III. MODERN CHALLENGES OF PRODUCTION AND WAREHOUSING

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THE ROLE OF CLOUD COMPUTING AND BIG DATA IN THE DIGITIZATION OF SUPPLY CHAINS

ABSTRACT

Background: Modern supply chains require not only fully integrate processes, but also a high level of activities flexibility that enable the provision of services and products in accordance with the customer's requirements. The development of modern technologies and tools supporting supply chain management observed in recent years, as well as significantly increasing customer requirements, often exceeding the capabilities of traditional supply chains requires from the logistics services providers adaptation of performing processes to changing market requirements. The purpose of this chapter is to present not only the essence of digitization of supply chains in the context of the development of the Industry or Logistics 4.0 concept, but also to pay attention to the key role of modern Cloud Computing and Big Data tools utilizing.

Methods: As part of the literature review conducted in this chapter, the definitions of tools relevant to the digitalization process were indicated, thus presenting the relationship between the diversity of Industry 4.0 tools used on the market and the level of supply chain digitization, but also the most important benefits and challenges resulting from their widespread use. In order to verify the relationship between the size of the enterprise and the use of tools supporting the digitization of supply chains, the analysis of seventeen randomly selected enterprises to questions about the use of cloud computing and big data as part of the interview conducted for the purposes of this chapter was performed.

Results: The analysis of the functioning of the tools presented in this chapter showed a significant degree of dependence between the degree of use of Industry 4.0 tools and the level of digitization of supply chains.

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Conclusions: The key factor influencing the development of chains, but also the increase of their profitability in the context of global cooperation of the logistics industry enterprises is the level of the digitization of processes implemented within the supply chains. The development of digital supply chains is conditioned by the use of modern tools that support the integration of all chain participants by providing more comprehensive services that respond to the needs of service recipients.

Keywords: Industry 4.0, Cloud Computing, Big Data, Digital Supply Chain

INTRODUCTION

Contemporary supply chains are customer-oriented networks that face the challenge of ensuring the full integration of processes implemented both within enterprises and between partners, but also a high level of flexibility in activities enabling the provision of both services and products in accordance with the clients' requirements at the right place and time. The increase in customer requirements for customization of products or services provided by supply chains, which has been observed for several years, determines the need to implement fully flexible, error-free business processes, which main purpose is to fulfill customer needs and generate the highest profits at the lowest possible costs. However, the effectiveness of processes is conditioned by such determinants as quality, degree of fulfillment of needs, ability to respond the requirements in real time or shortening of order processing cycles, which when using traditional methods of providing services and communication becomes almost impossible to perform.

The purpose of this chapter is to present the characteristics of Digital Supply Chains, the main conditions determining their functioning, as well as the impact of cloud computing and Big Data technologies, the implementation of which translates into the level of digitization of supply chains and the degree of their integration in the context of changing market requirements. As one of the most important elements of the implemented chapter, the authors pointed out the thesis under which cloud computing and Big Data contribute to the increase in the use of Digital Supply Chains as much as other technologies in the field of Industry 4.0 concept, including, for example, automation and robotization of manufacturing, warehouse or transport processes. In addition, this chapter assumes that SMEs use Industry 4.0 tools to a much lesser extent than large enterprises, which is the result of, for example, the differences in financial capabilities of the analyzed enterprise groups. The conducted literature review is only a verification of the legitimacy of choosing the topic presented in the chapter for

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further research verifying the relationship between the increase in the use of data collection and processing tools and the increase in the degree of supply chain digitization.

LITERATURE REVIEW

According to the definition, digitization assumes the use of a series of electronically exchanged data between business partners as well as modern, digital technologies used to improve processes and activities implemented in the supply chain, but also the change or elimination of those processes that do not bring the enterprise or the entire chain deliveries of intended benefits [Ivanov, Dolgui and Sokolov 2019]. Digitization of processes performed by individual units of the same enterprise or the entire supply chain assumes the use of data sent in electronic form, which significantly improves information exchange processes particularly important from the point of view of the assumptions of the concept of the 4th Industrial Revolution [Kayser 2004]. The continuous exchange of electronic data between business partners contributes not only to the improvement of individual processes, but also to entire supply chains. Access to data in real time, as one of the components of the Industry 4.0 concept, allows continuous development of processes realized for the clients, which are characterized by a high degree of customization, and thus fully fulfill the needs of recipients [Ivanov, Dolgui and Sokolov 2019]. The main assumption of the Industry 4.0 concept is decentralization of decisions regarding the deployment and control of processes implemented in the supply chain, characterized by a high degree of self-regulation. Industry 4.0 assumes digital support not only of products but also of all processes implemented along the supply chain, thus contributing to the increase in the level of digitization of existing value chains [Bauer et al. 2018]. One of the most important elements of the Industry 4.0 concept is continuous communication between the participants and the system's objects enabling the improvement of processes implemented for clients and adaptation of all services and products to the requirements of final recipients [Odważny, Szymańska, Cyplik 2018].

Digitization, which is based on electronic data exchange, assumes the possibility of immediate response to customer requirements that change over time, thus guaranteeing gaining a competitive advantage over less-digitized chains. The most important elements directly affecting the creation of Digital Supply Chains based on the assumptions of the Industry 4.0 concept are presented in Fig. 1.

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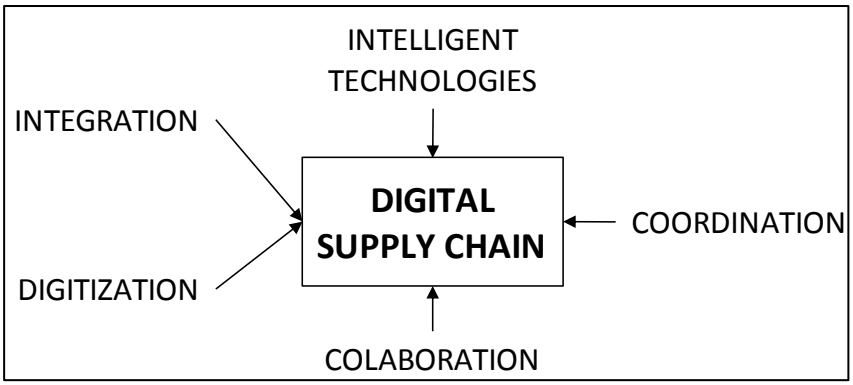

Fig. 1. Elements of the Digital Supply Chains. Source: [Iddris, 2018].

Digital Supply Chains (DSC) are defined as "(…) inter-organisational systems (IOSs) that firms implement to digitize the processes of transaction and collaboration with their supply chain partners (i.e., upstream suppliers and downstream customers)" [Xue, Zhang, Ling and Zhao 2013]. Digital Supply Chains assume the exchange of strategic business information between participants in the value chain regarding products manufactured, services provided, sales plans or financial operations using modern electronic and autonomous exchange, processing and data analysis tools. DSC are used primarily to achieve a growth of the level of integration of business partners and thus assume an increase in the efficiency of both the entire chain and its individual participants through access to management systems of production, transport, distribution or flow of funds [Korpela, Hallikas and Dahlberg 2017]. As indicated in Fig. 1, the most important elements affecting the digitization of supply chains are also components of the Industry 4.0 concept and relate to the use of intelligent, digital technologies capable of making autonomous decisions, a high degree of cooperation and integration between business partners as well as real-time process coordination enabling adaptation of performed activities to customer requirements.

The digitization of supply chains in relation with the existing and constantly evolving concept of Industry 4.0 is inevitable, it has become a reality that requires conventional chains to completely modify the process management system, as well as transfer some of the processes performed so far by employees to autonomous machines. The increase in the use of intelligent solutions supporting industrial and transport processes implemented in the links of the supply chain and the full integration of data exchanged electronically between partners

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are characterized by benefits, which are presented in Fig. 2.

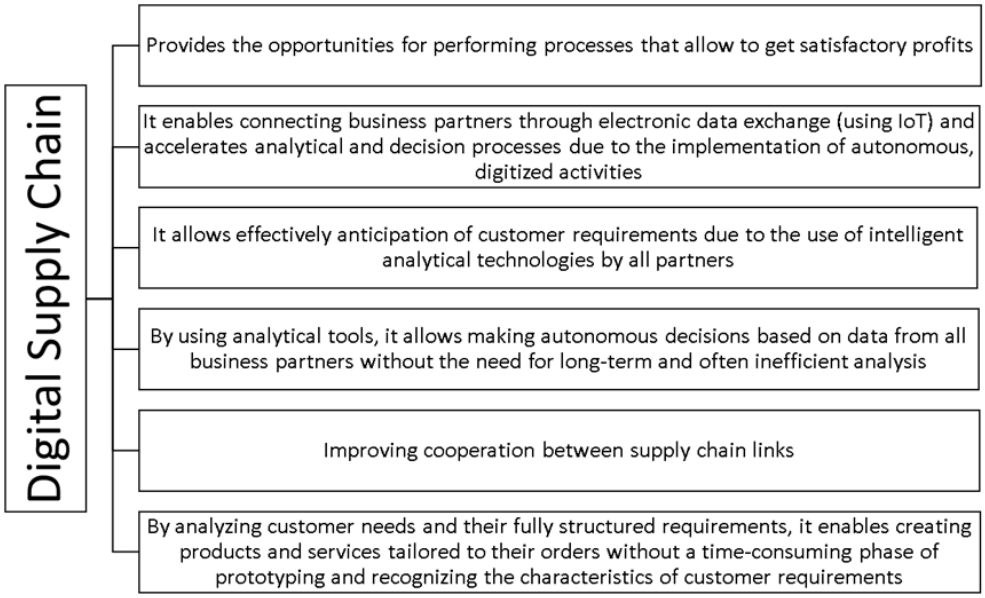

Fig. 2. Benefits of the Digital Supply Chain (DSC). Source: own work based on [Huddar, Kumatagi and Latte 2017; Agrawal and Narain 2018].

The physical flow of data between partners takes place using one of the most important pillars of the 4th Industrial Revolution, namely the Internet of Things (IoT). The Internet of Things is a technology that involves the exchange and processing of data using communication networks (usually the Internet) between objects, devices and machines collecting data on implemented processes [Stăncioiu 2017]. The use of IoT technology provides the ability to control the processes implemented by the company, which results in an increase in the efficient use of resources [Gubán and Kovács 2017]. The Internet of Things is a tool for exchanging data and controlling the flow of information between both participants in the chain and its customers, enabling real-time data access, which from the point of view of customizing products and services offered on the market plays a key role in the context of the ability to fulfull the clients' fully customized needs and also adjusting the functioning supply chain to the pace of changes taking place in its management and realizing decision-making processes [Oleśków-Szłapka and Lubiński 2016, Cedeño, Papinniemi, Hannola and Donoghue 2018].

The need for digitization noticed many times by participants in supply chains results primarily from the benefits associated with the use of modern technologies in the field of the Fourth Industrial Revolution significantly affecting the efficiency of processes implemented within the chains. The use of technologies related to both physical processes such

as production automation or robotization of warehouse processes as well as automation of information flow and digitization of data analysis processes and decision making at both operational and management level contribute to the economic growth of enterprises adapting their activities to the assumptions of the concept Industry 4.0 in relation to business partners gathered within traditional supply chains [Agrawal and Narain 2018].

Due to the significant role that the use of IoT plays as a key element of the digital transformation of modern supply chains in the development of Digital Supply Chains, much less importance is attached to the use of other technologies, equally crucial for the economic growth of all business partners. However, the authors of this chapter sencified the necessary to draw attention to the special role played by the tools of collecting and processing information flowing through Digital Supply Chains in the context of their further development. The tools of the Industry 4.0 concept supporting data collection and processing used as part of Digital Supply Chains include primarily cloud computing (or cloud services) and Big Data. In addition, as part of the literature analysis provided in this chapter, it should be pointed out that F. Iddris indicates as the most important activators of Digital Supply Chains technologies, which include:

- Big Data Analytics,
- Cloud Computing,
- 3D printing or direct digital manufacturing,
- Drones,
- Mobile Applications [Iddris 2018].

Cloud computing assumes the collection, processing and storage of data using software located in the "cloud", which can be viewed using any device with Internet access, without the need for physical storage of data [Gubán and Kovács 2017].

Big Data technology enables automatic downloading, processing and analysis of data allowing to increase control over the flow of many processes, detect errors before they occur, and also eliminate all activities that do not add value to implemented processes [Szymańska, Adamczak and Cyplik 2017]. Big Data tools are used as part of Digital Supply Chains, among others, to collect information on storage, transport, maintenance, the analysis of which is work- and time-consuming, complicated, but extremely important from the point of view of efficient use of resources and performed processes [Gubán and Kovács 2017].

Due to the fact that the digitization of product manufacturing processes or their physical movement between supply chain links and final customers depends to a large extent on the

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use of modern technologies, including automation and robotization of activities performed by enterprises integrated within one network, it should be stated that Digital Supply Chains should use modern technologies supported by autonomous, intelligent industrial solutions allowing independent decision making by both system entities, i.e. its users and components, i.e. machines and devices. However, the authors of this chapter have recognized the need to identify a key element from the point of view of increasing the efficiency of entire supply chains related to ensuring full integration of activities performed by individual business partners implemented not only in traditional networks, but also in DSC. From the point of view of the degree of intelligent and digital technologies usage, conditioning the fulfillment of Industry 4.0 demands, many business decisions are based on complex analyzes of huge amounts of information flowing between the links of the value chain. The data flow itself, guaranteed by the use of Internet of Things, is an incomplete process, requiring the involvement of additional tools with appropriate computing capabilities to support the processes of collecting and analyzing large data sets. According to the authors of this chapter, the degree of digitization of chains is largely dependent on the degree of integration of processes implemented between cells based on access to data exchanged between them in an electronic, digital way. Both cloud computing and Big Data tools allow a significant increase in the degree of digitization of the supply chain due to providing access to data collected in the cloud space, as well as to intelligent analyzes realized autonomously without employee involvement. The use of ready-made for managers decisions characterized by little or no risk are the basis for effective implementation of modern solutions that significantly contribute to the digitization of supply chains. The degree of digitization of supply chains depends to a large extent on the proper analysis of relevant data and on the basis of this decision making a decision conducive to increasing the efficiency of digital processes performed for clients by individual chain partners.

CLOUD COMPUTING AND BIG DATA TOOLS

Cloud computing enables the use of software as well as the functionality of many computer applications that do not need to be physically installed on computer equipment located at the company's headquarters. The use of cloud computing excludes the need to purchase expensive licenses, and the use of computer applications is available only for the time they are used by the relevant organizations offering them as services [Sosinsky 2011]. DSCs using cloud spaces have the ability to implement processes using private, public and hybrid clouds. Private clouds are characterized by the fact that, despite being provided by

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an external service provider, only the organization has access to the cloud space. In the case of public clouds, enterprises use the space made available to more users. Hybrid clouds assume that some services are provided based on the functionality of a public cloud, and remain based on a private cloud. The advantage of cloud systems is access to unlimited computing opportunities resulting from the use of software on web servers. The systems not only guarantee access to the cloud space, but also only allow "ad hoc" use of the application, which is a development opportunity especially for small enterprises that cannot afford to buy expensive licenses [Buyya, Broberg and Goscinski 2011]. Speaking of cloud systems, three most common types of services can be distinguished, which include:

- **Software-as-a-Service** - guarantees users access to many computer applications as well as systems using cloud computing located on the servers of service providers. SaaS allows users to access the software when they need it, without having to pay any license fees, even when the application is used sporadically [Rittinghouse and Ransome 2016].
- **Platform-as-a-Service** - is most often used by the developer environment due to the fact that its main functionality is to provide a virtual workplace for the organization's staff. This service allows programmers to create in the cloud space new applications, their any modification and improvement [Wang, Ranjan, Chen and Benatallah 2011].
- **Infrastructure-as-a-Service** - involves providing the user with access to the functionality of computer hardware owned by the service provider. Infrastructure-as-a-Service offers not only access to virtual equipment, but also to such elements as disk space, computing power and memory. IaaS is a service similar to SaaS because sometimes it can also offer users access to software [Kavis 2014].

The most important advantages of cloud computing include the effective use of available resources, through the use of computing power, disk space or software only when there is a demand, savings associated with the resignation from the purchase of expensive licenses and access to accumulated in almost unlimited space disk data in real time from anywhere on Earth with Internet access [Parlinska and Petrovska 2017].

Big Data as a tool for the autonomous analysis of huge data sets is used on a wide scale in intelligent supply chains as part of the increase in the degree of advancement of information exchange processes between links and final customers. The biggest advantages of using Big Data include the financial savings associated with the possibility of reducing the costs of enterprises resulting from the adaptation of the product or service corresponding

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to the customer's requirements without the need to implement both the cost-intensive and time-consuming design and prototyping phases. Big Data tools not only contribute to the development of the company in terms of adapting products to the customers' needs, but also enable full analysis of the market and trends prevailing on it, thus ensuring the indication of those areas of activity that should become a new trade area. This tool allows resignation from both non-profitable economic areas and customers. In addition, the most important benefits of using the Big Data tool include an increase in the organization's efficiency, as well as a greater efficiency in detecting all errors and irregularities affecting the decrease in the effectiveness of processes implemented in the company. Due to the orientation of supply chains to tailor products and services strictly to customer needs, data analysis and making the right decisions based on it is crucial in the context of not only customer satisfaction, but also in terms of gaining competitive advantage [Maheshwari 2017].

CLOUD COMPUTING AND BIG DATA'S IMPACT ON DIGITAL SUPPLY CHAINS

The main reason for the increasing scale of digitization of supply chains are primarily the changing customer requirements regarding the degree of customization of products and services as well as the pace of their implementation. Processes and activities taking place at ever shorter cycles put pressure on value chain managers, thus resulting in the emerging conviction that the efficiency of traditional supply networks is not sufficient. The need to adapt products to the individual needs of recipients as well as the shortening time of order execution requires from business partners the error-free and the shortest possible analyzes supporting decision-making processes performed at different levels. In the case where traditional analytical systems cannot be used, it is necessary to use autonomous analyzes supporting decision-making processes using tools such as Big Data. The need to use Big Data tools is associated with market requirements for error-free and timely delivery of orders, and requires managers to customize products to fulfill customer needs. It seems clear that supply chains that play a key position in the market must use modern data collection and analysis tools, which, along with the IoT responsible for communication between system participants, form the basis for digitizing value chains, thereby increasing the efficiency of processes implemented by business partners by monitoring flow information in real time, filtering unnecessary data that is not useful in analyzing, forecasting demand or selecting business partners and the best distribution channels [Tahiduzzaman et.al. 2017]. Supply chains supported by Big Data Analytics tools are characterized by a greater degree of effectiveness of implemented processes and competitiveness in relation to networks that do not use

intelligent technologies in the field of autonomous decision-making processes. In addition, Digital Supply Chains deal with the complexity of processes provided to fulfill the requirements of the clients in a much more efficient way. The use of these tools as part of DSC results in an increase in forecast verifiability, efficiency of implemented processes, shortening process cycles as well as response time, reducing the risk level and improving the control of the flow of goods and services [Awwad, Kulkarni, Bapna and Marathe 2018].

Digitization of supply chains depends primarily on the effective exchange of huge amounts of data sent electronically between business partners, which takes place using tools such as the Internet of Things. In order for the information sent between links to be used properly, it is necessary to collect it, as well as process and prepare it for use in subsequent analyzes. Therefore, the use of technologies such as cloud computing and Big Data is crucial from the point of view of the effectiveness of information flow between process management systems of individual business partners as well as their full integration, and thus one of the key elements of intelligent, Digital Supply Chains. In addition, cloud systems are an infrastructure that fulfill the requirements of analytical tools in the context of access to real-time data stored on servers adapted to store countless amounts of information autonomously downloaded and segregated by intelligent systems. The infrastructure covering not only disk space, but also unlimited computing power or access to specialized software is therefore an indispensable element conditioning the development of DSC. Thanks to the use of cloud computing, Digital Supply Chains are characterized by a high degree of implemented processes efficiency resulting from the use of error-free analysis and activities based on decisions often made by machines or devices in an autonomous manner. In addition, DSCs are characterized by a high degree of certainty of implemented processes, transparency of all activities undertaken by business partners, significant simplification of complex processes and low risk level [Toka, Aivazidou, Antoniou and Arvanitopoulos-Darginis 2013].

Pleading the statistics kept by the European Commission, the authors of this chapter indicated an increase in the use of services provided in cloud spaces in the years 2014-2016-2018. The highest increase was recorded in the case of the use of software, while the lowest increase was recorded in the case of the use of electronic mail. These data are presented in Fig. 3.

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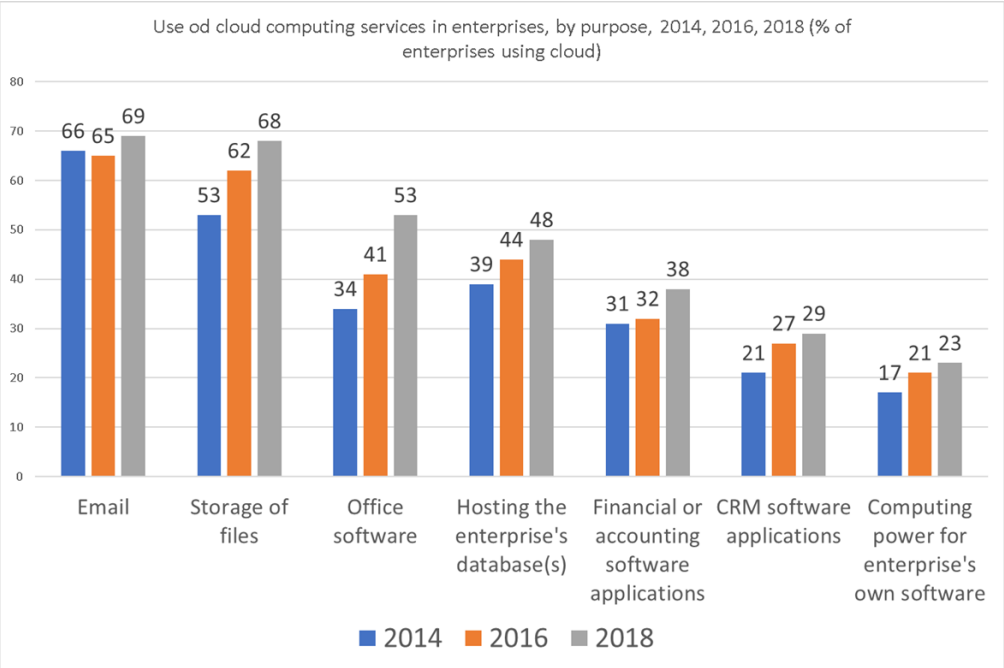

Fig. 3. Use of cloud computing services in 2014, 2016 and 2018. Source: [Eurostat].

In addition, it should be noted that in 2018 all European countries used cloud systems, among which Finland, Sweden, Denmark and Norway, i.e. the Scandinavian countries, have the highest percentage of digitized enterprises. It is worth emphasizing that only in two countries, namely Iceland and the Republic of Macedonia, there was no increase in the use of cloud systems in comparison to 2014. All other European countries are characterized by an increase in the percentage share of digitized enterprises [Eurostat 2018].

The use of Big Data tools is also characterized by growth in recent years and is on average 12% in the European Union, however, the largest share of enterprises using large data sets was recorded in Malta, the Netherlands, Belgium, Ireland and Finland. It should be noted that the percentage share of enterprises using autonomous data analysis increases exponentially, so a significant increase should be expected in subsequent years [Eurostat 2019].

Referring to the report on digitization of supply chains made by Stegkemper, it should be noted that there is a noticeable increase in the digitization of supply chains integrating both business partners and final recipients of individual industries, however the percentage of users using fully digitized information exchange processes is at the level of 28%. 41% of enterprises that partly use autonomous processes still declare that some of the data exchange processes are carried out using traditional methods, while 31% of respondents do

not use modern electronic data exchange solutions between partners and clients, as shown in Fig. 4.

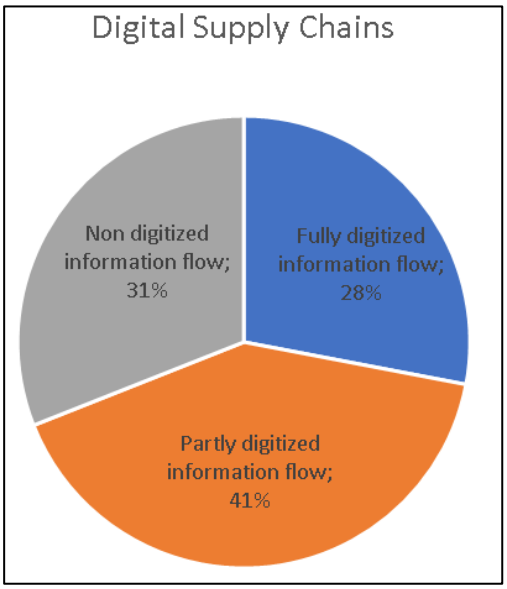

Fig. 4. Percentage of Digital Supply Chains. Source: own work based on [Stegkemper 2016].

The most important reasons for the low use of full digitization of information flow are the insufficient level of trust regarding data sharing or transparency as well as high implementation costs [Stegkemper 2016].

In addition, analyzing the data provided by the European Union regarding the use of big data tools and the relationship between the size of the enterprise and the data source (Fig. 5) it should be noted that enterprises employing over 250 employees are characterized by the use of data collected by their own sensors and based on analyzes carried out by employees of the organization. This relationship is also visible in the context of the use of data by SMEs, in which information taken into account in the analysis of implemented business processes usually comes from social media and geolocation of portable devices to a much greater extent than in the case of large enterprises.

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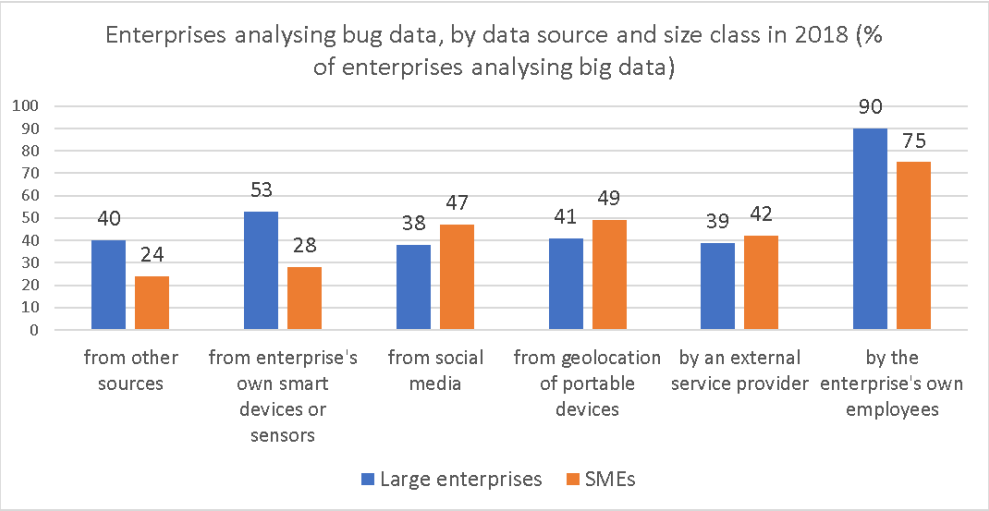

Fig. 5. Sources of data in big data analysis performed by large enterprises and SMEs. Source: [Eurostat].

Analyzing the data collected as part of the interview conducted in seventeen randomly selected enterprises, the relationship between the size of the enterprise and the number of enterprises implementing both cloud computing and big data tools was noticed. In the case of large enterprises, seven out of eleven analyzed do not use cloud computing, which is 64%, while in the case of SMEs this value reaches 83%. In addition, as many as four out of six companies do not use big data tools in the case of SMEs, which is 80%, while in the case of large enterprises this percentage reaches the value of 36%, which is illustrated in Figure 6.

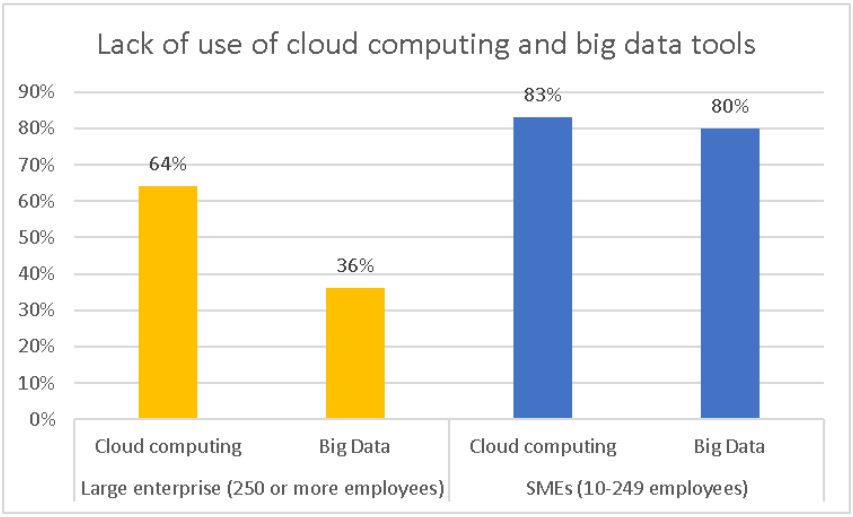

Fig. 6. The level of utilization of Industry 4.0 tools in questioned enterprises. Source: own study.

Considering the fact that the development of DSC is largely dependent on the degree of use of cloud computing and big data tools, the issue of development, especially SMEs, seems very important here. Interviews conducted under this chapter confirmed the assumption

that the degree of use of advanced analytical tools in small and medium-sized enterprises is much lower than in large companies.

Issues that cause this situation include, but are not limited to, financial opportunities and the availability of advanced tools for SMEs that use Industry 4.0 solutions to a much lesser extent..

Considering the fact that the digitization of supply chains depends not only on the use of intelligent industrial or transport solutions, but primarily on the degree of integration of business partners depending on the level of use of electronic information flow, one should agree with the thesis assumed in the preliminary chapter that the increase in the use of intelligent, autonomous tools such as cloud computing and Big Data contribute to the increase in the number of Digital Supply Chains implementing processes based on the assumptions of the Industry 4.0 concept.

CONCLUSIVE REMARKS

This chapter covers the characteristics of Digital Supply Chains, as well as the technologies used in the concept of Industry 4.0, i.e. cloud computing and Big Data, the use of which significantly affects DSC development. The literature analysis carried out in this chapter has allowed to indicate the main relationships that distinguish technologies used in the framework of the integration of processes implemented between business partners and the degree of digitization of supply chains. It should be noted that both Big Data and cloud computing are tools that, along with IoT, are one of the key elements of managing Digital Supply Chains, whose effective functioning is largely possible due to the use of real-time information exchange technology, data collection and processing as well as autonomous decision-making tools that are the pillars of the Fourth Industrial Revolution. It should be noted that managers of traditional supply chains that use the cloud space and autonomous data analysis only partly will have to take into account the loss of customers as well as the decline of their position on the market due to the lack of modification of their strategy in relation to the changing needs of consumers. Digital Supply Chains are characterized by the ability to fulfill the requirements of recipients, as well as react in real time to any changes taking place in the market. Considering the fact that both logistics and supply chains currently need to be customer-orientated they also must be characterized by a high degree of flexibility of processes performed for the final recipients. High DSC flexibility is only achievable if there is full access to real-time data, as well as their analysis enabling a faultless, in most cases autonomous decision-making process determining the efficiency of the entire chain.

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Continuous communication and integration of the management systems of individual business partners located at different levels of Digital Supply Chains is an indispensable element, however, requiring the provision of appropriate infrastructure and software to fulfill customer orders and generate satisfactory profit. Digitization of supply chains is therefore largely dependent on the degree of use of supporting and conditioning tools for integrating all links in the value chain. The increase in the use of cloud computing and Big Data results in a growth of digitization of supply chains.

This chapter verifies the research carried out by the European Union in terms of the use of big data and cloud computig tools, confirming that large enterprises use Industry 4.0 to a much greater extent than SMEs.

This chapter is the basis for conducting detailed future research in the context of the relationship between the increase in the use of Industry 4.0 tools by SMEs in relation to the increase in the degree of digitization of supply chains by increasing the group of enterprises surveyed and the detail of the analysis.

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