dr hab. inż. Bożena GAJDZIK, dr inż. Sandra GRABOWSKA, prof. dr hab. inż. Andrzej WYCIŚLIK

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Silesian University of Technology, Faculty of Production Engineering, Krasińskiego 8, 40-019 Katowice
e-mail: Bozena.Gajdzik@polsl.pl

EXPLANATORY PREVIEW OF DIRECTIONS OF CHANGES IN DEVELOPMENT OF INDUSTRY 4.0

POGLĄDOWE UJĘCIE KIERUNKÓW ZMIAN W ROZWOJU PRZEMYSŁU 4.0

Summary: *The paper is commenced with the citation of Klaus Schwab, founder and the Executive Chairman of the World Economic Forum; "We are at the beginning of a technical revolution that is fundamentally changing the way we live, work and relate to one another (...) (Schwab, 2016, p.12)". The environment of scientists and business practitioners speaks more and more frequently on the new challenges for the industry in connection with the Fourth Industrial Revolution. Industry 4.0 is a result of development of cyber-physical manufacturing processes within the frames of the 4.0 industrial revolution. Scientists, politicians and entrepreneurs discuss the trends of changes in the industry. Industry 4.0 sets the new areas of changes in the area of production and management of total chain of supplies (SCM, Supply Chain Management). The present paper has been created on the grounds of literature study concerning the area of the discussed subject. The authors of the article have compiled the industrial changes, as discussed in publications and created a list of the key trends of the changes. The present work may become a voice in discussion on the direction of the changes in Industry 4.0.*

Keywords: *the fourth industrial revolution, Industry 4.0, directions of changes*

Streszczenie: *Cytując Klausa Schwaba, założyciela i przewodniczącego World Economic Forum: „Stoimy u progu technologicznej rewolucji, która gruntownie zmienia sposób, w jaki żyjemy, pracujemy i współistniejemy (…) (Schwab 2016, p. 12)". Coraz częściej w środowisku naukowców i praktyków biznesu mówi się o nowych wyzwaniach dla przemysłu w związku czwarta rewolucją przemysłową. Przemysł 4.0 jest rezultatem rozwoju cyber-fizycznych systemów wytwarzania w ramach czwartej rewolucji przemysłowej. Naukowcy, politycy, przedsiębiorcy dyskutują o kierunkach zmian w przemyśle. Przemysłu 4.0 wyznacza nowe obszary zmian w sferze produkcji i zarządzaniu całym łańcuchem dostaw (SCM). Niniejsza praca powstała na podstawie studium literaturowego w przedmiotowym zakresie tematu. Celem publikacji było przybliżenie czytelnikom kierunków (tendencji) zmian w Przemyśle 4.0. Autorzy publikacji kompilując omówione w publikacjach zmiany przemysłowe, utworzyli listę kluczowych kierunków zmian. Praca może stanowić głos w dyskusji nad kierunkami zmian w Przemyśle 4.0.*

Słowa kluczowe: *czwarta rewolucja przemysłowa, Przemysł 4.0, kierunki zmian*

Introduction

Since the dawn of the history, we have observed a development of technical solutions which have to improve production. Under the conditions of dynamic changes in the environment which became intensive by the end of the 20th century, the enterprises are forced to introduce constantly the changes in the particular areas of their activity in order to maintain their competitive position. The introduction of modern technical solutions as compared to other market participants is the extremely significant activity for functioning of every enterprise. Industrial changes are concentrated on technology, time and quality. Combination of ICT, industry and Internet lie behind the conception of a new industry. The idea of "Industry 4.0" that was introduced in 2011 by Henning Kagermann, professor of physics and former President of SAP management, has been transformed into strategy for development of German industry. Recently, it has become also a very popular slogan, used to determine the changes concerning industrial sector in the period of shaping a new phase of development, being called the Fourth Industrial Revolution. The fourth industrial revolution that was commenced in 2012, utilizes the following technical solutions: automation and robotics, digitalization and Internet and is based partially upon the achievements of 3.0 industrial revolution (Industry 3.0 was identified with the growth in automation and IT systems, mainly in respect of production planning and control). Industry 4.0 is, therefore, the consequence of the development of changes, performed during the stage of the 3.0 industrial revolution. On the present stage, we already speak about full automation of production, robotics in systems, specified as cyber-physical manufacturing systems due to the fact of introducing the equipment into the network with the use of internet standards. Development of automation and robotics of the industrial operations is aimed at creation of artificial intelligence, that is (in a big simplification) self-improving devices (objects). The changes in manufacturing technologies and development of digitalization and Internet have brought the changes in the industry. The range of the changes is determined by the economic development of particular countries and investing possibilities of the enterprises. At present, Industry 4.0 is implemented already in highly-developed countries, including Germany, USA and Japan. Other countries initiate also the activities, aimed at development of industry 4.0. Not all sectors introduce the newest solutions of the fourth industrial revolution; Automotive belongs to the key ones. The process of introducing the changes proceeds gradually; it may be anticipated that the changes will become intensive in the coming decade and in further years of the contemporary century. The question: which directions of changes determine (describe) Industry 4.0, is the issue which was adopted as the aim of the paper: "Explanatory preview of directions of the changes in development of Industry 4.0". The design of the work includes the characteristics of the basic trends of changes. The paper contains also a scheme of the discussed trends of changes in Industry 4.0.

Trends of changes in Industry 4.0 – towards cyber-physical manufacturing processes

Development of Industry 4.0 means, first of all, a full automation and robotics of production, with the utilization of ICT and IT in respect of control of equipment and communication in the systems: man – machine (P2M), machine – machine (M2M), man – man (P2P). It means also an access to the data within the frames of cloud computing. Smart factory is a virtual (digital) copy of real world, utilizing Internet of Things (IoT), (Chui, 2010, pp.1-9). Systems – CCPS – are structures combining IT and OT (operating technology). Production is included in communication solutions within

Internet of Things – IoT (Ashton, 2016) and Internet of Services – IoS. The applied production technology in industry 4.0 is Advanced Manufacturing due to the automatic search for and introduction of the best solutions for manufacture of the products, with the existing resources of the enterprise and after consideration of personalized needs of the customer (Hermann, 2015). Industry 4.0 utilizes many technologies, including business analytics, robotics, printing 3D (Industry 4.0 – Summary report, 2015).

The fundamental direction of changes in the area of production, recognized as the initial (basic) includes further (as compared to Industry 3.0) automation of the manufacturing processes. The successive equipment with a limited work, implemented by man, is introduced to manufacturing areas. The number of robots and industrial manipulators, employed in manufacture of the products, is increasing. According to the data of the International Federation of Robotics (IFR), in 2015 there was sold the record – until now - number of industrial robots i.e. 240 thousand pieces (by 8% more than in 2014). The highest growth dynamics in 2015 was recorded in the east Europe (29%). The total number of industrial robots in the world is equal to 2 million pcs. Value of the discussed sector (sales, software and service) in 2015 amounted to 32 billion USD (Pierieguad, 2016).

The directions initiating the further development of Industry 4.0 include also digitization (digitalization) of the industry. The terms "digitalization" and "digitization" are often used interchangeably (Ciesielski). Apart from digital economy, there are also other terms such as new economy, e-economy, network economy (Pelts and Waldfogel, 2012; Gajewski et al., 2016). The development of digitization in economy results in development of digitization of the industry. Therefore, analogically, we may speak about new industry, e-industry and network industry. Digital transformation in the industry, especially in the area of production is called digital manufacturing technology. The components of digital manufacture technology include digital data, automation, connectivity and digital customer access (Greenstein, Goldfarb, Tucker, 2013). Digitization more and more differentiates the companies and classifies them into winners and the defeated. Its limitation mainly to sales and marketing will not assure the permanent competition advantage because the borders of competition are changing and disappearing; it will be held within the frames of new arising ecosystems. The studies of McKinsey, as conducted among the world companies indicate that the average level of their digitization is equal to 37%. The truly digitized business models are found sector of media, e-commerce and in the high-tech area. About 49% of the companies implement digitalized strategies of sales and marketing. Digitization includes also products and services (21%) (Pierieguid, 2015). There is no Industry 4.0 without Internet of Things (IoT). Internet has become a basis for information revolution, enabling creation of new forms of communication. IoT in industry 4.0 cannot function without Big data and Analytic Data (Ashton, 2009; Barciński, 2016, 2016; Chui, Lőffler, Roberts, 2010, pp. 1-9).

Owing to the development of Internet, the cyber-space is being created that combines people and equipment (Wellman, 2001, pp.227-252). More than three quarters inhabitants of Poland have an access to Internet and a decisive majority uses it regularly. It is followed from the report "Information population in Poland in 2018, published by the Main Statistical Bureau (GUS). About 77.5% of persons in Poland used Internet in 2018 (by 1.6% increase as compared to 2017). The percentage of households, equipped with computers was also increased. In 2018, it amounted to 82.7% (by 0.9% more than in 2017). Almost 96% of the companies in Poland have an access to Internet. There is increased the number of the companies using mobile links (67.6%), cloud services (11.5%), e-commerce (33.6%), e-administration (71.3%) and social media (30.3%) (The Main Statistical Bureau, GUS, Report "Information Population in Poland in 2018).

The mentioned three directions, i.e. automation, robotics, digitalization of IT technology and access to Internet have been recognized by the authors as the initiating/basic for the development of Industry 4.0. The mentioned directions were initiated as early as in the second half of the previous century and are continued and their further development contributes to introduction of the changes in manufacture of the products and logistics at the level 4.0.

In turn, the key direction of the changes without which there is no Industry 4.0, includes creation of new systems of manufacturing lines. First, the new solutions include the devices, furnished with sensors. The sensors, as being installed in the devices of the manufacturing line, transmit information to a computer network that links the equipment and people (M2M, P2M, and P2P). The data from the computer network are transmitted to the system of data collecting and processing. The systems of processing supply the data for decisional analysis. The mentioned equipment is controlled by the systems with the utilization of feedback information what facilitates the successive (better) production via introduction of the changes. The scheme of a new manufacturing system is given in fig.1.

The highest form of development of manufacturing systems includes building of cyber-physical systems (CPS). CPS means integration of computing and physical processes (Lee, 2006). CPS is integration of computation, networking and physical processes (Tőrngren, 2016 a). In the descriptions of CPS we can distinguish some key words: integrate physical, embedded, networking, IT systems, IoT, Industry 4.0 etc. (Tőrngren, 2015; Wang et al, 2015; Lee, Bagheri, Kao, 2015). CPS are embedded computers and networks which monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. On a more technical level CPS is embedded computational systems equipped with network capabilities (Lee, Seshia, 2015; Wang et al., 2015). Embedded systems are major drivers of innovation for current high-tech products. CPS are part of a globally connected world where products, devices and objects interact beyond classical application boundaries and form the internet of things, data and services (Lee, 2006). CPS is integration of computational with physical processes. The system consists of (Lee et al., 2015):

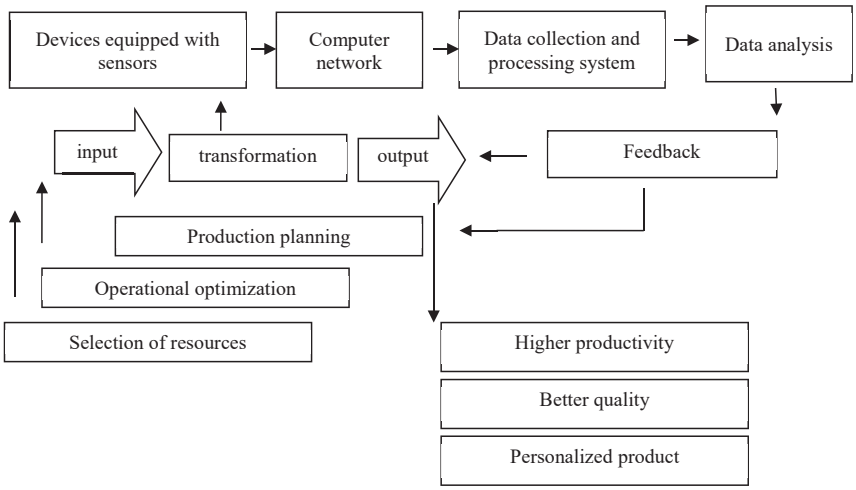


Fig.1. Scheme of production in Industry 4.0
Source: own development

1. Smart Connection
2. Data-to-information Conversion
3. Cyber
4. Cognition
5. Configuration.

In the mentioned above systems, a customer has a significant meaning; if he needs anything, he takes a mobile device. In the USA, we speak already about mobile-first what means that in various situations, when we need information about service or product; we take a mobile device that we have

at reach of hand. When using mobile devices, the people order products or services which concern strictly the specified person. The products are therefore personalized (customization).

The successive trend in development of Industry 4.0 is investing in manufacture of the products the properties of which meet the individual needs of the customers. The client uses IoT. A strong competition and growing expectations of the clients on the contemporary market cause that together with the increase of production effectiveness, the customization of the product takes place; it is manufacture of the products when the client decides on the product. At the same time, the price of the product should be approximate to the price of the products, manufactured in mass production. Such possibilities are guaranteed by the conception of Industry 4.0 that assumes building of completely integrated system of suppliers,, producers and customers, creating cyber-physical systems that are capable of implementing many functions and activities, imposed by production, logistics and management. In consequence, the chain of supplies becomes more elastic and production is more effective and quicker. Production on demand changes also storage and logistics. Owing to printers 3D the warehouses are more and more personalized (Bauerhansl, Hompel, Vogel-Henser, 2014; Gracel, 2017).

Industry 4.0 is not limited only to the mentioned changes because its essence consists in permanent adaptation to new external conditions and internal possibilities. A final direction of changes includes smart production that creates a new value for customer (Blaik, 2018; Kaliczyńska, Dąbek, 2015, pp. 51-63).

General information on the direction of changes in logistics

The process of control of equipment via access to Internet exceeds the production and includes also transportation means, systems of ordering, storehouses (Wang, 2016, pp. 259-268). Logistics, as introduced within the frames of Industry 4.0, is implemented using the newest solutions of communication in cyber-physical systems. In logistics 4.0, we introduce digitization of all possible operations of transmitting the products from point A to point B (Bauernhansl et al., 2014). In logistics 4.0, we assume greater (than until now) adaptation of operations according to the expectations of the customer via creation of new values and their higher utility for the customer. The mentioned client is a creator or the products (personalization) as well as of specification of logistic service (he chooses the parameters of logistic process according to his needs) (Blaik, 2018). His meticulous (detailed) decisions are implemented by logistic companies which cooperate mutually in a greater degree than before (the process of sharing the information) in the process of supply of a product to a customer – Quick Response Logistics – QRL). The Quick systems use IT technology, bar code of the products and cash registers with laser readers. The systems of quick reaction reduce the time of operations, facilitate the reduction of reserves in the whole system and have a favourable effect on meeting the requirements of the customers (Welman, 2001, pp. 227 – 252).

General information on the direction of changes in organization and management

The changes resulting from the requirements of Industry 4.0 impose restructuring or even creation a new business models in certain areas of management. In the future business realities, what was earlier the domain of many market participants, it will be offered within one application by one player. The tendencies will be shaped deeply by the expectations and experiences of the customers, creating the potential of transforming almost every sector, as least within the frames of B2C area. In consequence, during the few coming years, the companies will be forced to specify their strategies and business models in a completely different way – not only in relation to traditional market competitors but to the consume, being in statu nascendi.

The adaptation of the enterprises to Industry 4.0 requires considerable investments on automation, robotics and digitization which allow employing more intelligent communication technologies in the future and also developing innovatory models of business, considering new strategies of business, innovatory vision and mission of the enterprise, new culture of work, being oriented to teal organization, new systems of management of staff and, also, organizational structures, considering the necessity of on-line work (realities of virtual organization) (Gajdzik, Grabowska, 2018).

The creators of innovative business models in Industry 4.0 are not afraid of questioning the adopted way of thinking and introduce new solutions for a new group of customers (e.g. colour-changing material for clothes), via a new channels of sales and form of deliveries (e.g. autonomic vehicles), new way of establishing the prices or a source of incomes (e.g. apart from sale of coffee, Tchibo company generates the revenues coming from the sales of utility products).

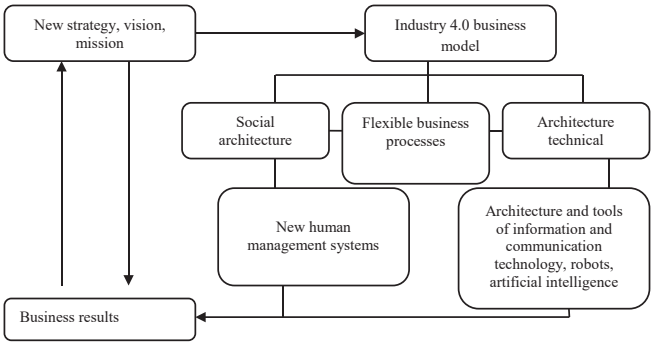
If we want to create a conception of business model of the enterprises functioning in the age of Industry 4.0, we have to begin with two basic assumptions (Prahalad, Krishnan, 2010);

- Value is personalized, that is, specified by the experience, acquired at a given time by a single consumer (the phenomenon will be called N=1 where N is a number of customers) who initiates the process of production and participates in designing of the product (customization). The product, as offered by the company is a proposal for a customer who participates in its modification and adopts it to his expectations and he gains also the satisfaction that he will receive the product which meets his expectations. Value is based upon the exceptional personalized experiences of the clients. The enterprises must concentrate on one customer. Irrespectively of the number of the customers, the attention is focused on the central position of the unit. Owing to orientation as to the needs of the individual client, it is possible to receive, in return, his ideas and conceptions, or directly materialized product. Such approach to the customer means treating him as active receiver and modifier of the product, i.e. pro-consumer what is the main assumption of the conception of Industry 4.0.
- The companies, serving the customers in the chain of values, are horizontally integrated (a wide range of cooperation of the entities) and cooperation between the participants is very flexible (on demand, as any company is not so big in respect of range and dimensions as to meet all expectations of individual consumer in a given time). The resources are a limitation, or rather the access to the resources in a given time (most frequently, in relatively short time e.g. implementation of order up to 24h or shorter). In the supply chain it is adopted that the resources will be taken from different suppliers and the access will be global (the mentioned trend will be marked as R=G where R means resources and G is Global) and production of the products, services and competencies have a multi-institutional nature. All enterprises have an access to global ecosystem covering also the resources. The enterprises seek for access to the resources and not only focus on their possession (the resources are global from many suppliers, often

from any place in the world) (Salvesen, 2014; Szymańska et al., 2017, pp. 299 – 310; Kadłubek, 2010, pp.55-60).

Business model is a configuration of business processes, which combine and develop the resources, shaped in a form of social and technical architecture of the enterprise (a simplified system of such model is given in Fig.2).

Fig.2. Structure of business model construction, being consistent with the requirement of Industry 4.0



Source: own development

In the area of management systems, the changes in business models and business processes play a significant role. The new business conceptions are reflected in specified model, constituting a strategic and operational basis for change in configuration of products and processes in the enterprise, enabling competing on the market, being determined by the rules of the conception of Industry 4.0. a significant value of the new models will include their treating of their structure as a construction based upon the superior values such as innovativeness and effectiveness which are reached by the appropriately selected and combined model elements in smart system. The utilization of innovations which radically change a strategy of the enterprise facilitates generation of a new market space – formula of success allowing certain "omission" of the s-far existing system of competition via creation of a network of new values.

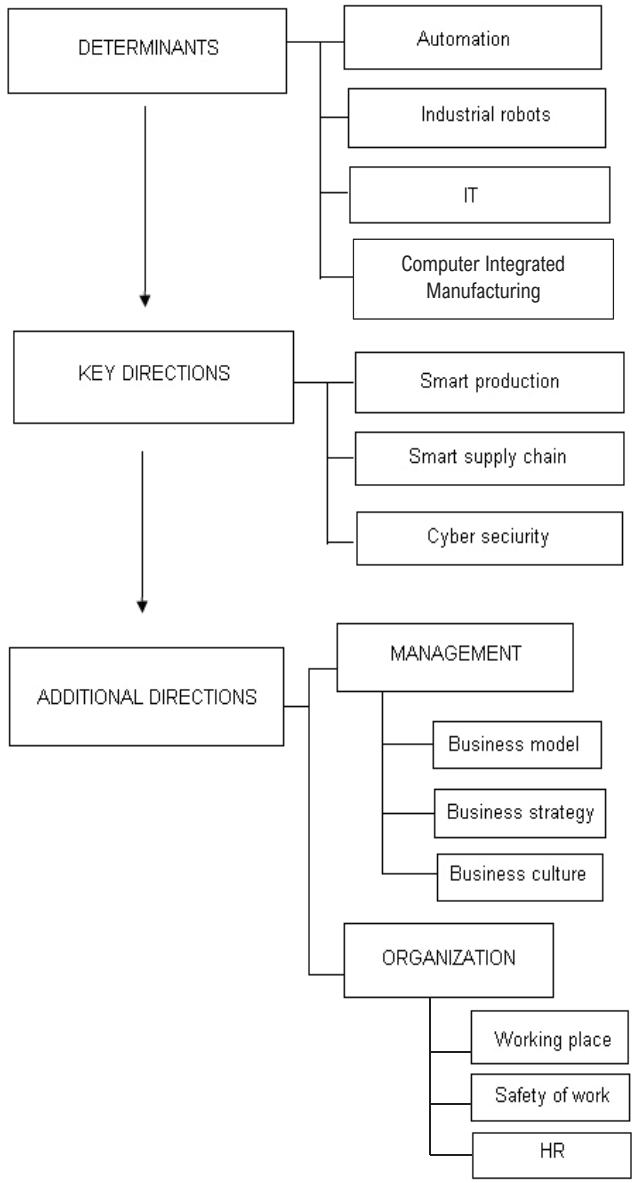
The emerging transformation of business from the conception of Industry 4.0 is based on the tendencies that cannot be reversed. The activity of the consumers, universal communication ability, convergence of technology and professional sectors, globalization of markets and global searches for resources and global access to these resources are the tendencies which are not subjected to control of any single company – hence, it is so important to create a networks of cooperation. They lead unavoidably to the world that has been described as N=1 and R=G, sharing economy, tech-life harmony, i.e. the models following the development of Industry 4.0.

The Industry 4.0 requires form the enterprises to create a new strategy, mission and vision of development. The companies are forced to construct the new organizational structures, being oriented to generation of virtual organization, working on-line, with the employees who learn constantly in a form of e-learning (Grabowska, 2018). A new culture of work is being created and consequently, the new systems of management of human resources. The changes concern also the traditional forms of management in favour of flexible process management. The problems connected with cyber-safety within the frames of social and technical architecture of the enterprise are also important.

Directions of the changes of the enterprises in industry 4.0 - summing up

Technological changes have acquired a strategic meaning in thinking and activities of many market entities, penetrating at the same time all links of the chain of values and the ways of their linking what has changed a range of competition and the way of satisfying the needs of the purchaser. Technical revolution has extended the borders of all this, what they may supply to the customers in a form of values. In the contemporary, strongly competitive manufacturing environment, the enterprises are faced against the challenge of dealing with a great amount of data, the necessity of undertaking quick decisions and implementation of flexibility of manufacturing processes (in aspect of maximally personalized products). The contemporary nature of production is shaped by the changes in paradigm from mass production into on demand production of a customer and more and more flexible control of the resources, engaged in the implementation of production (Gajdzik, 2018). The directions in the changes of the enterprises that adapt to the requirements of Industry 4.0, as discussed in the present article, are given in fig.3.

Fig.3. The explanatory scheme of the discussed directions of changes



Source: own development

Summing up

When summing up the directions of the changes of development in the idea of Industry 4.0, it should be mentioned that it is difficult to foresee how the conception of Industry 4.0 and the accompanying coming industrial revolution will be developing. We cannot be sure that the future reality will overlap the present forecasts. Together with the development of Industry 4.0, the new possibilities as well as threats for the entrepreneurs will appear. Construction of a new industry is not easy as it requires new resources of the enterprises. Formulation and adaptation to the changes is a long-lasting operation. The directions of evolution of the enterprises

to the Industry 4.0 as being presented in this publication should be treated as explanatory (in general).

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