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THE ROLE OF INDUSTRY 4.0 IN DIGITALIZATION OF PRODUCTION AND SUPPLY CHAINS

Abstract

Industry 4.0 enables intelligent manufacturing that focuses on designing, creating and delivering products and services tailored to individual customer requirements. This industry encourages the integration of various intelligent manufacturing systems and advanced information technologies, such as cyber-physical systems, the Internet of Things and the Internet of Services. The aim of this paper is to prove, on the basis of analysis of selected academic sources and examples from business practice, that Industry 4.0, as a global transformation of production and other business segments based on digitalization and the Internet, increasingly transforms existing supply chains into supply chains 4.0 and affects their business performance. There are three key parts of this paper. The first part presents the conceptual and business framework of Industry 4.0, as well as its dependence on certain digital technologies. The second part points to the business relevance of supply chains 4.0 and the technological conditionality of their adaptation to customer expectations. The last part proves the fact that Industry 4.0 enables the company to be transformed into a digital supply chain (supply chain 4.0) that can successfully respond to changes in the environment.

Keywords: *Industry 4.0, digital technologies, internet, supply chain 4.0, environmental challenges.*

JEL classification: *L86, M11, O33*

УЛОГА ИНДУСТРИЈЕ 4.0 У ДИГИТАЛИЗАЦИЈИ ПРОИЗВОДЊЕ И ЛАНАЦА СНАБДЕВАЊА

Апстракт

Индустрија 4.0 омогућава интелигентну производњу која се фокусира на дизајнирање, креирање и испоруку производа и услуга прилагођених индиви-

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дуалним захтевима купаца. Ова индустрија подстиче интеграцију различитих интелигентних производних система и напредних информационих технологија, као што су сајбер-физички системи, интернет ствари и интернет сервиси. Циљ овог рада је да се на бази анализе одабраних академских извора и примера из пословне праксе докаже да Индустрија 4.0, као глобално трансформисање производње и других сегмената бизниса на бази дигитализације и интернета, у све већој мери трансформише постојеће у ланце снабдевања 4.0 и детерминише њихове пословне перформансе. Три су кључна дела овог рада. У првом делу се презентују концептуални и пословни оквири Индустрије 4.0, као и њена зависност од одређених дигиталних технологија. У другом делу се указује на пословну релевантност ланаца снабдевања 4.0 и технолошку условљеност њиховог прилагођавања очекивањима купаца. У последњем делу се доказује чињеница да Индустрија 4.0 омогућава трансформисање компаније у дигитални ланац снабдевања (ланац снабдевања 4.0) који може успешно одговарати на промене окружења.

Кључне речи: *Индустрија 4.0, дигиталне технологије, интернет, ланац снабдевања 4.0, изазови окружења.*

Introduction

In the last three decades, there has been a revolutionary development of systems based on information technologies, which has affected all aspects of life. Computer-integrated systems connected to the Internet are increasingly present. Using information from different sources not only expands the possibilities for connecting people and machines in the context of cyber-physical systems, but also the possibilities for direct communication between machines. Such connections and communications are made possible by an Internet-based network. The introduction of this network in production and other business segments is called Industry 4.0.

The basis of Industry 4.0 is a wide range of digital technologies, the application of which enables the digitalization of processes and supply chain activities. Despite the constant spread of knowledge about Industry 4.0 technologies, both by researchers and managers, the real impacts of these technologies on the supply chain, whether positive or negative, are still not fully clear and identified. Aware of this, after presenting the key features of some of the Industry 4.0 technologies and the characteristics of supply chains 4.0, we strive to identify the capabilities of these chains to respond more successfully than traditional chains to the challenges of the environment.

The implementation of digital technologies in supply chains is a complex and challenging process for companies. Companies that are able to minimize or remove barriers to the implementation of these technologies will achieve better results in integrating supply chain processes and activities and meeting growing customer expectations.

Industry 4.0 in modern supply chains

The term Industry 4.0 (German *Industrie 4.0*; English *Industry 4.0*) was first used by *Robert Bosch GmbH* in 2011 at the Hannover Messe 2011 in Hanover. Experts then said that a new industrial revolution had arrived with innovations in production, brought about by the era of information. After the end of the fair in Hanover, the Working Group for Industry 4.0 was formed. In October 2012, this working group, chaired by Siegfried Dyce (CEO of Robert Bosch GmbH) and Henning Kagermann (CEO of SAP AG), presented to the Government of Germany a set of recommendations for the implementation of Industry 4.0 to promote the computerization of production. On April 8, 2013, the working group presented its final report at the Hanover trade fair. Since then, the rapid global expansion of the term Industry 4.0 has begun, as an increasing number of companies in the entire manufacturing sector are beginning to consider the potential of interconnected cyber systems in factories.

Industry 4.0 is characterized by an achieved level of automation, where machines can often largely manage themselves in many ways, using technologies such as: Internet of Things; cyber-physical systems (mechanical devices controlled by computer algorithms) that were created in 2006 by Helen Gill of the American National Science Foundation; technology of Big Data; Cognitive Computing − technology platforms that use artificial intelligence; augmented reality; additive manufacturing − production of a three-dimensional object from a digital model; simulation and modeling; automation and industrial robots; cybernetic security; blockchain technology; semantic technologies; Internet of Data − the concept of a network consisting of data entities that originate from the Internet of Things, i.e. the expansion of the Internet of Things into the digital world, because the amount of data collected is staggering.

Industry 4.0 promotes the use of these technologies. They appeared in the 21st century and were mainly implemented in supply chains by companies in developed countries. Such technologies enable companies to improve flexibility, quality standards, efficiency and productivity, as well as to create values through the constant introduction of new products and services tailored to market requirements. They also affect the supply chain and the context of Industry 4.0 and are sources of its competitive advantage. Some of the listed technologies will be presented in this part of the paper (Choo, October 2010, pp. 1-6).

Strogilopoulos and Tsiouki point out that Industry 4.0 is a “common term for technologies and concepts of value chain organization” which includes: cyber-physical systems, Internet of Things and Internet of Services. In Industry 4.0’s modularly structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions. Through the Internet of Things, cyber-physical systems communicate and collaborate with each other as well as with people in real time, while through the Internet of Service, value chain participants offer and use internal and interorganizational services (Lee, Lapira, Bagheri, & Kao, pp. 38-41).

McKinsey experts state that Industry 4.0 represents the fourth major turnaround in modern manufacturing, after the lean revolution of the 1970s, the phenomenon of outsourcing of the 1990s, and automation that began in the 2000s (Strogylopoulos, & Tsiouki, 2016).

Understood as an intelligent manufacturing system that focuses on the design, manufacture and delivery of products and services tailored to individual requirements, Industry 4.0 encourages the integration of a variety of intelligent manufacturing systems and advanced information technologies. In addition, it represents a radical shift in the way production facilities operate.

As pointed out, the term Industry 4.0 originated in Germany. However, in other European countries it is also known as: Smart Factories, Smart Industry, Advanced Manufacturing or Industrial Internet of Things. Advanced manufacturing is a major aspect of Industry 4.0. It can be defined as a family of activities that depends on the use and coordination of information, automation, computing, software, discovery and networking, and/or uses state-of-the-art materials and new opportunities provided by the physical and biological sciences.

The US National Institute of Standards and Technology uses the term smart manufacturing. These are "fully integrated" collaborative production systems that respond in real time to changing demands and conditions in a smart factory and supply network as well as changing customer needs (Wu, Yue, Jin, & Yen, 2016, pp. 395−417).

In the US, the term Industry 4.0 is often defined as the Internet of All.

Industry 4.0 facilitates the design and creation of smart factories (factories of the future) in which cyber-physical systems monitor physical processes, create a virtual copy of the physical world, and enable decentralized decision-making. Smart factories make it possible to connect machines and people into cyber-physical systems. These systems focus their resources on the introduction of intelligent products and industrial processes that enable the industry to cope with rapid changes in purchasing patterns.

The Capgemini Research Institute described smart factories as "digital platforms and technologies" aimed at significantly improving productivity, quality, flexibility and services. The economic impact of these factories is great, especially in the manufacturing industry. One study by the Institute found that by increasing investment in smart factories and overcoming certain challenges in Industry 4.0 (convergence of information and manufacturing technologies; and acquiring the skills needed to drive digital transformation in smart manufacturing, including multifunctional capabilities, digital talent and "soft" skills), the manufacturing industry could increase the value of the global economy annually from 1.47 to 2.2 trillion US dollars by 2023 (Khanna, 2016, pp. 357−365).

Smart factories create an environment in which smart machines can communicate with each other, not only to enable the automation of production lines, but also to analyze and understand certain problems in production, with minimal employee participation.

Industry 4.0 allows one to increase: flexibility, quality standards, efficiency and productivity. This will enable companies to adapt to customer requirements, through value creation by constantly introducing new products and services to the market.

Industry 4.0 has changed a number of professions. Thanks to this industry, people are getting to know new jobs every day, but they also use high-tech devices that are quickly becoming the most important factor in their working life.

The integration of the supply chain process and the transparency of information between customers and suppliers are key results of Industry 4.0. Without implementing technologies that enable Industry 4.0, it is not possible to optimize business processes in supply chains.

Industry 4.0 is one of the most important research topics, which is increasingly attracting the attention of academics and practitioners. Many scientific papers have been published on this topic. The number of scientific papers related to supply chains 4.0 is also increasing. However, the results of research to date on the very relationship between Industry 4.0 and Supply Chain 4.0 are still modest. Fortunately, there is a growing interest of scientists and practitioners in researching these (Burg, Chattopadhyay, Lam, 2017, pp. 38−60) relationships, as well as the nature of the supply chain 4.0 conceptual framework. Also, a growing number of scientists and practitioners want to learn about the role of Industry 4.0 in integrating supply chain processes and propose guidelines for further research (Tjahjono, Peláez-Lourido, Enrique, 2017, pp. 1175–1182).

Technological support to supply chains 4.0

Supply Chain 4.0 is defined as "…a series of interrelated activities related to the coordination, planning and control of products and services between suppliers and customers." (https://www.campaignlive.co.uk/article/amazons-anticipatory-shipping-explained/1228379). The goal of such a chain is to generate new ways of adding value to customers and suppliers as well as increase revenue through the integration and coordination of its processes such as: forecasting, procurement, production, distribution, sales and marketing.

Wu et al. (Xu, Yu, Griffith, Golmie, 2018, pp. 78238−78259) distinguish six supply chain characteristics 4.0 (Table 1). They are, first of all, the result of the implementation of four technologies (Internet of Things, cyber-physical systems, cloud computing and big data) which are considered to be the technological basis of Industry 4.0 (Martins, Simon, Campos, 2020, p. e5427).

Table 1: Supply Chain 4.0

Characteristics	Description
Equipped with measuring instruments	Systems with sensors, RFID tags, meters and other integrated components, capable of generating data for decision making.
Interconnected	Supply chain members fully connected, including their assets, IT systems, products and other smart facilities,
Intelligent	Intelligent systems capable of making decisions to optimize their global performance by collecting and analyzing large amounts of data
Automated	Numerous automated activities aimed at replacing less efficient resources (including manpower).
Integrated	Integrated supply chain activities, which include cooperation between members, joint decision-making, use of common systems and exchange of information.
Innovative	Able to develop and integrate new values through more efficient solutions.

Source: (Zekhnini, Cherrafi, Bouhaddou, Benghabrit, Garza-Reyes, 2021, pp. 465−501).

Internet of things. The term Internet of Things was first used by Kevin Ashton in 1999 during his presentation to convince the senior management of the company where he worked (Procter & Gamble) that it is necessary to put an RFID (Radio−Frequency Identification) tag (tag i.e. microchip) on everything it produces (Frederico, Garza-Reyes, Anosike, Kumar, 2019). The simplest Internet of Things can be described as a set of interconnected devices with built-in sensors that can provide data and/or be controlled over the Internet; Cloud technologies that enable backups on a server or medium elsewhere outside the primary server, all for the purpose of data protection.

The Internet of Things connects physical objects on the Internet (Uckelmann, Harrison, Michahelles, (Eds.), 2011) by integrating sensors, actuators, and other devices that collect, transmit, and process data (Ghobakhloo, 2018, pp. 910−936). In the supply chain, this technology connects business and web applications (such as social media) with machines, devices, products, materials and people, and thus enables the creation of an intelligent network that extends through all factory processes of both customers and suppliers (Szozda, 2017, pp. 401−414).

These are billions of physical devices around the world that are connected to the Internet. All are capable of collecting and sharing data.

Thanks to the advent of super cheap computer chips and the ubiquity of wireless networks, it is possible to turn anything (from something small like a tablet to something big like an airplane) into a part of the Internet of Things. Connecting all these objects and adding sensors to these objects increases the level of digital intelligence of the device and provides the ability to exchange data in real time without the involvement of a human (Frederico, Garza-Reyes, Anosike, Kumar, 2020, pp. 262−282). The Internet of Things makes the world around us smarter and more responsive. It connects the physical and digital universes.

Almost any physical object can be transformed into an internet thing (device) if it connects to the internet to manage or communicate information. A light bulb that can be turned on using an application in a smartphone is an internet thing, as well as a motion sensor in the apartment. Such devices can be in the engine of a jet plane, and far more within the project of smart cities where entire regions are filled with sensors that help in understanding and controlling the environment. In 2017, Levi's produced a $ 350 smart jacket, called Levi's Commuter Trucker Jacket, which is made possible by Google's Jacquard clothing platform (Xu, Yu, Griffith, Golmie, 2018, pp. 78238−78259). On the left sleeve of such a jacket, there is a module that is connected to a smartphone. The user of the jacket can, by simple hand swipe or by tapping the sleeve of a jacket, answer calls while riding a bicycle, standing in a crowded train or carrying groceries, without direct contact with his smartphone.

Technology known as the Internet of Things is generating positive changes in industry, medicine, logistics and households. It also enables: direct communication of machines, i.e. to tell each other what they need and when they need it; growth in the number of everyday items to be controlled remotely and labor market restructuring.

The new trend of digitalization is included in the concept of Retail of Things, which is a specialized component of the Internet of Things. Retail combines hardware and software tailored to retail applications. The key is the technology, i.e. devices and components that enable retail chains to improve customer connectivity and use the collected data to optimize business goals. Research by the American RFID Lab Institute has shown that the use of RFID technology at the level of individual items increases the accuracy of inventory management from 65 to more than 95 percent (Frederico, 2021, p. 49).

The implementation of the Internet of Things and sensors in retail has a key role to play in automating malicious processes such as gathering product information by bar code scanning, application integration, and mobile payments. A 2016 Cisco survey of the Internet of Things found that nearly 48 percent of retail processes can be automated (Tiwari, 2021, pp. 990‒1030). The number of retailers implementing technologies such as the Internet of Things and sensors is increasing. This technology allows connected devices to be transformed into smart devices and generate large amounts of business-relevant data.

The value of the global Internet of Things market is constantly growing. In 2019, it amounted to 250.72 billion US dollars, but by 2027 it could reach 1463.19 billion US dollars (da Silva, Kovaleski, Pagani, 2019, pp. 546‒562). The following companies play a key role on the global Internet of Things market: *Amazon.com Inc., AT&T Inc., Bosch Software Innovations GmbH, Cisco Systems, Inc., IBM Corporation, Intel Corporation, Oracle Corporation, Microsoft Corporation, SAP SE* and *Siemens AG*. The global increase in demand for artificial intelligence, digital twin technology and *precision farming* will spur the growth of the global Internet of Things market.

Cyber-physical systems. The term Cyber Physical Systems was first used in 2006 by Helen Gill of the National Science Foundation (Bordel, Alcarria, Robles, Martín, 2017, pp. 156‒184). These systems emerged in response to the need to develop a conceptual and efficient framework regarding the growing interactions between cyber computing systems and physical hardware. Cyber-physical systems include machines, storage systems and production facilities that are digitally developed and represent a complete (end-to-end) integration based on information and communication technologies. These are smart complex systems constructed by connecting integrated information processing subsystems and physical subsystems. The characteristics of these systems are: decentralization, adaptation and autonomous behavior. They enable the supply chain to monitor production conditions and logistics activities in real time, and to perform forecasting, remote diagnostics and control based on that (https://www.zdnet.com/article/google-and-levis-unveil-internet-connected-jacket/).

Cyber-physical systems, as concepts and technologies of Industry 4.0, are becoming increasingly important for the digital transformation of the supply chain. The use of cyber-physical systems provides the necessary prerequisites for flexible planning and control of supply chains.

Cloud computing. In the last three decades, there has been a shift from computers to smart devices that use infrastructure services based on cloud computing. Cloud computing (abbreviated cloud) (Tseng, Tan, Chiu, Chien, Kuo, 2018, pp. 146‒147), which has been on its way since 2006, uses a service delivery model known as SPI (Software Platform Infrastructure) and identifies three key groups of services provided through the cloud: Software-as-a-Service, Platform-as-a-Service and Infrastructure-as-a-Service (Birkel, Veile, Müller, Hartmann, Voigt, 2019, p. 384).

Cloud computing aims to integrate technologies or architectures to provide a platform or solution over the Internet, which would be available anytime and anywhere, and provide unprecedented visibility and flexibility.

The use of cloud computing in supply chains is still in its infancy. In addition, revenues from the sale of supply chain management software exceed $ 19 billion.

Hybrid supply chain management is increasingly present, which is the result of the coexistence of cloud-based applications and applications enabled by software installed on a company's computer (on-premise). Management of information hubs and vendor networks is largely cloud-based.

Cloud technology enables precise product monitoring during its life cycle. This technology can significantly reduce product loss, as it allows the shipment to be located during any stage of transport. It also allows supply chain managers to quickly redirect misdirected shipments.

Cloud computing is transforming the supply chain management process. Data integration of suppliers, service providers, etc. in the "supply chain cloud" provides the ability for all stakeholders to manage and decide based on the same facts.

Easyship is one of the most well-known cloud software that enables e-commerce companies to more effectively manage local and international deliveries (Zekhnini, Cherrafi, Bouhaddou, Benghabrit, Garza-Reyes, 2021, pp. 465−501).

Big data. The exponential growth of the amount of available data is primarily the result of the development of information technologies and the Internet, i.e. hardware capacities (data storage and processing capacities) and software capacities (development of new applications). Eric Schmidt, president of Google, points out that since the creation of civilization until 2003, a total of five exabytes (10^{18} bytes) of data has been created, which is the amount of data that is created today in less than two days. This enormous growth in available data is characteristic of almost all areas of life and business, from food, sports and leisure, through trade, finance, medicine and telecommunications, to security system management and environmental protection. Hyperproduction of data requires new approaches in its processing that are based on the use of information technologies that enormously exceed the analytical capacity of people. This has led to the development of a whole new dimension in data analysis called Big Data Analytics.

What does the term Big Data actually mean? In short, it represents the amount of data that exceeds the capabilities of commonly used computer techniques for their storage and processing. It is a large set of data from different sources, both traditional and digital, that can be used to obtain different results using different types of analyses. It is not necessary that all analyses use all data. The term big data, in addition to a large amount of data, also means innovative forms of data processing in order to improve the decision-making process and optimize the business processes of supply chains. The key characteristics of big data are: high database growth rate (Volume), high data diversity (Variety) and extremely high speed at which new data arrives (Velocity).

Big data differs according to five dimensions: (1) scope, (2) diversity, (3) speed, (4) truthfulness, and (5) value. It can be used for descriptive, predictive and prescriptive business analytics (Wang, Hulstijn, Tan, 2016, pp.76−85.).

In the supply chain, big data refers to applications that include material flows (related to: production status; process and quality; inventory management; logistics; research and development and collective solutions in procurement and distribution functions), information flows (related to: demand management, supply chain event management (type of business software for managing events occurring within and between supply chain organizations or partners), negotiations with suppliers, risk management, problem identification, automated decision support and management customers) and financial flows (related to: customer segmentation; demand modeling; designing a new business model; prices and assortment and financial aspect of human resources) (Marwedel, 2021).

In addition to the listed technologies, the following technologies, too, affect the functioning of supply chains in the context of Industry 4.0 and their competitive advantage: additive manufacturing, automation and industrial robots, augmented reality, cybersecurity, blockchain, internet data, people and services, semantic technologies and simulation and modeling.

Thanks to these technologies, their subsystems and devices, it is possible to integrate the entire supply chain (not only customers and suppliers, but also their assets, products and operating environment) and generate a larger amount of higher quality data faster (Uckelmann, Harrison, Michahelles (Eds.), 2011). Such technologies enable companies to reorganize the entire business in real time and thus create conditions not only for the growth of flexibility, productivity and responsiveness, but also for reducing the bullwhip effect and the total cost of the supply chain.

Advantages of supply chain 4.0

Industry 4.0, the technologies that form the basis of that industry, and changing customer expectations require companies to review business practices and adjust their supply chain.

Supply chains are facing increasingly dynamic changes in the environment. One of the most radical changes is the transition from computers to smart devices that use cloud-based infrastructure services. Still, the key changes in the environment are generated by online business, the expansion of which increases customer expectations regarding services and leads to the fragmentation (granulation) of orders. It is the growing expectations of customers that play a key role in supply chain management. In the business environment, the need for individualization and adaptation is growing faster, which requires a constant change of the portfolio of unique products. The Internet increases the transparency of the offer and facilitates access to a multitude of options regarding where and what to buy.

Supply Chain 4.0 can respond successfully to these changes. Compared to traditional, supply chains 4.0 are: faster, more flexible, more responsive to individually smaller orders and more accurate.

Supply Chains 4.0 enable faster delivery of products to customers. Thanks to new approaches to distribution, such supply chains shorten the delivery time of high-performance products to several hours. The basis of fast product delivery is advanced approaches to demand forecasting. One of such approaches is predictive analytics, which enables a very accurate forecast of customer demand not on a monthly basis, but on a weekly basis, and for products that sell quickly, on a daily basis. In the future, there will be so-called “predictive i.e. anticipatory delivery” for which Amazon holds a patent (Abdirad, Krishnan, 2021, pp. 187–201). It is a revolutionary method of delivering products to customers, which means that delivery of the product begins before the customer orders it. The customer’s order is later reconciled with the shipment that is already in the logistics network (transported according to the customer’s region) and that shipment is redirected to the exact destination of the customer. Amazon has been using this delivery method since 2014. At the beginning of its application, it was thought that it would be just an expensive logistical nightmare for Amazon. However, it turned out that it started a real revolution in retail sales and enabled Amazon to leave many rivals behind. The idea is to predict what customers want based on certain data, and then to have the products delivered to them automatically. Amazon and other online retailers are investing in machine learning to accurately predict customer demand and ship products before customers place an order. In this way, they reduce the costs of processing and delivering orders. Amazon can “predict” orders, because it has plenty of information about its customers and knows when and what to buy.

Compared to traditional supply chains, supply chains 4.0 are more flexible. Ad hoc and real-time planning of processes and activities enables flexible response of supply chains 4.0 to changes in supply and demand. With supply chain 4.0, planning becomes a continuous process, while planning cycles and so-called frozen periods are kept to a minimum. These chains can respond dynamically to changing requirements or constraints. Such a response is significant, for example, when large oscillations in the use of machine production capacity are identified on the basis of real-time feedback. Flexibility in delivery is also significant. After shipping the product, increased flexibility in delivery allows customers to redirect shipments to the most convenient destination.

New business models for supply chain function planning or transportation management, such as Supply Chain as a Service, increase the flexibility of supply chain organization. Companies can buy and pay the supply chain as a service based on use, instead of using their own (internal) resources and capabilities. Such specialization and focus on service providers enable companies to realize economies of scale and economies of breadth, as well as to exploit the potential of outsourcing. By entering into a partnership with a particular service provider, to support all or part of the operations of their supply chain (procurement, production control, production, quality control, warehousing and logistics), companies can increase their return on investment by four to five times (Núñez-Merino, Maqueira-Marín, Moyano-Fuentes, Martínez-Jurado, 2020, pp. 5034–5061).

Supply chain as a service is a new model of flexible service, which allows companies to achieve economies of scale without investing in people, processes and equipment. A good example is the “uberization” of transport (offering flexible transport capacity to people who need transportation services (crowdsourcing)), which leads to a significant increase in agility in distribution networks (Müller, Voigt, 2018, pp. 659–670).

Crowdsourcing is a procurement model in which individuals or organizations procure goods or services, including ideas, microtasks, and finances, from a large, relatively open, and often rapidly evolving group of participants. Uber is one of the best examples of crowdsourcing. Uber connects available drivers with people who need transportation services. Crowdsourcing involves getting work, information, or opinions from a large group of people who submit their information through the Internet, social media, and smartphone apps. People involved in crowdsourcing sometimes work as paid freelancers while others perform small tasks voluntarily. For example, traffic-related applications encourage drivers to report accidents and other problems on the road to provide users with real-time information.

Supply Chains 4.0 are becoming more willing to respond to customers’ individually smaller orders. Customer demand for more individualized products is constantly growing. This strongly encourages the offer of a wide range of products tailored to customer requirements. Thanks to Industry 4.0, customers have the opportunity to choose one of several “logistics menus” that exactly suits their needs.

New product transport concepts, such as drones, enable companies to efficiently manage the delivery of individual products as well as high-density and high-value products, from a central distribution hub to final destinations – companies or costumers (last mile). Due to the relatively low share of transportation costs in the price of these products, companies can use faster and more expensive modes of transportation. The English term last mile is used in supply chain management and transport planning to describe problems (such as rising delivery costs) that occur in the last segment of product delivery – from the central distribution hub to the final destinations. Products can be delivered to this hub by ships, trains, large trucks or planes. However, a number of difficulties arise after loading these products into smaller vehicles and delivering them to their final destinations – individual companies or customers.

Supply Chains 4.0 provide more accurate information. Modern digital performance management systems provide information that ensures transparency of the entire supply chain in real time. The information ranges from synthesized top-level key performance indicators (KPIs), such as overall service level, to highly detailed process information, such as determining the exact position of trucks in the network. This information represents a common basis for all levels of management and functions in the supply chain. Integration of information from suppliers, service providers, etc. into the "supply chain cloud" ensures that all stakeholders manage and make decisions based on the same facts.

In digital performance management systems, storage, transport, or inventory costing models are used to automatically set goals. In order to maintain the aspiration of supply chains towards goals and in case of their interruption, digital performance management systems automatically adjust goals to realistically achievable ones. Such systems "learn" to automatically identify risks and change supply chain parameters.

Automation of physical tasks and planning increases the efficiency of the supply chain. The robots, which are one of the key drivers of Industry 4.0, handle the material (pallets and boxes, as well as individual pieces) in the entire warehouse, completely automatically. Autonomous trucks transport products within the supply chain. In order to optimize truck use and increase transport flexibility, transport between companies in the supply chain is optimized.

Ideally burdening resources in the supply chain is a difficult goal to achieve. By using information to ensure transparency of the entire supply chain and dynamic planning, it is possible to initiate advanced demand shaping activities (e.g. to provide customers with the option to choose the time of delivery) with little use of means of transport.

Conclusion

The term Industry 4.0 has been around for ten years and represents the development of manufacturing and value creation systems by connecting the real and digital worlds. At the heart of this connection are self-controlled cyber-logistics systems that enable vertical and horizontal integration for efficient, decentralized and flexible production of products or services along the supply chain.

Digitalization is a prerequisite for the functioning of Industry 4.0. Industry 4.0 depends on the application of a wide range of digital innovative technologies (Internet of Things, additive manufacturing, process automation, artificial intelligence, big data, automation, virtual reality, robotics, etc.).

Industry 4.0, as a result of the strong integration of information and communication technologies to connect the physical world with the virtual world, creates new conditions for connecting and integrating companies and their resources. In this way, companies and supply chains can improve performance in terms of time, money and resource use.

Industry 4.0 enables the company to be transformed into a supply chain 4.0 (digital supply chain). Improving the business performance of companies will increasingly depend on the use of technologies to digitally transform their processes and activities. Unlike traditional, digital supply chains are: faster, more flexible and more responsive to individually smaller orders and able to more accurately meet new customer requirements and supply-side challenges.

The digital transformation of processes, generated by the use of digital technologies, enables the improvement of the competitiveness of companies and supply chains.

Scientific knowledge of the relationship between Industry 4.0 and Supply Chain 4.0 is still limited. The results of studies dealing with the role of Industry 4.0 in the integration of supply chain 4.0 are also modest. New theoretical and empirical research would significantly improve the understanding of the supply chain concept 4.0 and make its application in business practice more rational.

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