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POTENTIAL DIRECTIONS FOR IMPROVING PRODUCTION PROCESSES IN INDUSTRY 4.0 CONDITIONS BASED ON A POLISH FURNITURE ENTERPRISE – A CASE STUDY

POTENCJALNE KIERUNKI DOSKONALENIA PROCESÓW PRODUKCJI W WARUNKACH INDUSTRY 4.0 NA PRZYKŁADZIE POLSKIEGO PRZEDSIĘBIORSTWA MEBLARSKIEGO – *CASE STUDY*

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Abstract: The aim of the article is to outline potential directions of changes in production processes in furniture manufacturing that may occur under the impact of Industry 4.0. The research methods used as part of the study include a critical literature review, and a case study of a selected company operating in the furniture manufacturing sector supplemented with a survey. The results obtained indicate the impact of Industry 4.0 on enterprises operating in this sector, which is visible in their efforts aimed at modernizing their production processes. A particularly important direction of the changes involves the implementation of integrated systems, processing data in real time, which allows for customizing the manufacturing while meeting the requirements of mass production. The results obtained broaden the knowledge of the application of 4.0 technologies in areas that involve the use of simple technologies,

including industries with low levels of innovation, i.e. in sectors traditionally not susceptible to revolutionary changes brought about by new production management technologies.

Keywords: production processes, process improvement, industry 4.0, furniture sector.

Streszczenie: Celem badań, których wyniki zamieszczono w tym artykule, jest wskazanie możliwych kierunków zmian w procesach produkcji w sektorze producentów mebli, które mogą zajść pod wpływem Industry 4.0. Metodami badawczymi wykorzystanymi w badaniach są: krytyczny przegląd literatury, studium przypadku wybranej firmy sektora producentów mebli uzupełnione o badanie ankietowe. Uzyskane wyniki wskazują na wpływ Industry 4.0 na przedsiębiorstwa z polskiego sektora produkcji mebli, który widoczny jest w dążeniu tych przedsiębiorstw do modernizacji procesów produkcji. Szczególnie istotnym kierunkiem zmian jest wprowadzanie systemów zintegrowanych przetwarzających dane w czasie rzeczywistym, które pozwalają na kastomizację produkcji przy jednoczesnym zachowaniu założenia masowości. Uzyskane wyniki poszerzą wiedzę w zakresie stosowania technologii 4.0 w obszarach prostych technologii i w sektorach o niskim poziomie innowacji, czyli w sektorach tradycyjnie niepodatnych na rewolucyjne zmiany wywoływane użyciem nowych technologii w zarządzaniu produkcją.

Słowa kluczowe: procesy produkcji, doskonalenie procesów, industry 4.0, sektor meblarski.

1. Introduction

The development of modern technologies has a cross-sectional impact on contemporary reality, bringing changes that lead to developing new ways of functioning of enterprises and entire societies. The Fourth Industrial Revolution has led to the modernization of manufacturing, and the used technologies have spread beyond the factory gates. There are sectors of the economy that are particularly open to the impact of Industry 4.0 solutions, for example the automotive sector, which has become a driver of the changes taking place in Germany. However, not all manufacturing sectors benefit equally from the assumptions of Industry 4.0. For traditional industries that play a major role on the local markets, the technology penetration rate is significantly lower, and enterprises operating in such industries are just starting a large scale modernization. Such an example is furniture manufacturing, which plays a significant role in Poland not only in terms of its share in GDP but also with respect to developing national intellectual capital, since, as one of the few industrial sectors, it has retained the overwhelming share of Polish investors after the country's economic transformation. Enterprises operating in this sector are currently undergoing numerous changes related to the implementation of ICT technologies, which will allow for achieving a level of mechanization similar to that observed in modern industrial sectors. The goal of the article is to outline potential directions for improving the processes employed by enterprises operating in the Polish furniture manufacturers sector that are taking place under the impact of Industry 4.0.

The aim of the research is in line with the trends related to improving production processes with the use of Industry 4.0 solutions (Cheng, Liu, Qiang, & Liu, 2016; Lee, Davari, Singh, & Pandhare, 2018; Ustundag & Cevikcan, 2017). Those studies largely focus on the description of advanced technological implementations, for example the autonomization of production, and to a small extent, cover the aspect of the basic changes taking place in enterprises implemented with low technological advancement.

The research methods include a critical review of the literature over the last twenty-five years, the case study method and a questionnaire survey.

The first part of the article defines the basic concepts related to the production processes and Industry 4.0. Next, the main factors (determinants) impacting on the modernization of production systems in Industry 4.0 conditions are outlined, followed by the description of Poland's furniture manufacturing sector as well as its role and the key developments are discussed. The main directions for improving production processes are pointed out using a case study of a Polish furniture manufacturer. The conclusions of the research conducted are discussed in the final part of the article.

2. Production processes – basic definitions and evolution

The production process is the basic concept that the research plan is designed around, which is an organized (ordered) and logical sequence of operations to be performed, as a result of which input materials are converted into final products. According to Kozłowski and Liwowski (2011), the production process is a set of developments and activities that gradually bring about changes in the workplace, ultimately creating the final product. The production processes can be divided based on the value added to the product they create (Table 1).

Table 1. Division of production processes

Process type	Process description	Criterion
1	2	3
Technological processes with a direct impact on the product	Technological processes directly affecting the product involve activities which result in a change in the composition, form, shape, dimensions and other physical or chemical properties of the product, in accordance with the agreed route	directly creating product value
Natural technological processes	Natural technological processes take place without human intervention, in natural conditions, e.g. (wood seasoning)	directly creating product value
Measurement and control processes	Measurement and control processes involve verifying the quality of the product at every stage of its production. Quality control includes: verification of the quality of the input material into the production process, control of the correctness of routes, control of employee qualifications, control of the efficiency of machines processing the product, quality control of product workmanship and control of manufacturing conditions	indirectly creating product value

Table 1. cont

1	2	3
Internal transportation processes	Internal transportation processes involve movement of cargo within a single enterprise	indirectly creating product value
External transportation processes	External transportation processes involve movement of cargo between the enterprise and its suppliers and customers	indirectly creating product value
Storage processes	Adequate storage of materials and ensuring sufficiently good conditions at the storage facility for as long as such materials are needed for some purpose. (delivery to the production area, shipment to the customer)	indirectly creating product value

Source: own study based on (Kozłowski & Liwowski, 2011).

The processes listed in Table 1 can take various forms, depending on the level of technological advancement of the given enterprise and the features (characteristics) of its operations. Technological changes taking place in the economic environment impact on the evolution of production processes. The economic transformation observed over a number of years, brought about by industrial revolutions, have led to a rise in the efficiency (productivity) of production processes, which in turn resulted in an increase in the supply of consumer goods (Greenwood, 1997). Table 2 presents the changing features of production processes following the successive industrial revolutions.

Table 2. Changes of the features of production processes following the individual Industrial Revolutions

Feature	Industry 1.0	Industry 2.0	Industry 3.0	Industry 4.0
Timing	after 1770	after 1837	after 1980	after 2011
Diversity of manufactured products	very high	very low	medium	very high
Productivity (efficiency)	very low	very high	high	high
Production type	handicraft production	mass production	mass production, personalized	individual unit, customized production, end-customer as a co-producer
Product unit price	high	low	medium	Low
Key technologies	mechanization, use of steam as a propulsion method	electricity, electric motors	IT (CNC, PLC)	autonomous robots, big data, simulations, integrated systems, internet of things, cyber security, cloud computing, virtual reality technologies, Cyber Production System

Source: own study based on (Greenwood, 1997; Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014).

Taking into account the data collected in Table 2, it can be observed that the time between the revolutions is getting shorter. The changes are faster and visible in the global context (Rahman, 2020). The period between the first industrial revolution, which dates back to the end of the 18th century, and the second one, which dates back to the end of the 19th century, is equal to the timeframe within which all others occurred. The scope of the changes introduced to the production processes, which impacted on their efficiency and quality, also expanded over time. In the case of the First Industrial Revolution, the most significant invention for the production processes was the steam engine designed by James Watt in 1764, and the first spinning factory was established in 1784. Steam engines were used as machine drives, replacing the propulsion that had used the power of human muscles. Machine control was enabled by the use of the cam mechanisms (Michalski, 2019). Thanks to the use of machines, production efficiency (productivity) was increased and transportation processes were improved by reducing the time and scope of transportation. As part of the next revolution, Industry 2.0, which dates back to the turn of the 19th and 20th centuries, discoveries in the field of electricity were made. That revolution introduced electric motors into manufacturing, replacing steam engines and ensuring several times higher efficiency (productivity) of the production processes. Punch cards were also used for the first time as a data carrier for storing information. The automotive industry was also growing fast during that time. Batch (series) production was designed and launched on the production (assembly) line (Wilson, 2014). Therefore, the Second Industrial Revolution contributed primarily to the optimization of production processes through automation, which led to an overall increase in production efficiency and volume, whereas the introduction of the production (assembly) line also solved the problem of the relatively low qualifications of the factory workforce and allowed for reducing the need for training with respect to the entire production process. A low-skilled worker, thanks to his/her specialization, was able to focus only on his/her job. The trend of deepening automation with the use of a new type of technology is continued as part of the next industrial revolution, Industry 3.0, in the 1970s. It is assumed that this revolution was triggered by the invention of programmable controllers (logic circuits), the invention which enabled the partial automation and robotization of production processes. Industrial robots were employed on the production (assembly) lines, while microcontrollers were used to control the machines. Thus, production could take place with limited human participation in the process. During the Third Industrial Revolution, the first IT systems were developed to support production planning and control (monitor) the correctness of its course (Greenwood, 1997). ICT (Information and Communication Technology) technologies supported the production management system, but also led to the modification of the logistics processes. Electronic channels were developed at that time, enabling placing orders via the Internet (online). This resulted in a shorter information flow, which allowed, for example, for aligning production volume with orders. Compared with the previous revolution, the third one sought

to reduce employee participation rather than create prospects for more employment, thus activities aimed at eliminating certain types of costs were initiated. This trend was continued as part of the Fourth Industrial Revolution that began in the first decade of the 21st century. Industry 4.0 is a concept that describes a set of technologies generating developments that contribute to cross-sectional changes taking place in the modern world. K. Schwab, in collaboration with the World Economic Forum, developed one of the first definitions of the term, according to which it is a set of technologies linking the physical, digital and biological worlds, affecting all disciplines, economies and industries. It should be emphasized that the essence of the cited definition are not the technologies themselves, but their linking and intertwining in such a way that the boundaries of the technological and real world become blurred. Industry 4.0 is the period of production digitization where machines, devices and interconnected systems function as part of a network of mutual links. During this period, the data transferred between machines, devices and the manufactured product began to be sent, collected (stored) and utilized. Advanced IT algorithms, capable of using artificial intelligence to analyze data and make decisions, are used to control machines (Wollschlaeger, Sauter, & Jasperneite, 2017). Data management and information processing have become some of the key optimization areas.

There are two information flow routes in the production area, supported by integrated IT systems. The first one is the vertical information flow taking place between material suppliers and the production system (machines), and the second is the horizontal information flow among the machines used to manufacture the given product. Such flows are performed with the use of Industry 4.0 technologies and systems, for example: Big Data, the Internet of Things, and the Cyber Production System (Lasi et al., 2014). A factory site, relatively separated from the outside world, has become a natural field for testing robots, drones and other solutions that do not require human participation. These conditions are difficult to achieve in another area of business operations, such as services, where people are the key element in the performance of tasks. Hence, manufacturing (production) has become an area under scrutiny and a precursor for changes driven by the impact of Industry 4.0 factors, later subjected to a detailed observation.

3. Determinants of the production process in Industry 4.0

The origin of the Industry 4.0 concept is related to the manufacturing industry. The concept has been developing fastest in those countries where manufacturing (production) is an important branch of the economy. Germany is the industrial leader in Europe, and it was in this country that the the Fourth Industrial Revolution was first introduced. This is related to the German government seeking to stimulate the competitiveness of industry, especially the automotive sector, through the implementation of new technologies and innovative solutions. The basis for taking

actions aimed at the development of Industry 4.0 in Germany was the conviction that this area would be characterized by a strong product customization in a highly flexible (large batch) production environment, which would translate into the development of the so-called hybrid products. In Industry 4.0, conditions production processes are characterized by the integration and cooperation of business partners in the processes of creating added value. Therefore, the fundamental goal is to move away from the concept of automated manufacturing to smart manufacturing. A number of different Industry 4.0 definitions have been developed in the literature on the subject of manufacturing. Kagermann pointed out that Industry 4.0 was carried out with the use of independent, interconnected machines and devices, capable of reacting to various external situations, equipped with sensors and spatially dispersed, as well as taking into account the planning and management systems in their operation. In Industry 4.0, the goal of production processes is to achieve the ability to flexibly control the manufacturing of products in such a way that they could be personalized, while maintaining relatively constant production costs, regardless of the production batch size (Zagajewski & Saniuk, 2018). Industry 4.0 manufacturing is associated with the digitalization and automation of processes, which is implemented in order to enable the exchange of information among products, the environment and business partners (Müller et al., 2018). In Industry 4.0, the production process is integrated, flexible, optimized, service-oriented and interoperable. It is characterized by the content of a large amount of data and the use of advanced technologies. The goal is to create the most efficient production system through the use of technological solutions (Lasi et al., 2014; Popkova, Ragulina, & Bogoviz, 2019; Ślusarczyk, 2018). The impact of Industry 4.0 technologies on production processes is described by Blunck and Werthmann. They list eight most important factors that help determine the degree of an enterprise's advancement (progress) in the context of implementing Industry 4.0. Table 3 shows factors specific to the use of 4.0 technologies.

Table 3. Factors defining areas where 4.0 tools and technology impact on production processes

Factor	Description
1	2
Information management	IoT and CPS technologies enable real-time management of production processes. The exchange of information among machines interconnected in the network and people enables reacting in a quick and effective manner to the changes taking place.
Machine downtime management	4.0 Technologies enable reducing the number of defects by constantly monitoring machines and their sub-assemblies. Such observation enables the early detection of a potential failure and guarantees continuous maintenance of the machines. An adequately early response minimizes production losses due to machine downtime and increases overall production efficiency.
Production flow management	4.0 Technologies enable an increase in production efficiency by managing the path that the product travels, for example it facilitates selecting the optimal machine for processing the given component, which results in reducing the waiting time between the individual stages of the manufacturing process.

Table 3. cont.

1	2
Inventory management	4.0 Tools enable adequate management of the delivery process. Accumulation of too much inventory leads to unnecessary freezing of capital and overproduction as well as reduces usable storage space.
Quality management	4.0 Tools enable improving the quality of products and processes by detecting quality deterioration and acceptable product tolerance violation in real time.
Supply and demand management	4.0 Technologies are able to forecast the demand for products based on advanced analyses and market needs, which allows for avoiding unnecessary losses and costs due to storage.
New product implementation management	Quick and cheaper prototyping, for example thanks to the use of 3D printing, allows for reducing the time it takes to introduce a product to the market, which raises the company's competitiveness.
Support (maintenance) services management	Digitization and computerization enable new options for providing support (maintenance) services. Faster repairs are possible because technicians are able to connect with machines without the need to be physically present at the production plant. Faster responses to malfunctions can also help extend the life cycle of the machines.

Source: own study based on (Blunck & Werthmann, 2017).

The effect of correctly running the processes described in Table 3 is achieving a correctly functioning production process. The above processes are focused on activities that optimize the product's added value, improving production efficiency (Pereira & Romero, 2017). The implementation of technology 4.0 in the production area enables continuous production process optimization (Pereira & Romero, 2017). The CPS system enables introducing changes to the production planning process in real time, reducing or eliminating the negative consequences of such decisions (Zhou, Liu, & Zhou, 2015). In the case of Industry 4.0, the production process is standardized, which facilitates optimizing the decision-making processes (Weyer, Schmitt, Ohmer, & Gorecky, 2015). Technologies implemented in line with the 4.0 concept enable self-optimization of the production environment (Ivanov, Dolgui, & Sokolov, 2019). This is achieved through, among others, enabling real-time interaction and information exchange between machines, between operators and machines, as well as between the manufactured product and the machines (Lee, Bagheri, & Kao, 2015). Real-time exchange of information between systems related to the production processes enables inventory management, machine maintenance management, supply chain risk management, employee absenteeism management and reduces waste in the company. Processes that are intelligently interconnected and interoperate with one another constantly look for information and process it in such a way that the production can be as efficient as possible (Lee, Kao, & Yang, 2014). Intelligent value chain networks cover all phases of the product life cycle. In this way, the process can utilize user (customer) feedback to improve the product. Enterprises with networked supply chains enable optimizing the individual

production stages and the entire value chain (Barreto, Amaral, & Pereira, 2019). Based on a critical review of the literature on the subject, Table 4 presents the characteristics of production processes in relation to the visible Industry 4.0 trends.

Table 4. Characteristics of production processes in relation to Industry 4.0.

Process	Characteristics related to Industry 4.0
Measurement and control process	Use of mobile devices to support and manage production processes in real time.
Transportation process	Use of rfid technology
Transportation process	Use of autonomous mobile robots
Technological process	Use of collaborative robots
Measurement and control process	Use of virtual and augmented reality
Measurement and control process	Use of big data technology
Measurement and control process	Use of cloud computing technology
Technological process	Use of additive printing
Technological process	Use of artificial intelligence
Technological process	Manufacturing of products with a modular structure
Technological process	Implementation of mass product customization
Technological process	Use of automated machines or automated production (assembly) lines or industrial robots
Technological process	Use of computer programs (software) to design new products
Measurement and control process	Simulating the course of manufacturing processes for products that are newly implemented into production
Measurement and control process	Production support systems are interconnected with one another
Measurement and control process	Data is transferred between systems in real time.
Measurement and control process	Production support systems are used to communicate with suppliers and customers
Measurement and control process	Use of sensors that measure geometry of components in order to assess the quality of their workmanship
Measurement and control process	Implementation of security measures against cyber attacks
Measurement and control process	Backing up data

Source: own study based on interviews conducted at the enterprise and (Barreto et al., 2017; Blunck & Werthmann, 2017; Lasi et al., 2014; Lee et al., 2014, 2015, 2018; Lu, 2017; Niemczyk & Trzaska, 2020; Pereira & Romero, 2017; Zagajewski & Saniuk, 2018).

Verification of the occurrence of the phenomena described in Table 3 allows for assessing whether the impact of Industry 4.0 is visible in the manufacturing company, made on the example of an enterprise operating in the furniture sector.

4. Poland's furniture sector

The furniture sector is one of the main manufacturing sectors in the world. It boasts a long tradition of development and evolution, while the discussion on the changes in it is part of the latest trends related to a sustainable development economy. The furniture sector plays, especially in Poland, an important role because compared to other sectors related to services that are dominant in Poland, it is the driver of the national economy's development. Furniture-making as an industrial activity is listed in the Polish business operations classifications as "furniture manufacturing" (PKD code 31), and that sector constitutes a significant part of Polish industry. Its share of GDP annually tops 2%, and reached 2.30% in 2018 (GUS, 2020). The number of registered entities operating in the sector stood at 28,678 in January 2017, rising to 34,488 in January 2021, an increase by more than 20%. Figure 1 shows the number of registered entities in the furniture manufacturing sector, broken down by the number of employees.

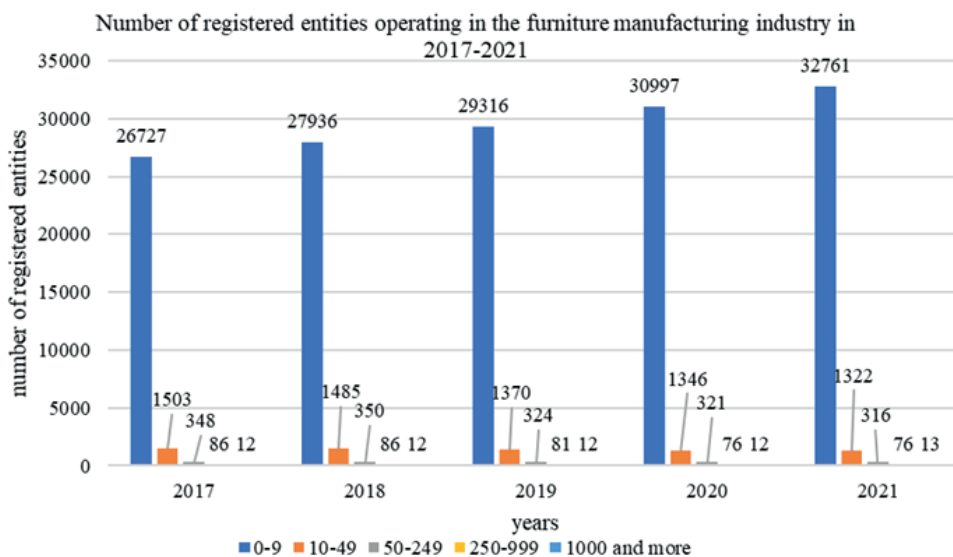


Fig. 1. Number of registered entities operating in the furniture manufacturing industry in 2017-2021

Source: own study based on (GUS, 2020).

The data provided in Figure 1 shows an increase in the number of entities with up to 9 employees. Such an increase can demonstrate the low costs of launching a furniture manufacturing business. Furniture manufacturing at a basic level does not require the use of complicated technologies or tools. However, a number of small enterprises continue to expand, leading to the need to use modern technologies, for example robots, which may explain the headcount decline observed at larger

enterprises. Therefore, an assertion can be made that the furniture manufacturing sector is on one hand open to new entities, but on the other hand it is also an industry undergoing transformation and enabling the adaptation of innovative solutions. It should be emphasized that the Polish furniture market is not only local. Poland ranks third in the world in terms of the value of furniture exports value, after China and Germany (see Figure 2).



Fig. 2. The value of exports of the top 5 largest furniture exporters in 2016-2019

Source: own study based on (Trade Map, 2020).

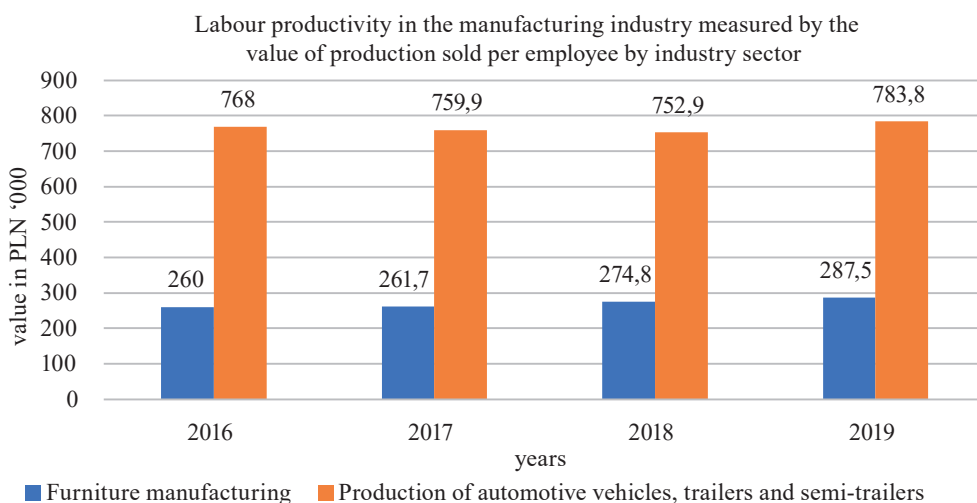


Fig. 3. Labour productivity in the manufacturing industry measured by the value of production sold per employee by industry sector

Source: own study based on (GUS, 2020).

The increase in the value of the Polish furniture sector's exports in 2016-2019, which is presented in Figure 2, may indicate the strengthening of its position on the European market and an expansion of the Polish manufacturers onto other markets. It should also be noted that the prices of Polish furniture are lower than, for example, the prices of German furniture, which enables Polish companies operating in the furniture sector to increase their market share in Western countries. However, low product costs are not related to high labour productivity, which is key for stimulating competitiveness on the international market. In order to present the relative labour productivity in the furniture sector, a comparison of labour productivity in the manufacturing of automotive vehicles, trailers and semi-trailers versus the furniture sector was made (Figure 3).

In accordance with Figure 3, an assertion can be made that labour productivity measured by the value of production sold per employee in the period 2016-2019 in the furniture sector is significantly lower than in the automotive sector, but it rose by more than 10%, i.e. by PLN 27,500. On the other hand, labour productivity in the manufacturing of automotive vehicles, trailers and semi-trailers increased by only 2%, i.e. by PLN 15,000, but this growth was in relation to a much higher level of productivity. The cited data shows that the automotive sector is already highly modernized, and modern technologies are already used there. Investments are stimulated by the inflow of capital transferred by large foreign corporations bringing their know-how to the domestic automotive industry, for example VW and Fiat. Such a large difference between the presented sectors may also be a consequence of the advanced automation deployed at companies operating in the automotive sector. Polish furniture companies are financed mainly with incomparably smaller Polish capital, which limits potential investments in new technologies. The level of automation and robotization in the furniture sector is lower than in the automotive sector, and as a consequence, its efficiency is also lower. Capital expenditure in the furniture sector declined by more than 1% in 2015-2019, i.e. by PLN 4.2 million, while in the production of automotive vehicles, trailers and semi-trailers, investment outlays went up by over 39%, i.e. by PLN 3,001.3 million, as shown in Figure 4.

In accordance with the data presented in Figure 4, it can be indicated that five times less capital was invested in the furniture sector than in the automotive sector in 2019. The low investment (capex) level may indicate that the furniture sector is still under the influence of traditional methods of minimizing costs, for example through staff redundancies. However, in order to fuel further expansion and increase productivity, furniture enterprises will have to consider investing in new machinery. The conducted analysis allows for concluding that the Polish furniture sector is highly ranked on the international market. It is noted that despite the year-on-year increase in the value of furniture exports, furniture manufacturing in Poland is characterized by low labour productivity. The lack of increase in the capital allocated to investment in this sector may lead to a decline of the sector's growth rate or, in the future, even make such growth impossible to achieve. Changes are

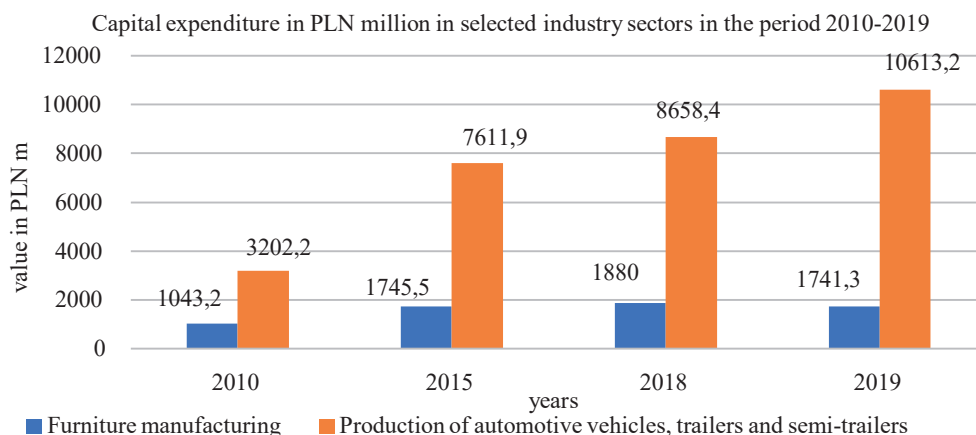


Fig. 4. Capital expenditure in PLN million in selected industry sectors in the period 2010-2019

Source: own study based on (GUS, 2020)

necessary to improve the competitiveness and enable potential further expansion of the Polish furniture manufacturers. The implementation of Industry 4.0 may initiate an acceleration of the technological and organizational advancement in the Polish furniture sector, which in turn may translate into an increase in production process efficiency (productivity). Potential directions of transformation of an enterprise operating in the furniture sector are discussed further on in the article.

5. Direction for improving processes in Industry 4.0 conditions at a Polish furniture manufacturer – a case study

The selected enterprise is an interior design brand that has been steadily strengthening its position as one of the most innovative companies operating in the furniture industry in Poland for some years. The company employs approximately 500 persons. The sales markets for the furniture manufactured by the company include mainly Western Europe (Germany, Great Britain, France, the Netherlands) and Poland. Currently, the enterprise is facing challenges related to increasing production volume due to the growing demand fueled by its efficient marketing activities. The company is in a period of growth and expansion, acquiring customers in new markets. Therefore, it is necessary to search for ways and directions for improving the production process. The selected enterprise is developing its product strategy in the direction of customization, so that an individual customer's needs can be taken into account during mass production, and this creates another area of requirements for the production system.

In order to determine the potential directions of changes in the enterprise's production processes, an assessment of the current level of implementing Industry 4.0 concept technologies and tools was made. A questionnaire survey was used for this purpose, carried out in a group of 20 managers from the production team of the company, from January to April 2021. It was conducted using a questionnaire based on the data collected in Table 4, which became the basis for assessing the degree of use of Industry 4.0 technology in the production processes. The study used the rating system based on a three-point scale, where 0 means that the given factor does not exist at all, 1 – it occurs to a small degree, 2 – in two or more areas, 3 – in the entire enterprise.

Table 5. The results of assessing the implementation level of the Industry 4.0 concept technologies and tools at the selected enterprise using the model proposed in Section 3, extended by adding the “rating” column.

Process	Metric	Score (0-3)
1	2	3
Measurement and control process	Use of mobile devices to support and manage production processes in real time.	0
Transportation process	Use of rfid technology	1
Transportation process	Use of autonomous mobile robots	0
Technological process	Use of collaborative robots	0
Measurement and control process	Use of virtual and augmented reality	0
Measurement and control process	Use of big data technology	1
Measurement and control process	Use of cloud computing technology	1
Technological process	Use of additive printing	0
Technological process	Use of artificial intelligence	0
Technological process	Manufacturing of products with a modular structure	2
Technological process	Implementation of mass product customization	2
Technological process	Use of automated machines or automated production (assembly) lines or industrial robots	1
Technological process	Use of computer programs (software) to design new products	1
Measurement and control process	Simulating the course of manufacturing processes for products that are newly implemented into production	0
Measurement and control process	Production support systems are interconnected with one another	2
Measurement and control process	Data is transferred between systems in real time.	1
Measurement and control process	Production support systems are used to communicate with suppliers and customers	0
Measurement and control process	Use of sensors that measure geometry of components in order to assess the quality of their workmanship	0

1	2	3
Measurement and control process	Implementation of security measures against cyber attacks	1
Measurement and control process	Backing up data	2

Source: own study.

Taking into account the results of the study presented in Table 5, the highest number of points (score) was awarded to the responses related to the desire to customize production and real-time information management. The enterprise already enables end-customers to participate in furniture design. The customer, as a co-producer, is able to design furniture on his/her own using the software available on the corporate website and the attached library of materials. Meanwhile, the interoperation between systems is visible in the production process itself. The two systems that manage production are interconnected and transfer data between each other in real time. This enables efficient value chain management. Based on the research conducted, the results of which are summarized in Table 6, the potential directions of changes in the selected enterprise production processes were determined.

Table 6. Potential directions of changes in production processes at selected enterprise

#	Current situation	Possible scenarios
1	2	3
1	Mobile devices are not used to support and manage production processes in real time	Equipping the management staff (managers, foremen, team leaders) with mobile devices (tablets), which, connected to the internal PROX and SAP systems, would enable system wide tracking of production orders and provide information on the sequence of orders to be executed, which is particularly important to ensure continuity of shipments and timely execution of the production plan.
2	RFID technology is used to record employees' work time, to confirm the start and end of an order execution, to report improvements and to enter some premises	Extending the use of the RFID technology to support communication between the product and the system guarantees contactless logging of the production and monitoring its stages. Thanks to the communication between the products/pallets/components and the machines/production system, it is easy to locate downtime (outages), respond to an incident in real time and, as a consequence, eliminate (fix, troubleshoot) the problem.
3	No mobile robots	Autonomous mobile robots could be used to deliver the required components to the assembly department (pins, couplings (sleeves), screws) or to transport pallets, for example transporting pallets with ready-made packages between the production department and the storage department or between machines in the production department.

Table 6. cont.

1	2	3
4	No collaborative robots	Collaborative robots could be used in the assembly department to, for example, assemble cot side bars (frames) or the cot floor, dispense glue into cot side bars (frame), screw in couplings (sleeves). Robots equipped with inspection cameras could also be used to control the quality of manufactured components. Such robots would enable identifying and precisely locating damaged or defective parts before they are packaged and shipped to the customer.
5	Virtual and augmented reality solutions are not used	VR technology could be used to train new employees in the field of furniture assembly.
6	BIG DATA technology is not used	Implementation of this technology would increase production efficiency by reducing machine failure rates, for example, information collected from sensors configured to monitor various parts of machines would allow for early detection or prediction of potential failures, which could, consequently, prevent downtime due to earlier replacement of defective parts.
7	Cloud computing technology is used to a small extent	Cloud computing technology could be used to perform activities related to the diagnostics of the machine condition. This would allow for predicting and preventing unplanned downtime in the production process. Readings from the sensors collecting diverse data (vibrations, temperature, pressure, stress) can be interpreted by comparing them with nominal values. Cloud computing enables determining the machine condition by using various digital time series analysis methods.
8	Additive printing is not used	Additive printing could be used in the maintenance department as an option to reproduce a damaged part of the machine or in the production department as a technology enabling printing of fixtures or other auxiliary materials.
9	Artificial intelligence systems are not implemented	Use of genetic algorithms to determine the adequate processing parameters. Use of neural networks to schedule machine work and make changes in the event of disturbances.
10	Manufactured products have a modular structure, (for example, children's cots, which can be later converted into a bed, a chest of drawers onto which a baby changing table can be mounted)	Extending furniture modularity to cover more products and more options.
11	Customization of the final product is utilized to a large extent	Implementation of pure customization where the customer is involved at the product design stage.
12	Lack of fully automated machines and automated manufacturing (assembly) lines, there is a single industrial robot for palletizing parcels at the plant	Implementation of automatic loading and unloading of machines and automatic roller tracks conveyors between machines.

1	2	3
13	Computer programs (software) are used to design new products (CAD, CAM) at the production plant	Use of software to design (model) shapes that automatically generate machine processing procedure.
14	No simulations of the performance of the products newly introduced into production	Use of simulation systems for the strength analysis of manufactured components, for the analysis of whether it will be possible to assemble the components, following its processing, into a single shape, while maintaining the quality rules, simulation of what the most optimal production path for the given product will be.
15	Production support systems are interconnected with another (PROX, SAP)	Combining into a single system.
16	Data is transferred between systems at specified intervals	Reducing time intervals between data transfers between systems and leading to the implementation of real-time data exchange further down the line.
17	Production process support systems are not used to communicate with suppliers or customers	Connecting with suppliers in a single system in order to exchange information more efficiently, in particular with respect to delivery delays. Enabling customers to check at what manufacturing stage their order is.
18	There are no sensors that measure geometry of components	Implementation of mobile workstations controlling the dimensions of components and implementation of the SPC (Statistical Process Control) system.
19	Standard security measures are used to protect against cyberattacks	As various IT systems are implemented and the plant's technology is becoming more advanced, use of stronger security measures should be considered.
20	Data backup is made on an ongoing basis	Storing data backup copies on two independent servers should be considered.

Source: own study based on interviews conducted at the enterprise.

Based on the data collected in Table 6, it can be stated that the main direction for improving production processes at the enterprise is mass production customization, involving the customer in furniture design, developing a relationship with the market where the customer is treated as a co-producer. The next natural direction of development is the implementation of a central production system that will enable the supplier-company-end customer communication. The outcome of including all production processes of various entities within a single system should be a more optimal supply chain management, which may reduce external disruptions and shorten the end customer's waiting time for furniture delivery. A further step would be to automate and robotize selected production processes and the implementation of the so-called "zero waste" approach in the production system, which assumes an approach to manufacturing that would enable to eliminate material and non-material losses arising during production and the re-use of the generated waste. Such an approach is used throughout the product life cycle. The result of such activities

would be a circular system that continuously uses resources and does not generate waste.

Summarizing the research conducted, it can be stated that the furniture sector is impacted by Industry 4.0 trends. This influence is visible in the scope of the production process technological modernization concepts being developed. However, the implementation of these concepts is still in its early stages. The desire of enterprises to customize manufacturing while maintaining mass production is particularly visible. An important direction of changes is also the integration of systems, as well as the desire to process data in real time. Meeting such assumptions constitutes an introduction to deepening the process of automation and implementing machine control. It should also be emphasized that the furniture manufacturing sector continues to be an open sector where small enterprises are expanding and striving to introduce new technologies.

6. Conclusions

The impact of modern technologies on the manufacturing industry brought about a number of industrial revolutions. Currently, however, changes are so cross-sectional that they infiltrate the technological and physical world. The very ability to change by adopting new technologies is a prerequisite for the survival of a number of enterprises on the market. Even traditional sectors such as the furniture manufacturing, have to adapt their processes to modern requirements imposed by the economic transformation driven by the impact of Industry 4.0. The current low level of technological modernization of this sector makes it necessary to introduce rapid changes. The goal of this article was to diagnose the potential directions for improving the production processes taking place under the impact of Industry 4.0. This goal was achieved by identifying key, possible to be implemented, improvements that are related to the integration of production systems, real-time data processing and enhancing product customization while maintaining mass production. Such research methods as a critical review of the literature, a case study based on the selected enterprise and a questionnaire survey, were used in the article.

The limitation of the analysis conducted was the relatively limited knowledge among the respondents of the possibilities of using Industry 4.0 technology, which were associated primarily with highly advanced autonomous manufacturing technologies. Conducting further detailed research, focused on selected production improvement aspects driven by the implementation of Industry 4.0, is an interesting research area, both in practical as well as scientific terms.

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