teoretycznych [Management, organization and organization - review of theoretical perspectives]* (pp. 298-318). Warsaw: Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego. Retrieved from http://timo.wz.uw.edu.pl/wp-content/uploads/2016/09/20-Marcin-Kardas-Poj%C4%99cia-i-typy-modeli-biznesu-Klincewicz-Krzysztof-red-Zarzadzanie-organizacje-i-organizowanie.pdf [in Polish].

Kocór, M. (2015). Niedopasowanie kompetencyjne [Competency mismatch]. In J. Górniak (Ed.), *Polski rynek pracy – wyzwania i kierunki działań [Polish labor market - challenges and directions of activities]* (pp. 12-26). Warsaw: PARP. Retrieved from https://www.ncbr.gov.pl/fileadmin/user_upload/import/tt_content/files/POWR.03.01.00-IP.08-00-3MU18/zalacznik_nr_12_polski_rynek_pracy___wyzwania_i_kierunki_dzialan_na_podstawie_badan_bilans_kapitalu__ludzkiego_20102015.pdf [in Polish].

Kwilinski, A. (2018a). Mechanism for assessing the competitiveness of an industrial enterprise in the information economy. *Research Papers in Economics and Finance, 3*(1), 7-16. https://doi.org/10.18559/ref.2018.1.1

Kwilinski, A. (2018b). Mechanism of formation of industrial enterprise development strategy in the information economy. *Virtual Economics, 1*(1), 7-25. https://doi.org/10.34021/ve.2018.01.01(1)

Kwilinski, A. (2018c). Mechanism of modernization of industrial sphere of industrial enterprise in accordance with requirements of the information economy. *Marketing and Management of Innovations,* 4, 116-128. http://doi.org/10.21272/mmi.2018.4-11

Lee, J., Lapira, E., Bagheri, B., & Kao, H.A. (2013). Recent advances and trends in predictive manufacturing systems in big data environment. *Manufacturing Letters, 1*(1), 38-41. https://doi.org/10.1016/j.mfglet.2013.09.005

Liczmańska, K., & Kuczyńska, M. (2016). Wartości dla klienta jako główny element modelu biznesu linii lotniczych Rynair [Values For The Customer As The Main Element Model Business Airline Rynair]. *Acta Universitatis Nicolai Copernici. Zarządzanie, XLIII*(3), 193-207. [in Polish] http://dx.doi.org/10.12775/AUNC_ZARZ.2016.040

Magruk, A. (2017). Minimalizacja niepewności w systemie Przemysłu 4.0 [Minimizing of uncertainty phenomenon in system of Industry 4.0 by anticipation of unprecedented events*]. Zeszyty Naukowe. Organizacja i Zarządzanie,* 108, 243-254. Retrieved from http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-fa3aaa01-67eb-4153-a260-cb53280f8fcb/c/magruk_ ZNPSL_OZ_2017_108.pdf [in Polish].

Mazurek, G. (2018). Internet Rzeczy a cyfrowa transformacja - implikacje dla marketingu B2C [Internet of Things and digital transformation - implications for B2C marketing]. In L. Sułkowski and D. Kaczorowska-Spychalska (Eds.), *Nowy paradygmat rynku [A new market paradigm]* (pp. 33-57). Warsaw: Difin [in Polish].

Miśkiewicz, R. (2019). *Organisational structure in the process of integration on the example of iron and steel industry enterprises in Poland. Process digitisation in the industry 4.0 concept.* Warsaw, Poland: Wydawnictwo PWN.

Olender-Skorek, M. (2017). Czwarta rewolucja przemysłowa a wybrane aspekty teorii ekonomii [Fourth industrial revolution and selected aspects of economics]. *Nierówności Społeczne a Wzrost Gospodarczy [Social Inequality and Economic Growth], 51*(3), 38-49. http://dx.doi.org/10.15584/nsawg.2017.3.3 [in Polish].

Osterwalder, A., & Pigneur, Y. (2013). *Tworzenie modeli biznesowych. Podręcznik wizjonera Creating business models. Visionary Handbook].* Gliwice, Poland: Wydawnictwo Helion [in Polish].

Pająk, K., Kamińska, B., & Kvilinskyi, O. (2016). Modern trends of financial sector development under the virtual regionalization conditions. *Financial and Credit Activity: Problems of Theory and Practice, 2*(21), 204-217. https://doi.org/10.18371/fcaptp.v2i21.91052

Pieriegud, J. (2016). Cyfryzacja gospodarki i społeczeństwa – wymiar globalny, europejski i krajowy [Digitization of the economy and society - global, European and national dimensions]. In J. Gajewski, W. Paprocki, and J. Pieriegud (Eds.), *Cyfryzacja gospodarki i społeczeństwa – szanse i wyzwania dla sektorów infrastrukturalnych [Digitization of the economy and society - opportunities and challenges for infrastructure sectors]* (pp. 11-37). Gdańsk, Poland: Instytut Badań nad Gospodarką Rynkową – Gdańska Akademia Bankowa. Retrieved from https://www.efcongress.com/sites/default/files/publikacja_ekf_2016_cyfryzacja_gospodarki_i_spoeczestwa.pdf [in Polish].

Schwab, K. (2016). *The Fourth Industrial Revolution.* Davos: Word Economic Forum. Retrieved from https://luminariaz.files.wordpress.com/2017/11/the-fourth-industrial-revolution-2016-21.pdf

Siemens. (2017). *Digitalization Productivity Bonus: Sector Insights.* Retrieved from https://new.siemens.com/global/en/products/financing/whitepapers/whitepaper-the-digitalization - productivity-bonus-sector-insights.html

Weyer, S., Schmitt, M., Ohmer, M., & Gorecky, D.(2015), Towards Industry 4.0-Standardization as the crucial challenge for highly modular, multi-vendor production systems. *IFAC-PapersOnLine, 48*(3), 579-584. http://dx.doi.org/10.1016/j.ifacol.2015.06.143

Whitmore, A., Agarwal, A., & Xu. L. (2015). The Internet of Things—A survey of topics and trends. *Information System Frontiers, 17*(2), 261-274. https://doi.org/10.1007/s10796-014-9489-2

Wirtz, B.W., Pistoia, A., Ullrich, S, & Gottel, V. (2015). Business Models: Origin, Development and Future Research Perspectives. *Long Range Planning, 49*(1). 36-54. http://dx.doi.org/10.1016/j.lrp.2015.04.001

Wosiek, M. (2015a). Niespójności w rozwoju kapitału ludzkiego w Polsce – spojrzenie przez pryzmat koncepcji kapitału intelektualnego, Part 1: Kapitał ludzki a kapitał społeczny [The Inconsistencies in the Development of Human Capital in Poland - a View through the Prism of the Concept of Intellectual Capital. Part 1: Human Capital and Social Capital]. *Nierówności Społeczne a Wzrost Gospodarczy [Social Inequality and Economic Growth],* 41, 340-353 [in Polish].

Wosiek, M. (2015b). Niespójności w rozwoju kapitału ludzkiego w Polsce – spojrzenie przez pryzmat koncepcji kapitału intelektualnego, Part 2: Kapitał ludzki a kapitał strukturalny rozwoju [The Inconsistencies in the Development of Human Capital in Poland - a View Through the Prism of the Concept of Intellectual Capital. Part 2 : Human Capital and Renewal Capital]. *Nierówności Społeczne a Wzrost Gospodarczy [Social Inequality and Economic Growth],* 42, 327-339 [in Polish].