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The Business Model of Industrial Networks in the Context of the Industry 4.0 Environment

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Abstract
The article presents a business model based on an industrial network of companies capable of producing personalized products in an Industry 4.0 environment. Based on research conducted in Poland, in manufacturing companies, the critical problems associated with the implementation of Industry 4.0 technologies and the expected benefits associated with their implementation are addressed. The model's task is to integrate a customer expecting personalized production with a network of companies with the appropriate production resources. The original achievement is the integration of the customer and the manufacturer around an e-business platform, which allows the rapid prototyping of a network of SME companies capable of realizing personalized production. The proposed model describes the architecture of enterprise cooperation under the conditions of implementing the Industry 4.0 concept and is dedicated to the SME sector. The model provides a basis for building prototypes of e-business platforms of small and medium-sized enterprises.

Keywords
Industrial networks; Business model; Industry 4.0; Small and medium enterprises; Personalization.

Introduction

The Industry 4.0 implementation is accompanied by ubiquitous digitalization of processes, a characteristic of the contemporary industrial environment. Digitalization is a technological dominant of changes in production, services, education, science and administration. It is the basis of intelligent automation, robotization, logistics and communication (Vaidya et al. 2018; Hermann et al., 2016; Lu, 2017).

The technological revolution has expanded the boundaries of what companies can deliver as value to customers (Weking et al., 2018). The hallmark of Industry 4.0 will be the agile and flexible production of individualized customer-centric products. Today, customers expect products that are closely tailored to their personal preferences, tastes, needs, and lifestyles (Wang et al., 2017; Lee et al., 2014). The production paradigm is changed, in favor of customized production, tailored to the individual customer's needs (Lampel & Mintzberg, 1996). The need to offer highly personalized products to customers at low prices is forcing companies to change how they operate. There is greater interaction between the company and the customer, involving them in creating or even final product assembly. Consumer activism, ubiquitous communicability, the convergence of technologies and industries, globalization of markets, and global access to resources are trends beyond the control of any single company (Ritter et al., 2020; Bai et al., 2020). Hence the orientation towards the development of networked forms of enterprise collaboration. Currently, the participation of a company in a network is particularly attractive for small and medium-sized enterprises, which in this way can overcome the main competitive advantage of large companies in terms of access to all kinds of resources (capital, competence, know-how, etc.) (Mahmood et al., 2018). In addition, the ability of companies to exist in multiple alliances increases the productivity of the available production resources and human resources. Functioning in a network also positively influences learning by acquiring experience, know-how and knowledge based on mutual relations between cooperating enterprises (Quade et al., 2020). The intensive development of mobile,

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digital and communication information technologies determines the need for changes in the functioning of modern enterprises. Hence the need to intensify research on developing business models (Brzóska & Knop, 2020) and concepts for creating networks that use intelligent resources to realize specific, personalized products in interaction with the consumer. In the Industry 4.0 environment, the enterprise plays the role of an integrated, intelligent module sending and receiving information streams via ICT networks and performing tasks within the supply chain.

The article has research and conceptual character. Based on the literature review, the research gap was identified as a lack of business models dedicated to the SME sector operating in the Industry 4.0 environment. The article's main aim is to establish a theoretical framework of the business model based on cyber-physical networks of SMEs capable of producing personalized products in an Industry 4.0 environment. Achieving the aim of the paper requires answering the following research questions:

1. What are the critical problems related to the implementation of Industry 4.0 technologies?
2. What expected benefits are associated with the implementation of Industry 4.0 technology?
3. What are the expected model assumptions technologies for cooperation between small and medium-sized enterprises supporting the implementation of the Industry 4.0 concept?

Research method

A literature synthesis – research studies and expert studies – was used to achieve the paper's aim and identify the research gap and answers to research questions. The study was of a pilot nature, and the selection of production companies was purposeful based on the adopted criteria, i.e., the company has introduced at least one technology identified with Industry 4.0. The authors used the IDI (Individual In-Depth Interview) method to research with experts from selected enterprises. Data was collected between December 2020 and June 2021. The experts include representatives from R&D, production, and IT departments. The research used the Computer-Assisted Web Interview to determine the expectations and preferences of small and medium-sized industrial enterprises in networking in the Industry 4.0 environment. Fifty enterprises (located in Poland) participated in the study; 27 were small, and 23 were medium. The leading business profile of the surveyed companies was manufacturing from area of automotive, food sector, pharmacy. Due to the lack of widespread use of the Industry 4.0 concept in small and medium-sized manufacturing enterprises, selecting of the research sample is purposeful. Figure 1 presents an outline of the study's methodology.

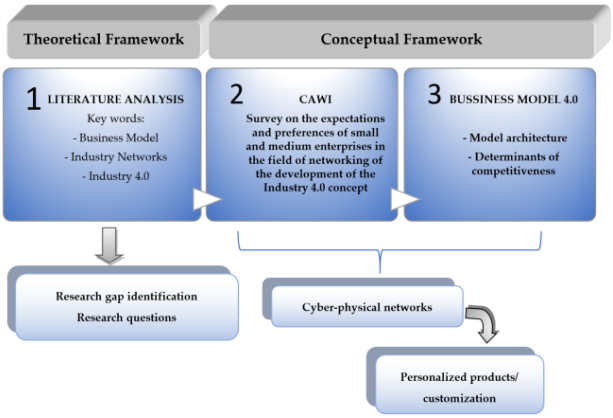

Fig. 1. Methodology of the study

Results

Bibliometric analysis – results

Table 1 presents the details of the literature synthesis performed. The focus was on articles that were indexed in the scientific databases Web of Science and Scopus. The subjects of the study were business models, industrial networks and Industry 4.0.

The final stage of the bibliometric analysis was a qualitative analysis of the extracted articles during the advanced search. This analysis provided information – what issues are addressed by the authors of these publications. It was found that the business model under the conditions of the fourth industrial revolution integrates topics specific to business management (decision-making, outsourcing, value chain, talent management, SME, B2B, B2C, flexibility, cyber-physical networks, sustainability, globalization) with technical topics (innovation, personalization, Big Data, 3D printing, servitization, IoT, Smart Factory, modularity, Blockchain, machine learning, Cloud Computing).

Results of a survey of SMEs

The surveyed enterprises overwhelmingly perceive the positive impact of the Fourth Industrial Revolution on their business model. Most of the surveyed enterprises are only at the beginning of their path of implementing the Industry 4.0 technology, and they

Table 1
Detailed search data from Web of Science (WoS) and Scopus databases

	Database	
	WoS	Scopus
Year range	01.01.1990–01.11.2021	01.01.1990–01.11.2021
Languages	English	English
Document type	Article	Article
Field Tags:	Number of articles	
"Business Model"		
TS = "business model"	8.872	16.532
AK = "business model"	2.602	5.824
"Industrial networks"		
TS = "industrial networks"	467	894
AK = "industrial networks"	124	418
"Industry 4.0"		
TS = Industry 4.0	4.635	5.548
AK = Industry 4.0	1.541	3.752
Advanced Search		
TS = "business model" AND "industrial networks" AND "Industry 4.0"	0	1
AK = "business model" AND "industrial networks" AND "Industry 4.0"	0	0
TS = "industrial networks" AND "Industry 4.0"	26	4
AK = "industrial networks" AND "Industry 4.0"	2	2
TS = "business model" AND "industrial networks"	3	4

also perceive multidimensional benefits from its application. After implementing the Industry 4.0 technology, respondents expect an increase in the number of production orders, lower unit costs of products, increased productivity and flexibility of used resources and quality of production. Due to the low level of employment, they do not see the possibility of employment reduction. Figure 2 shows the percentage values of the most frequently selected answers.

At the same time, the respondents stressed problems connected with the implementation of the Industry 4.0 technology. The most frequently indicated problems identified by small and medium enterprises include a low level of cybersecurity, high consulting costs in the field of new technologies, low level of return of investment, lack of effective business models

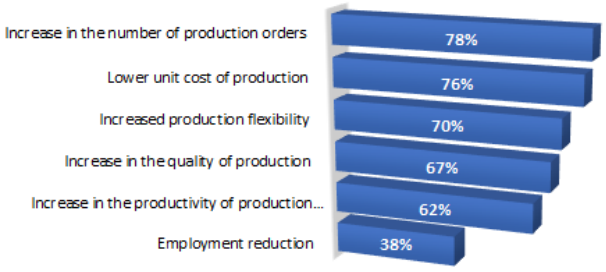

Fig. 2. Expected benefits from implementing Industry 4.0 technology

for the cooperation, lack of qualified employees for new technologies, problems with network cooperation, etc. Figure 3 presents the percentage data of the obtained answers.

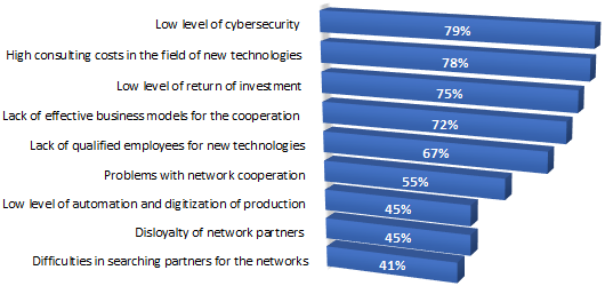

Fig. 3. Most frequently identified problems of implementing Industry 4.0 technology

The surveyed companies indicated interesting possibilities of solving the existing problems in effectively implementing the Industry 4.0 concept. The most important of them include: building e-business platforms and IT systems supporting network cooperation, developing business models dedicated to network cooperation in the Industry 4.0 environment, development of a training system and knowledge bases in the field of Industry 4.0 technologies, and creation of exceptional financial support programs for investments in innovative technologies (Fig. 4).

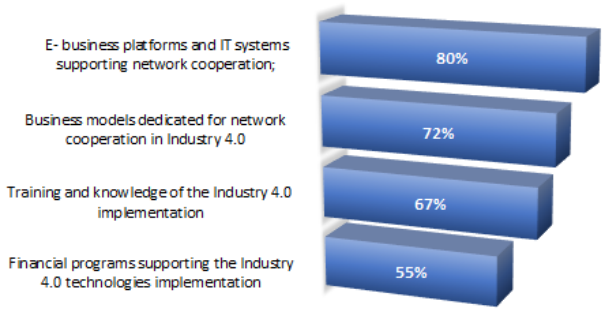

Fig. 4. Expectations of SMEs that can support the implementation of the Industry 4.0 concept

Discussion

The bibliometric analysis of scientific works in the concept of business models, industrial networks and Industry 4.0 shows a clear research gap in the absence of recognized architecture of business models adequate to the Industry 4.0 concept. The idea of business model 4.0 under the Fourth Industrial Revolution conditions is gradually built using the pillars of Industry 4.0 to achieve a modern form of management that can meet the challenges of a turbulent, competitive and technologically advanced environment (Ibarra et al., 2018; Ilic et al. 2017). Industry 4.0 means broadly understood networking in the economy achieved mainly through telecommunications technologies and IoT, Big Data and Cloud Computing (Basl 2019). Participation of enterprises in networks provides new opportunities. It enables the use of modern organizational solutions that significantly impact the efficiency of their functioning in the so-called virtual organizations (Panetto et al., 2019), manifested by process orientation, decentralization of management, and development of narrow specialization and communication. Therefore, the essence of any industrial network is the cooperation of partners, which often leads to a synergy effect. This effect is achieved by using their potential (know-how, resources, etc.) to achieve a common goal of the entire network. The significant role of coordination mechanisms in attaining the network's synergistic effect is pointed out by Sirota-Cohen et al. (2019).

The study confirms the benefits of cooperation, and at the same time, indicates many problems that require a systemic solution in the organization of new business models. In addition, the SME sector needs additional support. The digitization process of the Polish economy should be supported to a greater extent by the government, especially in supporting the development of the SME sector. The digitization process requires intensive training of employees of the SME sector and special financial support programs for investments in intelligent technologies. One of the critical problems that the respondents have indicated is a lack of knowledge on introducing the concept of Industry 4.0, including selecting appropriate technologies and IT systems dedicated to SMEs. Similarly, Cyfert et al. (2018), in the case of the implementation of various strategic projects, identified the following barriers in the case of SMEs: lack of financial resources and lack of qualified personnel (Cyfert et al., 2018). The need for changes in the functioning business models or building new ones is also emphasized by numerous studies, e.g. (Müller et al., 2018; Ślusarczyk, 2018; Sony & Naiks, 2020; and the McKinsey&Company report, which shows that there are several main pillars of digital transformation of business models:

- application of digital technologies;
- collaboration – alliances, strategic partnerships, and networks;
- collection and management of large data sets as an essential business resource;
- cybersecurity.

The idea of a cyber-physical industrial network means the production of joint production orders using fully automated processes of individual network partners. Communication occurs via the Internet, and the necessary data is stored in Cloud Computing (Saniuk et al., 2019). As a result, all network participants have constant access to selected essential information about available resources, the status of the implementation of part of the process in real-time from anywhere in the world. Thus, the opportunity for development arises in creating a partnership involving the combination of specialized competencies and the ability to change to meet customer expectations better and enable the effective acquisition of competitive advantage in the market. A company in a network changes its orientation from product to service (servitization). It becomes a link in the value chain, contributing a specific service that is part of the product's production process offered by the network (Saniuk & Grabowska, 2019). A proposed network is a temporary network established to execute a specific production order organized within enterprises associated with e-business platforms and has certain features of a virtual organization. After completing the order, it is dissolved. Similarly, to a virtual organization, it creates networks on a voluntary and mutual trust basis by enterprises that enter into various types of relationships to achieve greater benefits than if they operated traditionally. Additionally, enterprise communication uses ICT (Information and Communications Technology). The cyber-physical industrial network can be organized within enterprises belonging to clusters or other associations of companies in a given industry. This is related to ensuring the reliability of the partner for temporary cooperation.

Enterprises that operate within cyber-physical industrial networks should meet certain minimum requirements. These requirements include implementing technologies that allow systems and intelligent resources to communicate with each other in real-time, such as Cloud Computing, Big Data, and the Industrial Internet of Things. Additionally, it's essential for these enterprises to develop critical competencies in

intelligent resource services and be open to network cooperation.

Based on the research results, the business model under the conditions of the fourth industrial revolution was called "business model 4.0". It was defined as a configuration of business processes that connect and develop resources, formed in the form of the social and technical architecture of the enterprise. The architecture of this model is built on flexible digital processes. These processes enable cyber-physical collaborative networks that can meet the demand for personalized products.

The business model 4.0 is based on a solid combination of the megatrends of the fourth industrial revolution and the Industry 4.0 pillars. The implementation of strategies in business model 4.0 in practice takes place through the construction of a cyber-physical cooperation network that ensures both the efficient use of resources and skills and their renewal. Implemented technological innovations enable cooperation in cyber-physical networks, aiming to produce personalized products and offer complementary services. These activities take into account the principles of sustainable production.

The key elements affecting the competitive advantage of business model 4.0 are the megatrends of the fourth industrial revolution and the pillars of Industry 4.0. The fourth industrial revolution's megatrends are Economic 4.0, Smart Factories, Society 5.0, Sustainable Consumption, and Sustainable Production. The Industry 4.0 pillars include autonomous robots, Big Data, cloud computing, systems integration, additive manufacturing, Industrial Internet of Things, augmented reality, simulation, and technologies supporting cybersecurity. Also impacting competitive advantage are cyber-physical CPS, value chain and technological landscape, personalization, customization, and servitization.

Business model 4.0 is based on a configuration of social architecture and technical architecture connected by business processes. The model exposes the role of business processes, which are supported by the pillars of Industry 4.0. The model is influenced by the megatrends of the fourth industrial revolution, resources and customers. Micro and macro environments, competitors and stakeholders are exposed in the model. A crucial element is a set of intelligent resources forming a cyber-physical collaboration network system (CPS) of small and medium enterprises. Figure 5 shows the architecture of business model 4.0.

In Figure 5, the technical architecture of business model 4.0 encompasses the pillars of Industry 4.0, which can help form a cyber-physical collaboration network system (CPS).

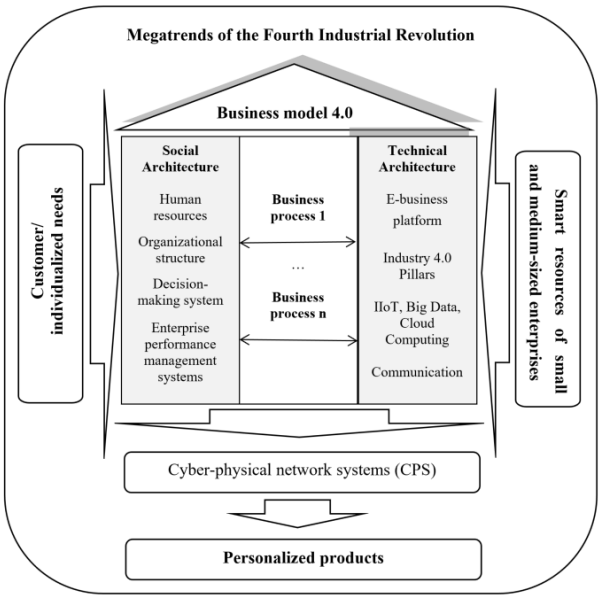

Fig. 5. Business model 4.0 architecture

The technical architecture of business model 4.0 enables CPSs to collect data, process it, and influence physical processes across the entire industrial network through unlimited interconnected networks of communicating intelligent, mechatronic assets (machines, equipment, robots, vehicles, etc.). The foundation of this architecture is communication, allowing devices and sensors to transfer data between each other and directly with Ethernet or the cloud. In the future, using decentralized computing power, data will be transformed into information instantly in the sensor, and a smart system will make decisions on a decentralized level autonomous. Maximizing the digitization of the technical architecture is to increase machine availability, increase manufacturing speed, improve product quality, increase manufacturing flexibility, and increase worker safety.

The social architecture of this model is human resources, organizational structure, decision-making authority and corporate performance management systems. Because the fourth industrial revolution is creating new work environments and labor market conditions, the enterprise's competency management and talent management will be an essential component of this architecture. The automation and digitization of business and the need to constantly adapt to the changing conditions of the company's environment require completely new employees' competencies, and therefore a change or reorganization of the social architecture of the business model.

Another foundation of business model 4.0 is the business processes that constitute value for customers,

particularly the delivery of products and/or services that meet specific needs. Business processes are a combination of social architecture and technical architecture, while at the same time deriving from them the resources necessary to realize appropriate products that create value for the customer, often personalized. Business processes are characterized by (Saniuk & Grabowska, 2022):

- interoperability – creating communication standards between businesses, cyber-physical systems, and human teams;
- virtualization – creating virtual work/collaboration/cooperation models and simulation models;
- decentralization – devolving decisions on how smart products are manufactured, with full electronic tracking along the value chain;
- real-time decision-making capability – access to all key process information automatically, based on data collected from machines and devices;
- service orientation – opening to the use of assets (factories, technology, human teams) for service use in other factories, as well as for servitization;
- personalized production – supplying the customer with the product maximally adapted to his needs;
- servitization – increasing the proportion of services in the enterprise's portfolio;
- Sustainable production and consumption – producing and using products and services in a socially-expected way to be sustainable and environmentally friendly throughout their entire life cycle.

Conclusions

Nowadays, flexible company management in a dynamic environment is one of the essential factors in achieving a competitive advantage. The ability of the organization to perform the tasks set before requires fast adaptation to changes occurring in the turbulent environment and the creation of innovative solutions that fit into the concept of Industry 4.0.

Business model 4.0 is intended to augment and leverage enterprise resources to achieve competitive advantage through product personalization. The proposed model is an original reference configuration of business processes that connect and develop enterprise resources. The business processes are shaped in an enterprise social and technical architecture built on flexible, digitalized processes that enable cyber-physical networking to meet the demand for personalized products.

It has been determined that the technical architecture of this model is digitized, based on highly flexible processes, enabling the establishment and collaboration of cyber-physical enterprise networks and servitization, i.e., the integration of services into the offerings of the manufacturing enterprise. In contrast, the social architecture is based on the organizational culture of agile teams based on virtual collaboration. These teams are formed each time to implement a specific project (order) and cover the entire value chain of enterprises. The basis of this model is communication. Unlike the business models described in the literature, the business model 4.0 makes it possible to deliver a personalized product to the customer at a mass-production price – this is its key competitive advantage. The proposed business model 4.0 states framework of the functioning of cyber-physical industrial networks and requires further in-depth research, primarily related to the development of e-business platforms supporting the rapid prototyping of temporary networks focused on joint personalized production orders, scheduling and control of geographically dispersed resources in conditions of logistic constraints, financial settlements of partners, etc.

The proposed model provides an original solution to the problem of integrating customer and manufacturer oriented personalized production. In addition, it allows rapid prototyping of a network of small and medium-sized enterprises with intelligent resources, knowledge and competencies of their employees with the aim of realizing personalized products. The model provides a basis for building an e-business platform bringing together small and medium-sized enterprises oriented to exchange production capacity and jointly realize customer-oriented production.

The primary limitation of the conducted research is its limited scope. To account for the possibility of international cooperation among small and medium-sized enterprises within cyber-physical industrial networks, the research sample must be expanded, and further research should be conducted in other European countries.

The authors' future research focuses on developing scenarios for implementing the Industry 4.0 concept in the sector of small and medium enterprises, absorbing elements of the proposed business model considering the level of technological and organizational maturity of SMEs.

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