LogForum

> Scientific Journal of Logistics <

2017, 13 (4), 401-414

http://dx.doi.org/10.17270/J.LOG.2017.4.2

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

INDUSTRY 4.0 AND ITS IMPACT ON THE FUNCTIONING OF SUPPLY CHAINS

Natalia Szozda

Wroclaw University of Economics, Wrocław, **Poland**

ABSTRACT. **Background:** There is an increasing use of automation, data processing and exchange, cyber-physical systems, Internet of things and cloud technology in industry. Modern factories undergo constant transformation, which has impact not only on the organization of manufacturing activities, but also on the functioning of supply chains. The model of contact with the end customer, who frequently moves into the virtual world, is changing, which directly translates to the formation of distribution channels. The occurring changes are referred to as the Fourth Industrial Revolution, and we are its eyewitnesses. This paper explores the challenges for modern supply chains that arise as a result of the fourth industrial revolution. It attempts to answer the question to what extent the Industry 4.0 affects the organization of products and information flows in supply chains.

Methods: The article makes use of the results of social research, whereas the applied research technique was a survey conducted among 122 supply chains. Moreover, the results of the research performed in 2015 by McKinsey in the form of an interview with 300 experts from production and service companies from USA, Japan and Germany were demonstrated. Additionally, the following 5 case studies were presented: Logistics Knapp AG, Nova Chemicals, BMW, Stratatys and Bosch.

Results: One of the research results of the article is a review of the literature on the development of the supply chain concept, as well as on the development of industry, with particular focus on the Fourth Industrial Revolution. The article attempts to determine the impact of the Fourth Industrial Revolution on the functioning of contemporary supply chains. On the basis of social research and case studies, conclusions are drawn about the significance of application of the assumptions of Industry 4.0, as well as about the concerns of companies and entire supply chains regarding the inevitable changes. Finally, a hypothetical supply chain using the assumptions of the Fourth Industrial Revolution is presented on the example of a manufacturer of electric toothbrushes.

Conclusions: On the basis of the collected examples and presented research, it can be concluded that the idea of Industry 4.0 is not foreign to contemporary companies and has an influence on the organization of physical and information flows in supply chains. Managers are aware of the changes occurring in the organization of production, procurement and distribution processes in the entire supply chains. However, they are concerned about transferring processes into the virtual world, due to data security issues and capacity of long-distance wireless networks.

Key words: supply chain, Industry 4.0., Internet of Things (IoT), cloud technology.

INTRODUCTION

The last five years have involved further revolutionary changes in industry, referred to as 'the Fourth Industrial Revolution' - Industry 4.0. Everywhere people are connected together in social media, and this is transferred to the field of industry, where machines, items and employees get linked into a network in virtual reality by means of IoT (Internet of Things) technology. Communication between machines and their users will be disseminated using digital connections in the real time. Production processes will be available and managed in virtual space, whereas ICT (Information and Communication Technology) will dominate future business models.

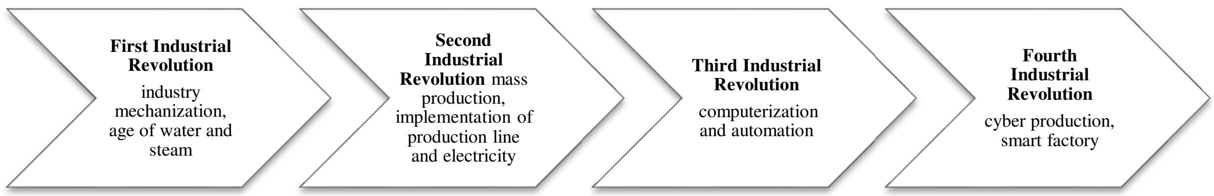
Citation: *Szozda N., 2017. Industry 4.0 and its impact on the functioning of supply chains. LogForum 13 (4), 401-414, http://dx.doi.org/10.17270/J.LOG.2017.4.2*

Received: 31.03.2017, Accepted: 23.08.2017, on-line: 29.09.2017.

The Fourth Industrial Revolution is associated mainly with factories; however, it is a far broader notion, referring also to other areas of organization activities, e.g. global supply chain management. This concept goes beyond a single company and is carried over to a network of links between organizations where data are integrated in a cloud and processes are organized along a supply chain in virtual space.

INDUSTRY 4.0.

The industry has been developing on an ongoing basis since the ancient times. The biggest industrial revolution took place in the 18th century and was related to the transition from the economy based on agriculture, manufacturing and handmade production to mechanical large-scale factory production. The 19th century was the age of steam and electricity, referred to as the Second Industrial Revolution. The other years of intense development was the period after the Second World War which continues until nowadays, with scientific and technical development taking place. The most important elements of the Third Industrial Revolution include computerization, use of new energy sources, automation of work processes, as well as improvement of means of telecommunication and transport (Freeman, Louçã 2001). One of the most significant changes in factories in the post-war period was the implementation of MRP (Material Requirements Planning) by the team of Joseph Orlicky [Bayraktar et al. 2007, Mabert 2007], as well as the so-called Lean Manufacturing, initiated by Taiichi Ohno and Eiji Toyoda in Toyota automotive plants [Ohno 1995, Hadyś, Stachowiak, Cyplik 2014]. Industry 4.0., which was started in Germany in 2011, is another milestone in industry [Pfohl, Yahsi, Kurnaz 2015]. This notion comes from a government project intended to promote computerization of manufacturing processes. In October 2012, a working group managed by Siegfried Dais from Robert Bosch GmbH provided the federal government with a list of recommendations concerning the concept implementation, and on 8 April 2013 the group presented the final report. Industry 4.0. stems from the concept of smart factory, involving the electronic flow of production processes [Hermann, Pentek, Otto 2015]. This means that centrally controlled devices communicate using the operating principle of social media [Radziwon et al. 2014]. Machines and production materials organize production on their own, beyond the borders of a company, or even countries, in order to ensure its optimum operation. [Pfohl, Yahsi, Kurnaz 2015].



Source: own study

Fig. 1. Industrial revolutions - historical overview
Rys. 1. Rewolucje przemysłowe – przegląd historyczny

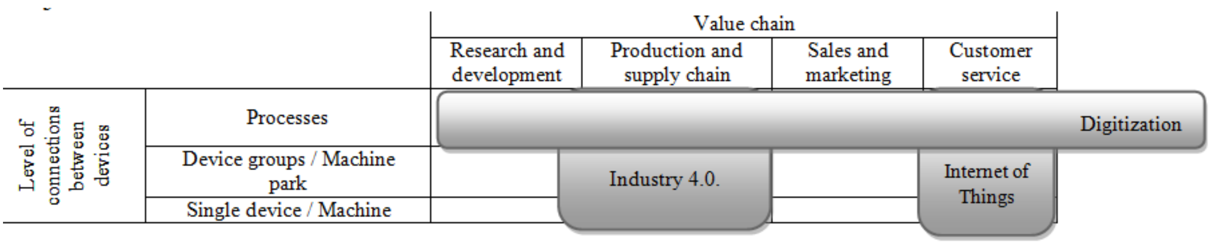
Factory 4.0 covers three possible archetypes [Industry 4.0. How to navigate digitization 2015]. The first one is a fully automated company, in which cost efficiency is most significant. This solution is applied for mass products with a limited number of product groups. The second model is mass personalization of production. The functioning of such companies is based on meeting individual needs of customers, production is carried out in small batches, whereas products are highly individualized and delivered for particular customer orders. There is a very high variety of products. The third archetype are the so-called e-factories, focused both on individualization and remote operations. These companies operate on a small scale, producing limited amounts of products. They are oriented towards low investment expenditure in order to maintain cost competitiveness.

However Industry 4.0 does not only refer to changes in factories but also in distribution and procurement. General Electric emphasizes the role of the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes [Drath, Horch 2014]. According to Pfohl, Yahsi, Kurnaz [2015], Industry 4.0 can be considered on the process, technology or management level in the whole supply chain and is defined as the sum of all disruptive innovations derived and implemented in a value chain to address the trends of digitalization, autonomization, transparency, mobility, modularization, network-collaboration and socializing of products and processes. Industry 4.0 is a collective term for technologies and concepts of value chain organization [Herman, Pentek and Otto 2015]. Based on the literature research, conducted by Herman, Pentek and Otto [2015], the most important are: Cyber-Physical Systems (CPS), Internet of Things, Smart Factory and Internet Service. However, Industry 4.0 is something more, Pfohl, Yahsi, Kurnaz [2015] distinguish more than 60 technologies related to this concept. All of them can be divided into the following four groups [Lee, Kao, Yang 2014]: (1) data and connection, (2) analytics and artificial intelligence, (3) human-machine interactions [Chen, Wan, Li 2012], (4) automated machine park. The description of these groups is presented in Table 1.

Table 1. Technologies used in Industry 4.0.
Tabela 1. Technologie stosowane w Industry 4.0.

Technologies in Industry 4.0.	Components and benefits
Data and connection	Large databases (*big data*) - data storage, processing and calculations Internet of Things (*IoT*) and communication between machines (*Machine to Machine*) - connection and transfer of information / data Cloud technologies (*cloud technology*) - centralization of data storage and virtualization of storage
Analytics and artificial intelligence	Digitization and automation of work based on knowledge - use of artificial intelligence and machine learning Advanced analytics - improved algorithms and data availability, implementation of advanced data mining systems used mainly for predictions
Human Machine Interaction	Touch interfaces and new GUI interfaces - possibility of quick communication using portable devices Virtual reality - use of optics, including augmented reality glasses, in industry, e.g. in a warehouse
Automated machine park	New production opportunities, e.g. using 3D printers - extended range of materials, increased precision / quality, possibility to obtain spare parts or raw materials immediately Advanced robotics - use of artificial intelligence, full automation of production, use of M2M technology Energy storage - production and storage of energy by performing daily activities in companies

Source: Lee, Kao, Yang 2014, Pfohl, Yahsi, Kurnaz 2015; Yu, Nguyen, Chen 2016



Source: own study based on [Shrouf, Ordieres, Miragliotta, 2014, Wortmann, Flüchter 2015; Castro, Jara, Skarmeta, 2012; Yu, Nguyen, Chen 2016]

Fig. 2. Industry 4.0. vs. Internet of Things
Rys. 2. Industry 4.0. vs. Internet rzeczy

One of the fastest developing technologies used in Industry 4.0 is IoT (Internet of Things). It is the indirect or direct ability of things and objects to store, process, share or exchange data using network connections [Shimizu, Hitt 2004, Yu, Nguyen, Chen 2016]. In contrast with Industry 4.0., Internet of Things is not focused on factory, and its application is visible particularly in the distribution area, mainly in customer service and use of objects.

Business models created using IoT technology are completely different from the traditional ones. They demonstrate departure from conventional linear oriented value streams to creating values within a network of units. This means that when defining business models, the focus is on the entire ecosystem, including a supply chain, rather than on a single company, so that all parties involved improve their processes in order to maximize benefits for the end customers. [Atzori, Iera, Morabito 2010]

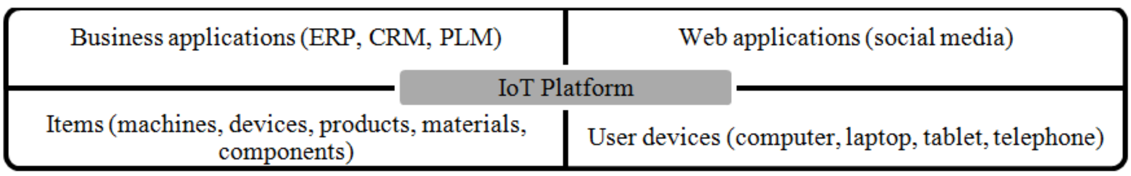
SUPPLY CHAIN - FROM LEAN MANUFACTURING TO VIRTUAL REALITY

From the moment when the supply chain concept was formed, both its meaning and the way of thinking about the concept has undergone significant transformation [Christopher, Holweg 2011]. The traditional approach to thinking about a supply chain refers to lean manufacturing concepts, in which supply chains are organized in accordance with the lean assumptions [Christopher, Towill 2000; Witkowski 2010]. Products in such chains are characterized by a long life cycle and long period of product delivery to market (lead time), relatively small variety, large amounts of sales and stable demand, to the extent possible; an example is Toyota, a global automotive manufacturer. Lean supply chains are intended to counteract operational risk and Forester effect, the so-called bullwhip effect [Lee, Padmanabahn, Whang 1997, Rutkowski 2005], which is recognized in the case when long-term forecasts which carry a large margin of error are used for planning [Christopher, Holweg 2011]. Solutions such as VMI (Vendor Managed Inventory) [Jaspersen, Skjott-Larsen 2005], or CPFR (Collaborative Planning, Forecasting and Replenishment) [Mendes 2011] are applied in them. The solutions applied in these chains are based on stream values in order to eliminate waste, particularly the waste of time [Potter, Towill and Christopher 2015]. A different approach is employed for the so-called innovative products [Fisher 1997], the attributes of which are an opposite of the above-described. The efficiency of action is replaced with flexibility or agility, and such chains are referred to as flexible or agile supply chains. According to Potter, Towill and Christopher [2015], such approach means being close to the customer and using knowledge gained from the market and virtual organization in order to operate successfully in a turbulent environment. An example of a company using this approach is Dell (American corporation operating in the IT industry), which is moving its entire supply chain organization into the virtual world [Christopher, Holweg 2011], or Zara (Spanish clothes manufacturer), which is capable of implementing a new product for sale within two weeks, including the design stage [Kaipia, Holmström 2007]. Christopher and Holweg [2011] referred to flexible supply chains as supply chains 2.0 and distinguished between two types of flexibility, namely dynamic and structural. The dynamic type consists in adjusting to customer needs with the use of own internal resources of a particular supply chain. The structural type means going beyond the existing structures and it concerns elements such as: (1) use of various supply sources, (2) sharing company resources, (3) distinction of base demand which is considered to be predictable, and maintenance of appropriate stock levels of materials and raw materials on the basis of the determined forecasts, (4) flexible employment adjusted to the company's needs, (5) production of small batches, (6) outsourcing.

However, contemporary supply chains are not divided into lean, flexible or agile. The concept of migratory supply chains is used [Potter, Towill and Christopher 2015], with the activity based on the strategy of production to customer orders (pull strategy) and it combines both agile and lean supply chain management. The customer initiates activities undertaken in a supply chain and creates its structure [Christopher, Towill 2000] by specifying how, when and where distribution of a selected product is supposed to take place. This results in gradual disappearance of the difference between physical and online supply chain [Potter, Towill and Christopher 2015] and new distribution channels originate; they are referred to as omnichannels [Brynjolfsson, Hu, Rahman 2013, Cummins, Peltier, Dixon 2016]. This notion comes from marketing and is related to the use of multiple channels and integrated communication. In omnichannel supply chains, distribution channels are used not only in vertical, but also horizontal direction, and the so-called crossing of existing connections between production and end customer takes place [Cummins, Peltier, Dixon 2016]. It is a combination of all possible sales channels into one coherent system, adjusted to the needs and habits of the purchaser. The focus is on the comfort and facility of shopping. Customers are not attached to a particular retail outlet, on the contrary, they select the convenient location for shopping. This leads manufacturers and distributors to using various distribution channels, however, they cannot have an impact on the experience of the customer, which is supposed to be uniform, regardless of the selected manner of delivery. [Brdulak 2016].

Industry 4.0 in global supply chain management moves traditional relations between supply chain links to a network of connections in which data are aggregated in disseminated servers. This is process organization, starting from extraction, through production, ending with sales, in virtual space. Customer orders are automatically completed upon receiving an order from the purchaser. On the other hand, the warehouse knows the time and amount of goods to be delivered, so that there were enough products in stock. Industry 4.0. in supply chains is supported by technologies such as automatic identification of cargo - AutoID, including in particular RFID, which enables to trace a product at every flow location [Whang 2009]. Each collection of a product from a store shelf, or bookcase in the warehouse, is recorded in the system, and next stored in the cloud, which provides all supply chain links with access to this information. If stock levels are close to critical values, the devices send relevant information and the supply is launched. Thanks to this type of solutions, stock management is moved into the virtual world, which prevents the shortage of materials, raw materials and products.

Communication is an important aspect in establishing connections between the links of a supply chain operating on the basis of the principles of the Fourth Industrial Revolution [Rogers, Clark 2016]. The attributes such as information delivery time, flexibility in determining the location of message sent, control of the source of message formation, information owner, as well as type and character of the message are significant [Cummins, Peltier and Dixon 2016]. Proper communication management is possible thanks to the implementation of IoT communication platforms.



Source: own study based on [Wortmann , Flüchter 2015; Castro, Jara, Skarmeta, 2012]

Fig. 3. IoT platform
Rys. 3. Platforma IoT

Platforms of this kind allow to control infrastructure and costs of its maintenance, as well to ensure proper scalability. IoT devices obtain digital representation similar to profiles on social network services. Any data gathered by the connected devices are collected on a particular profile. A platform is capable of communicating with solutions of various manufacturers and other links in a particular supply chain, using IoT protocols and allowing for integration of devices. It also enables two-way communication - not only are advanced IoT solutions capable of transmitting data, but also of receiving instructions, information and necessary support.

RESEARCH DESCRIPTION AND METHODOLOGY

Multiple questions arise on the basis of the above assumptions, including: To what extent does the Fourth Industrial Revolution have an impact on the functioning of contemporary supply chains? Do these supply chains apply Industry 4.0 solutions in their structures? What will supply chains look like in the future?

In order to address these questions, the research conducted by the consulting company McKinsey, as well as the results of social research conducted among 122 supply chains will be presented in the further part of the article . Moreover, the concept of supply chain operating in line with the assumptions of the Fourth Industrial Revolution, as well as the real examples of application of the Fourth Industrial Revolution in contemporary supply chains, will be presented.

SOCIAL RESEARCH

McKinsey [Industry 4.0. How to navigate digitization 2015] conducted research in 2015, based on interviews with more than 300 experts working in production and service companies in USA, Japan and Germany, operating in the following industries: automotive, chemical, consumer goods, health care, software, transport and logistics, industrial devices, industrial automation and semi-conductors. The purpose of the research was to obtain expert opinions regarding Industry 4.0 and the impact which, in their opinion, this revolution will have on the functioning of supply chains in the future, as well as to determine the related opportunities and risks. According to the experts, the Fourth Industrial Revolution will increase income by 23% and efficiency by 26%. It will also have an impact on reducing the lead time for delivery of products in the market, as well as on improving the quality of products and services, and on reducing labor costs. 80% of companies expect the Fourth Industrial Revolution to have an impact on their business models. Companies are not feeling confident in the new environment yet. Only 48% of manufacturers consider themselves to be well prepared for the implementation of new technologies. The most confident are Americans - 83%, followed by Germans - 57%, whereas only 37% of Japanese companies are ready to implement changes in accordance with the assumptions of Industry 4.0. The companies expect that the following technologies will be leading during the Fourth Industrial Revolution: cloud technologies, large databases, work automation and touch interfaces. Advanced analytics is less important. For the surveyed experts, the biggest obstacles in the implementation of the Fourth Industrial Revolution are as follows: process control, data security, uniform standard for data transmission, connection of all process participants by means of wireless networks. As can be noticed, the concerns are mostly related to data sending. This has been confirmed by the results obtained from the research. Only 19% of American companies, 14% of German companies and 12% of Japanese companies are willing to locate their servers outside the territory of their country and allow external companies to manage their data. This will most likely be the biggest obstacle in the implementation of the assumptions of Industry 4.0.

In order to check what solutions in the field of Industry 4.0 are applied in contemporary supply chains, the following part of article will present the result of the research based on primary sources. Survey data obtained from 122 supply chains were used for the analysis. The applied research process is descriptive in nature. Due to the fact that research sample selection was non-probabilistic and only the organizations that gave their consent took part in the research, statistical deduction was not applied for the interpretation of results, whereas the results of empirical data analysis were formulated very carefully, rather in the form of noticeable tendencies than certain and representative conclusions. The obtained results demonstrate that a part of the examined supply chains apply solutions related to the Fourth Industrial Revolution. 47% of examined supply chains have information systems which allow for precise monitoring of all operations along the entire supply chain. These solutions are particularly common for fast-moving consumer goods (FMCG), and thanks to their application companies have current data concerning the status of deliveries, stocks of finished goods, infrastructure and employees. 35% of examined supply chains have efficiently applied Collaborative Planning, Forecasting and Replenishment (CPFR) programs, whereas 39% of them use Business Intelligence solutions, executed e.g. by means of data warehouses which allow to transform data into information and information into knowledge. The pull concept has been applied by 61% of research participants, mainly automotive industry organizations. As many as 75% of examined supply chains allow for purchase of finished products online, and the leader in this field is the clothing industry, in which 95% of examined supply chains offer this type of solution. However, the possibility of adjusting a product to individual customer order is possible only among 5% of examined organizations. A similar situation concerns the use of IoT platform and transfer of processes into virtual space - only 4% of examined supply chains have applied these solutions in their structures. With reference to production processes, they have not been moved into virtual space in any of the examined supply chains.

CASE STUDIES

In order to illustrate in which areas of modern supply chains the elements of the fourth industrial revolution are implemented, the article presents four case studies based on the examples of the following companies: Knapp Logistics AG, Nova Chemicals, BMW, Stratatys and Bosch.

Logistics Knapp AG [Jost, et al. 2017] has developed modern technology of completing in a warehouse based on Augmented Reality - KiSoft Vision15 in which hard paper copy was replaced with digital carriers. It is based on using glasses instead of paper or electronic carriers, in which an additional image (virtual reality) is imposed on the actual image. The additional information in the form of an image within a field of view allows an employee to locate products intended for loading more precisely, i.e. faster. Not only do glasses enable to find particular materials, but they also contain information regarding the manner of loading products onto the pallet. The program optimizes cargo, taking into consideration dangerous and fragile objects. The use of glasses releases the hands of a warehouse employee, and their work is more effective as a result. Additionally, the camera installed in the glasses is capable of scanning the product code, thanks to which stock levels are monitored in the real time and information about the location of objects is available at every stage of the flow. The main advantages of using this technology include time savings, less errors and reduced hours of completing process.

In the manufacturing company Nova Chemicals [Ottewell 2013], there was a problem with repair and maintenance of the machine park in 11 factories of chemical substances and plastics around the world. Over the course of one year, more than 20,000 downtimes were identified, caused by necessary repairs or maintenance of devices. Due to the above, the company has implemented a device (SAP EAM software) in the field of analytics and cloud technology which monitors devices, checks and determines the schedule of necessary repairs and maintenance in such manner that the downtimes caused by excluding a particular machine from production should be the least intrusive (time and cost consuming) for the manufacturer. The process participants may get access to information concerning the downtimes of a particular machine at any moment. As a result of implementing this software, the following benefits were observed: the number of unplanned equipment downtimes was significantly reduced, time spent on sudden failures was reduced by 47%, time intended for preventive maintenance increased by 61% and observance of maintenance schedule increased by 22%.

One of the most automated factories in the automotive industry is BMW factory in Leipzig [Kochan 2006]. Robots are used there at every stage of production, both in the paint shop and during the assembly. The RFID implemented system enables tracing both the product and its particular components (materials and raw materials) at every stage of the flow. Employees are equipped with mobile tablets which are a control tool and provide access to all data in the real time. The management system is centralized, located in the main building and operates as the 'central nervous system'.

The Fourth Industrial Revolution is present on a relatively large scale at Bosch [Rüßmann, et al. 2015]. Integration between 11 factories and 5,000 machines takes place here, whereas all information is stored in the central database. There is full automation of the flow of materials and products in factories and warehouses, e.g. through the use of RFID technology. Moreover, there is a logistics support system implemented, which enables to obtain information in the real time. Another important change consists in the implementation of machine management system (tool management) which optimizes device operation. It ensures analysis and measurement of the functioning of the entire machine park in all factories in the real time, which allows for ongoing tracing of operation of a particular device, checking availability, failure frequency and occurrence of failures, e.g. excessively slow machine operation. This system enables machine repair, identifies the reason of defect occurrence and provides a ready solution for repairing a particular device. If it is not capable of identifying the defect, the issue is referred to an expert who solves it online. Having information about the machine park operation at all production links of a supply chain allows to determine production schedule in an optimum manner, without unnecessary downtimes and with the maximum use of available resources. In the event of problem occurrence, central management ensures flexibility of operation and possibility to find the best solution. The combination of business applications, i.e. ERP and CRM class systems, web applications and user devices, machines, products, materials and components into one system is possible thanks to the application of IoT communication platform. It covers elements such as platform design, data storage, formation of network of connections, as well as taking care of the security of data transmitted between objects [Shrouf, Ordieres, Miragliotta, 2014].

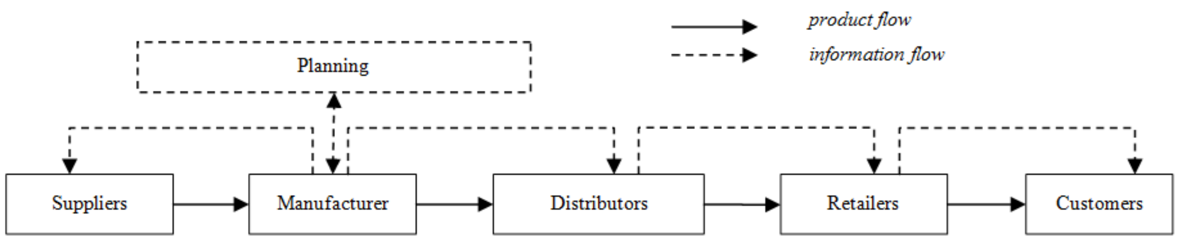
Another example of the application of the Fourth Industrial Revolution in a supply chain is the American company Stratasys [Rader 2016; Liaw, Guvendiren, 2017]. The company is working on a project of producing prostheses with the use of cloud technology and 3D printers. It is a medical project, expected to be completed in 2017. As of now, production of prosthesis means that the patient needs to wait for more than 8 weeks. This period is to be reduced to the duration of the project and prosthesis printout, which, according to the researchers, will take one day. Traditional production of prosthesis is a process consisting of five stages. First, the orthopedist with a technician take the measure and prepare a working model, usually made of plaster. Next, it is tried and adjusted to the patient. The completed model is used for manufacturing the mold form. The following stages include casting and the first fitting, which usually leads to further work on the prosthesis, i.e. manual cutting and sanding in order to adjust it to the patient. The new prosthesis production model uses the Industry 4.0 technology. During the first meeting, the measure is taken and processed by an IT system. It is there that the prosthesis design is formed, taking into consideration medical indications and the patient's stature. The completed design is printed on a 3D printer. Precision of the printout allows to develop a prosthesis which does not require any further adjustment. The product is then ready to be handed over to the patient.

Summarizing the above case studies, to which the fourth industrial revolution applies, it can be seen that the premise for the implementation of the changes is the desire to streamline processes, i.e. to make organizational changes, including the improvement of quality, reductions of time, greater flexibility, and cost reduction. These streamlines are implemented through the use of modern technologies in the area of the fourth industrial revolution, and are set out in Table 1.

They, in turn, constitute technological changes that improve processes and contribute to the introduction of organizational changes.

The above research results, as well as the presented case study prove that companies begin to introduce changes in their structures, and the Fourth Industrial Revolution has already started. However, these are changes in particular supply chain links and they do not concern the entire supply chain organization. Therefore, a question arises - what will be the functioning of a supply chain that uses the entire potential provided by the Fourth Industrial Revolution? In order to illustrate the occurring changes, below is presented an example of the supply chain of a manufacturer of electric toothbrushes producing in a traditional manner, as well as one using the assumptions of the Fourth Industrial Revolution [Dawid et al. 2017].

The traditional functioning model of a supply chain of a manufacturer of electric toothbrushes is based on mass production, the so-called production for stock, executed in line with the push concept. It consists in performing consecutive activities (design, production, sale) whose organization takes place on the basis of plans specified at the manufacturer, usually within the process of forecasting product sales.

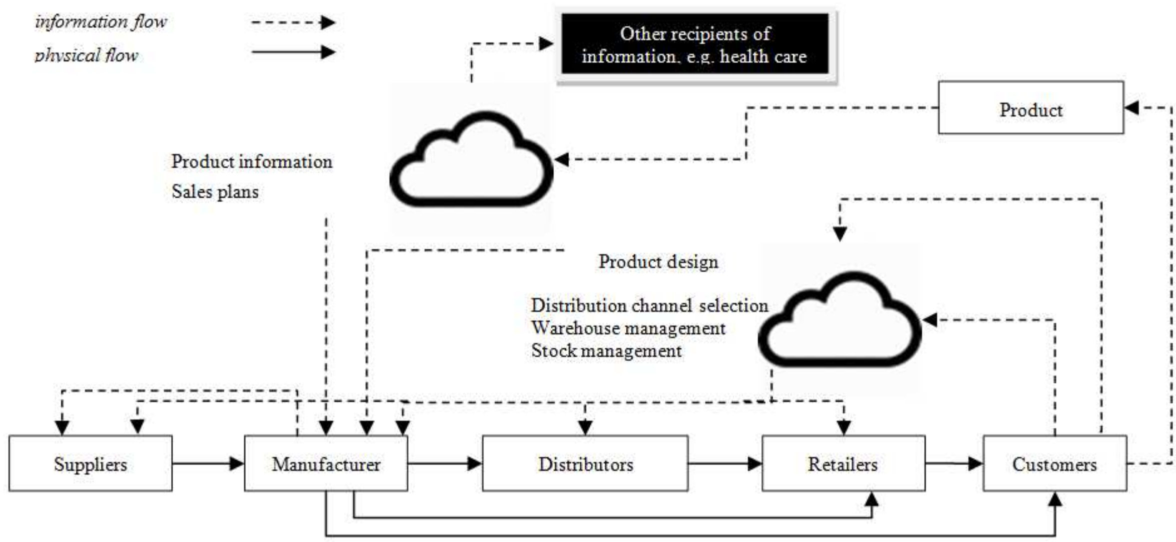


Source: own study

Fig. 4. Supply chain for electric toothbrushes for mass production
Rys. 4. Łańcuch dostaw produkcji masowej elektrycznych szczoteczek do zębów

In the new model, the planning process is transferred to the distribution area, whereas sales data are collected directly from end customers and finished products. This is a transition to pull model, i.e. organization of operations in a supply chain to a specific customer order. However, there is one difference in comparison with the traditional understanding of the pull concept. Data are gathered not only from retail outlets, but also directly from the products. Products provide information regarding customer behaviors, manner of toothbrush use, as well as wear and tear, repairs, etc. These data are valuable for the research and development department, which is capable of improving future product models on the basis of the collected information about the product. At the same time, demand forecasts are determined on the basis of customer behaviors. The manner of production is also changing. It is fully automated, whereas production processes are transferred into the so-called cloud where production is managed. However, it is possible to go one more step ahead. The data on customer behaviors can be made available to other entities, such as e.g. insurance companies or health care units. On this basis health insurance rates, as well as the reasons of problems with teeth, are determined. And this is not the end yet. Although electric toothbrushes are a mass product, it is possible to carry out 'mass personalization', which means that toothbrushes are manufactured on the basis of individualized customer needs concerning e.g. color, type of bristle or printout. Such solution has already been implemented e.g. by Nike. In certain retail outlets and online stores, it is possible to design your own shoes, the so-called Nike ID. The customer has the possibility to select the model outer surface and color of even up to eight footwear elements.

The application of the Fourth Industrial Revolution in a supply chain also includes development of distribution channels, the so-called omnichannel, which has already been referred to before. It is the toothbrush users who determine when and how they want a product to be delivered. It is important to meet their needs and provide uniform experience during the purchase, return or complaint related to the product, regardless of the applied distribution channel [Brdulak 2016].



Source: own study based on [Dawid et al. 2017].

Fig. 5. Supply chain for electric toothbrushes using the assumptions of Industry 4.0.
Rys. 5. Łańcuch dostaw dla elektrycznych szczoteczek do zębów przy użyciu założeń Industry 4.0.

CONCLUSIONS

Industry 4.0 is still an unexplored market, and its development directions are multi-branch. The business models of the functioning of supply chains are changing; the same is applicable for the end product, which is getting increasingly individualized and adjusted to the expectations and taste of the purchaser. Not only does it concern selected industries where products of high value are delivered, such as automotive industry, but the changes are also related to mass production, which is confirmed by the results of the conducted social research. Despite this, the use of available technologies is still not common, which has also been indicated by the research results. However, this is only the beginning of an upcoming industrial revolution, which is focused on communication between devices and aggregation of data obtained from devices in the databases where they are stored. This obviously creates numerous risks, related e.g. to data security and capacity of long-distance wireless networks. Therefore, construction of appropriate supply networks and distribution channels, as well as secure communication networks of large capacity, will become a future trend and significant element in the development of industry and supply chains.

ACKNOWLEDGEMENTS

The study was financed by the National Science Centre as a research project no. 2015/18/M/HS4/00388.

REFERENCES

Atzori, L., Iera, A., Morabito, G., 2010, The internet of things: A survey. Computer networks, 54(15), 2787-2805, http://dx.doi.org/10.1016/j.comnet.2010.05.010

Bayraktar E., Jothishankar M.C., Tatoglu E., Wu T., 2007, Evolution of operations management: past, present and future. Management Research News, 30(11), 843-871, http://dx.doi.org/10.1108/01409170710832278

Brdulak H., 2016, Rola handlu internetowego w budowaniu nowego modelu biznesu w łańcuchach dostaw [The role of internet commerce in building a new business model in the supply chains], materials from the conference „Budowanie łańcuchów dostaw jutra", 26-27.09.2016, publication on CD-ROM.

Brynjolfsson, E., Hu, Y.J. Rahman, M.S., 2013, Competing in the age of omnichannel retailing, MIT Sloan Management Review, 54(4), 23-29

Castro, M., Jara, A. J., Skarmeta, A. F., 2012, An analysis of M2M platforms: challenges and opportunities for the Internet of Things. In Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2012 Sixth International Conference on IEEE, 757-762, http://dx.doi.org/10.1109/IMIS.2012.184

Chen, M., Wan, J., Li, F., 2012, Machine-to-Machine Communications: Architectures,Standards and Applications. KSII Transactions on Internet and Information Systems, 6 (2), 480-495, http://dx.doi.org/10.3837/tiis.2012.02.002

Christopher M., Holweg M., 2011, Supply Chain 2.0: managing supply chains in the era of turbulence, International Journal of Physical Distribution & Logistics Management, 41(1), 63 – 82, http://dx.doi.org/10.1108/09600031111101439

Christopher M., Towill D.R., 2000, Marrying Lean and Agile Paradigms, Proceedings of EUROMA, Ghent Belgium, 114-121

Christopher M., Towill D.R., 2000, Supply Chain Migration from lean and functional to agile and customised, Supply Chain Management: An International Journal, 5(4), 206-213, http://dx.doi.org/10.1108/13598540010347334

Cummins S., Peltier J., Dixon A., 2016, Omni-channel research framework in the context of personal selling and sales management: a review and research extensions. Journal of Research in Interactive Marketing, 10(1), 2-16, http://dx.doi.org/10.1108/JRIM-12-2015-0094

Drath, R., Horch, A., 2014, Industrie 4.0: Hit or hype? [industry forum]. IEEE industrial electronics magazine, 8(2), 56-58, http://dx.doi.org/10.1109/MIE.2014.2312079

Dawid, H., Decker, R., Hermann, T., Jahnke, H., Klat, W., König, R., Stummer, C., 2017, Management science in the era of smart consumer products: challenges and research perspectives. Central European Journal of Operations Research, 25(1), 203-230, http://dx.doi.org/10.1007/s10100-016-0436-9

Fisher M.L., 1997, What is the Right Supply Chain for Your Product? Harvard Business Review, 75(2), 105-116, https://hbr.org/1997/03/what-is-the-right-supply-chain-for-your-product

Freeman Ch., Louçã F., 2001, As Time Goes By: From the Industrial Revolutions to the Information Revolution, Oxford University Press, NY USA, http://dx.doi.org/10.1093/0199251053.001.0001

Hadyś Ł., Stachowiak A., Cyplik P., 2014, Production-Logistic System In The Aspect of Strategies for Production Planning and Control and for Logistic Customer Service, LogForum, 10 (3), 331-349, http://www.logforum.net/pdf/10_3_9_14.pdf

Hermann, M., Pentek, T., Otto, B., 2016, Design principles for industrie 4.0 scenarios. In System Sciences (HICSS), 2016 49th Hawaii International Conference, IEEE, 3928-3937, http://dx.doi.org/10.1109/HICSS.2016.488

Industry 4.0. How to navigate digitization of the manufacturing sector, 2015, Raport of McKinsey&Company,

https://www.mckinsey.de/files/mck_industry_40_report.pdf

Jaspersen B.D., Skjott-Larsen T., 2005, Supply Chain Management – in Theory and Practice, Copenhagen Business School Press, Copenhagen Sweden

Jost, J., Kirks, T., Mättig, B., Sinsel, A., Trapp, T. U., 2017, Der Mensch in der Industrie–Innovative Unterstützung durch Augmented Reality. In Handbuch Industrie 4.0 Bd. 1, Springer Berlin, Heidelberg, 153-174, http://dx.doi.org/10.1007/978-3-662-45279-0

Liaw, C. Y., Guvendiren, M., 2017, Current and emerging applications of 3D printing in medicine. Biofabrication, 9(2), 024102, http://dx.doi.org/10.1088/1758-5090/aa7279

Kaipia, R., Holmström, J., 2007, Selecting the right planning approach for a product, Supply Chain Management: An International Journal, 12(3), 3-13, http://dx.doi.org/10.1108/13598540710724347

Kochan A., 2006, BMW innovates at new Leipzig assembly plant, Assembly Automation, 26(2), 111-114, http://dx.doi.org/10.1108/01445150610658086

Lee H., Padmanabhan P., Whang S., 1997, The bullwhip effect in supply chains, Sloan Management Review, Vol. 38, p. 93-102, http://sloanreview.mit.edu/article/the-bullwhip-effect-in-supply-chains/

Lee, J., Kao H., Yang S., 2014, Service innovation and smart analytics for Industry 4.0 and big data environment, Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems, 16, 3-8, http://dx.doi.org/10.1016/j.procir.2014.02.001

Mabert V.A., 2007, The Early road to material requirements planning. Journal of Operations Management. 25(2), 346-356, http://dx.doi.org/10.1016/j.jom.2006.04.002

Mendes P., 2011, Demand Driven Supply Chain. A Structured and Practical Roadmap to Increase Profitability, Springer, Berlin

Ohno T., 1995, Toyota Production System: Beyond Large-scale Production, Productivity Press Inc.

Ottewell, S., 2013, Maintenance Gets a Makeover, Chemical Processing, http://www.chemicalprocessing.com/articles/2013/maintenance-gets-a-makeover/

Pfohl H.Ch., Yahsi B., Kurnaz T., The impact of Industry 4.0 on the supply chain, Proceedins of the Hamburg International Conference of Logistics (HICL) 2015, 29-58, https://hicl.org/publications/2015/20/31.pdf

Potter A., Towill D.R., Christopher M., 2015, Evolution of the migratory supply chain model, Supply Chain Management: An International Journal, 20(6), 603-612, http://dx.doi.org/10.1108/SCM-06-2015-0231

Rader S., 2016, Transforming Orthotics with 3D Printing and Industry 4.0, http://blog.stratasys.com/2016/02/25/3d-printed-orthotics/

Radziwon, A., Bilberg A., Bogers M., Madsen E.S., 2014, The Smart Factory: Exploring Adaptive and Flexible Manufacturing Solutions. Procedia Engineering, 69, 1184-1190, http://dx.doi.org/10.1016/j.proeng.2014.03.108

Rogers, B., Clark, L., 2016, CABS: A conceptual model for context-aware B2B sales applications, Journal of Research in Interactive Marketing, 10 (1), 40-66, http://dx.doi.org/10.1108/JRIM-03-2015-0023

Rutkowski K., 2005, Logistyka dystrybucji. Specyfika. Tendencje rozwojowe. Dobre praktyki. [Logistics in Distribution. The specificity. Development tendencies. Good practice. Warsaw School of Economics Publishing House SGH, Warsaw

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnisch, M., 2015, Industry 4.0: The future of productivity and growth in manufacturing industries. Boston Consulting Group, https://www.zvw.de/media.media.72e472fb-1698-4a15-8858-344351c8902f.original.pdf

Shimizu, K., Hitt, M.A., 2004, Strategic flexibility: Organizational preparedness to reverse ineffective strategic decisions, Academy of Management Executive, 18(4), 44-59, http://www.jstor.org/stable/4166123

Shrouf, F., Ordieres, J., Miragliotta, G., 2014, Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm, Industrial Engineering and Engineering Management (IEEM), 2014 IEEE International Conference on, 697-701, http://dx.doi.org/10.1109/IEEM.2014.7058728

Whang, S., 2009, Timing of RFID Adoption in a Supply Chain. Management Science, 56(2), 343-355, http://dx.doi.org/10.1287/mnsc.1090.1121

Witkowski J., 2010, Zarządzanie łańcuchem dostaw [Supply Chain Management], Polish Economic Publishing House PWE, Warsaw

Wortmann, F., Flüchter, K., 2015, Internet of things. Business & Information Systems Engineering, 57(3), 221-224, http://dx.doi.org/10.1007/s12599-015-0383-3

Yu X., Nguyen B., Chen Y., 2016, Internet of things capability and alliance: entrepreneurial orientation, market orientation and product and process innovation, Internet Research, 26(2), 402-434, http://dx.doi.org/10.1108/IntR-10-2014-0265

CZWARTA REWOLUCJA PRZEMYSŁOWA I JEJ WPŁYW NA FUNKCJONOWANIE WSPÓŁCZESNYCH ŁAŃCUCHÓW DOSTAW

STRESZCZENIE. **Wstęp:** W przemyśle ma miejsce coraz powszechniejsze wykorzystanie automatyzacji, przetwarzania i wymiany danych, systemów cyber-fizycznych, Internetu rzeczy i cloud technology. Nowoczesne fabryki ulegają ciągłej transformacji i wpływa to nie tylko na organizację działań wytwórczych, ale również na funkcjonowanie łańcuchów dostaw. Zmienia się model kontaktu z ostatecznym klientem, który często przenosi się w świat wirtualny, co bezpośrednio przekłada się na kształtowanie kanałów dystrybucji. Zachodzące zmiany nazwane są czwartą rewolucją przemysłową, a my jesteśmy jej naocznymi świadkami. W artykule tym przedłożone są wyzwania przed którymi stoją współczesne łańcuchy dostaw w wyniku czwartej rewolucji przemysłowej. Celem artykułu jest próba odpowiedzi na pytanie w jakim stopniu czwarta rewolucja przemysłowa wywiera wpływ na organizację przepływów fizycznych i informacji w łańcuchach dostaw.

Metody: W artykule wykorzystane są wyniki badania społecznego, a zastosowaną techniką badawczą jest ankieta przeprowadzona wśród 122 łańcuchów dostaw. Przedstawiono również wyniki badania przeprowadzonego w 2015 roku przez firmę McKinsey w formie wywiadu z 300-toma ekspertami z firm produkcyjnych i usługowych z USA, Japonii i Niemiec. Dodatkowo zaprezentowano 5 case studies: Logistics Knapp AG, Nova Chemicals, BMW, Stratatys oraz Bosch.

Rezultaty: Jednym z rezultatów badawczych artykułu jest przegląd literatury z obszaru rozwoju koncepcji łańcucha dostaw oraz rozwoju przemysłu, ze szczególnym uwzględnieniem czwartej rewolucji przemysłowej. W artykule podjęta jest próba określenia wpływu jaki czwarta rewolucja przemysłowa wywiera na funkcjonowanie współczesnych łańcuchów dostaw. Na bazie badań społecznych oraz case studies zostają wyciągnięte wnioski na temat istotności stosowania założeń Industry 4.0. oraz obaw przedsiębiorstw i całych łańcuchów dostaw dotyczących nieuniknonych zmian. Na koniec przedstawiony jest hipotetyczny łańcuch dostaw wykorzystujący założenia czwartej rewolucji przemysłowej na przykałdzie producenta elektrycznych szczoteczek do zębów.

Wnioski: Na bazie zgormadzonych przykładów i przedstawionych badań można stwierdzić, że pojęcie Industry 4.0. nie jest obce współczesnym przedsiębiorstwom i ma wpływ na organizację przepływów fizycznych i informacji w łańcuchach dostaw. Menedżerowie oni świadomi następujących zmian w organizacji procesów produckyjnych, w zaopatrzeniu i dystrybucji w całym łańcuchu dostaw. Obawiają się jednak przeniesienia procesów w świat wirtualny, ze względu na bezpieczeństwo danych oraz przepustowość sieci bezprzewodowych dalekiego zasięgu.

Słowa kluczowe: łańcuch dostaw, przemysł 4.0., Internet rzeczy (IoT), technologie w chmurze

DIE VIERTE INDUSTRIELLE REVOLUTION UND IHR EINFLUSS AUF DIE FUNKTIONSAUSÜBUNG MODERNER LIEFERKETTEN

ZUSAMMENFASSUNG. Einleitung: In der Industrie findet eine immer breitere Inanspruchnahme von Automatisierung, Datenverarbeitung und -austausch, Cyber-physischen Systemen, Internet der Dinge und Cloud Technology statt. Moderne Fertigungseinrichtungen unterliegen einer ständigen Transformation und dies beeinflusst nicht nur die Organisation von Erzeugungsaktivitäten, sondern auch die Funktionsausübung von Lieferketten. Es verändert sich das Modell der Berührung mit dem Endverbraucher, der sich oft in die virtuelle Welt versetzt, was unmittelbar die Ausgestaltung von Distributionskanälen mit beeinflusst. Die sich vollziehenden Veränderungen werden als die vierte industrielle Revolution bezeichnet, deren wir Augenzeugen sind. Im vorliegenden Artikel wurden die Herausforderungen, vor denen die modernen Lieferketten infolge der vierten industriellen Revolution stehen, unterbreitet. Das Ziel des Beitrags ist es, die Frage inwieweit die vierte industrielle Revolution die Organisation von Material- und Informationsflüssen innerhalb der Lieferketten beeinflusst, zu beantworten.

Methoden: Im Artikel wurden Ergebnisse einer sozialen Umfrage in Anspruch genommen, und die angewendete Untersuchungstechnik war die innerhalb von 122 Lieferketten durchgeführte Befragung. Es wurden dabei auch die Ergebnisse der Erforschung, die 2015 von der Firma McKinsey in Form eines mit 300 Experten aus Produktions-Dienstleistungsunternehmen aus den USA, Japan und Deutschland durchgeführten Interviews projiziert. Zusätzlich wurden 5 Fallstudien: Logistics Knapp AG, Nova Chemicals, BMW, Stratatys und Bosch dargestellt.

Ergebnisse: Eines der Forschungsergebnisse des Vorhabens ist die Literaturübersicht im Bereich Entwicklungskonzepte von Lieferketten und Industrieentwicklung mit besonderer Berücksichtigung der vierten industriellen Revolution. Es wurde dabei ein Versuch zwecks der Ermittlung von Beeinflussung der Funktionsausübung von modernen Lieferketten seitens der vierten industriellen Revolution unternommen. Anhand der sozialen Umfragen und Fallstudien wurden Schlussfolgerungen zur Relevanz der Inanspruchnahme der Industrie 4.0 und zu Befürchtungen seitens der Unternehmen und der ganzen Lieferketten hinsichtlich unvermeidbarer Veränderungen gezogen. Zum Schluss wurde eine hypothetische Lieferkette, die die Annahmen der vierten industriellen Revolution am Beispiel eines Produzenten von elektrischen Zahnbürsten in Anspruch nimmt, dargestellt.

Fazit: Aufgrund der angeführten Beispiele und projizierten Forschungsergebnisse kann man feststellen, dass der Begriff Industrie 4.0 den modernen Unternehmen nicht fremd vorkommt und die Organisation von Material- und Informationsflüssen innerhalb von Lieferketten weitgehend und positiv beeinflusst. Die Manager sind sich der sich vollziehenden Veränderungen in der Ausgestaltung von Produktionsprozessen, in der Versorgung und Verteilung innerhalb der ganzen Lieferkette bewusst. Wegen der Datensicherheit und der Kapazitäten von drahtlosen Netzwerken bei längeren Reichweiten befürchten sie jedoch die Versetzung der Prozesse in die virtuelle Welt.

Codewörter: Lieferkette, Industrie 4.0. Internet der Dinge, Cloud-Technologien

Natalia Szozda
Department of Logistics
Wroclaw University of Economics
Komandorska 118/120, 53-345 Wrocław, Poland
e-mail: natalia.szozda@ue.wroc.pl