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The Importance of Digitalization and Innovation within the Framework of Industrial Revolution in the Context of Modern Challenges

Abstract. An analysis of the main digital trends within the framework of Industry 4.0 and its successors — Industry 5.0 and Industry 6.0 has been conducted in this paper. The concept of digitalization has been analyzed as a prerequisite to innovative technologies' development. It has been substantiated that digitalization and automation can help increase labor productivity and ensure resource savings, improve interaction with customers, detect changes in customer needs in a timely manner and effectively respond to current pandemic and geopolitical challenges. The results of the study demonstrate clear signs of the need for further digital development and innovation to support industrial transformation and future industrial revolution. It has been recommended for the global industrial manufacturers to actively work towards digitalization strategy development and use analytics, process analysis and robotic process automation as key technologies to build further innovations upon.

Keywords: industrial revolution, Industry 4.0, Industry 5.0, Industry 6.0, digitalization, innovation, advanced technologies, digital production

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1. Introduction

Global and domestic industry today faced the challenges of the geopolitical crisis, the COVID-19 pandemic and other negative factors that disrupt supply chains, production sustainability, change the labor market and increase labor turnover. Each of these challenges has a negative impact on the development of industrial production, but at the same time defines and stimulates innovation and transformation, especially given the progress of digital technologies. Digitalization of-

fers companies a basis for the implementation of modern advanced technologies and innovations: additive manufacturing, artificial intelligence (AI) and machine learning (ML), augmented and virtual reality (AR/VR) and industrial metauniverse.

The evolution of information systems and technologies in general has contributed to the progress of the digitalization of industry, which has forced companies to increase their investment in solutions and tools that allow the automation of processes within the company and improve their productivity. Global industrial manufacturers pay special attention to the process of production development, investing in new technologies adapted to their requirements.

Industrial manufacturing companies today are actively working towards digitalization strategy development and use analytics, process analysis and robotic process automation as key technologies, thus optimizing production processes for digital production. Digital business models and automation of production systems aim to achieve the highest cost efficiency, better customer satisfaction, greater transparency and faster processes to ensure sustainable economic success. By reducing low-value-added processes, the saved resources can be redirected to improve other strategically important processes.

2. Digitalization and the Digital Revolution as Prerequisites for the Emergence and Development of Industry 4.0

It was digitalization and the digital revolution that became a prerequisite for the emergence and development of Industry 4.0. The concept of “Industry 4.0” emerged after the digital revolution, and this concept is based on close interconnection, automation and machine learning. The concept of “Industry 4.0” was first presented in 2011 thanks to the strategic initiative of the German government. One of its strategic goals was the maximum digitalization of companies’ activities, using the potential of new technologies. Each of these technologies has benefits and capabilities that can help companies address today’s challenges of supply chain disruption, resilience and changing working conditions, as well as employee turnover (Steden and Kirchner, 2018).

There are still debates among scientists and practitioners regarding the universal definition of the industrial revolution, and the technological revolution itself is viewed through the prism of four generally recognized stages. The first revolution is characterized by the introduction of mechanical means for the production of water and steam, the second covers the application of electrical technologies of mass production. The use of electronics and information technology (IT) that

support additional automation of production characterizes the third revolution. Finally, the use of the Internet of Things (IoT) and Cyber-Physical Systems (CPS) project a new industrial revolution (Khaitan and Mccalley, 2014). The term «Industry 4.0» arose in the context of innovation policy, which is defined by the combination of advanced technologies in which the Internet is widely used to support other technologies, such as the integration of intelligent machines, people and physical objects, throughout the organizational value chain (Borras and Edquist, 2013).

Industry 4.0 transforms production systems by digitizing processes and business models, as well as by automating and expanding the use of the latest technologies. Often, ways to improve Industry 4.0 are evaluated in terms of productivity, flexibility and efficiency. Given how rapidly new technologies are changing the economy and society in general, it is important for governments to have objective mechanisms for assessing the timeliness and pace of technological advancements to achieve inclusive economic growth.

Innovation is necessary for effective development in the era of the Fourth Industrial Revolution, so many countries have developed plans to stimulate industrial innovation and digitalization, which often differ by region and level of economic development. Innovation is the main driver of the development of domestic science and technology, but the risks associated with the financing of innovation are high due to the uncertainty of the rate of return on investments, mainly related to high-tech products. The policy of stimulating the progress of science and technology affects not only scientific, technical and industrial development, but also accelerates the formation of national industrial competitiveness. Government policies on industrial innovation can reduce business difficulties and, thus, corporate leaders can innovate more effectively and take risks (Kniaziev, 2020).

An example of a successful strategic initiative for the development digital transformation is German «Industrie 4.0» (Industrie 4.0 (I40)) — a national strategic initiative from the German government through the Ministry of Education and Science (BMBF) and the Ministry of Economy and Energy (BMWi). This initiative is aimed at the development of digital technologies in production by increasing the digitalization and interconnection of products, value chains and business models. It also aims to support research, a network of industry partners and standardization. I40 is designed for 10–15 years and is based on the German government strategy «Strategy of high technologies 2020». The initiative was launched in 2011 by the efforts of the Industry Science Research Alliance (FU) with the assistance of the Ministry of Education and Science. Its result was the approval of the High Technology Strategy 2020 Action Plan. Representatives of German industry and other interested parties see I40 as a strategic initiative and a mechanism for consolidating German technological leadership in mechanical engineering and

industry in general. I40 managed to limit segregation among industry sectors, rapidly translate scientific research into common practice in a fairly short period of time, and scale nationally into the largest industry community united around a given initiative (Rodrigues et. al., 2021).

Approximately 15 million jobs in Germany are directly or indirectly related to the production of goods, so the evolution of digital technologies in manufacturing opened up key opportunities for German manufacturers. As a leading supplier of industrial equipment at the global level, the digital restructuring of German industry created the prerequisites for increasing the international competitiveness of German production and creating new jobs (Rodrigues et. al., 2021).

Modern digital industrial production consists of a set of integrated, cross-functional smart manufacturing approaches at the enterprise level that take advantage of today's advanced information systems, technologies, and tools to improve manufacturing competitiveness through efficient supply chains, high flexibility and optimized energy efficiency, enabling efficient production of highly customized product and components from digital designs at the right time and place. The key components of such production include an improved research and development mechanism, as well as taking into account the final speed and productivity, efficiency of supply chains, output processes, energy efficiency and improved sustainability in the production process; improved security, configurability and flexibility of the process, as well as a higher level of satisfaction and professional pride in the work performed. Modern digital industrial production defines how digital flows, integrated information systems, big data and analytics mutually reinforce and ensure a high level of use of advanced information technologies by the industrial complex in order to improve the competitiveness of the latter. Digital flows connect data supply chains (from creation, transformation, extension, manipulation, transformation to use) that reflect the evolution of a product throughout its life cycle from conception to production and to its end use, including maintenance.

An efficient digital flow enables the interconnection, visualization, interpretation and optimization of digital designs through integrated artifact modeling while the product structure is produced digitally through manufacturing add-ons or is used to digitally drive traditional manufacturing in multi-enterprise end-to-end supply chain operations. Such digital flows predict the future of production, where the time from design to production is significantly optimized thanks to advanced manufacturing technologies, high-precision modeling and simulation, new models of human interaction (for example, the use of virtual reality and environments), which will significantly shorten the process of creating a design, developing a prototype and testing cycles.

Integrated information systems foresee the future of production using knowledge, data and key attributes that will positively influence the speed of development of digital designs, will be effectively exchanged and used by actors and objects of supply chains at many levels (manufacturers, consumers, suppliers, distribution users, supply nodes, partner channels, etc.) with no or low resistance to ensure high quality and configurability of products for consumers. The integration of currently diverse heterogeneous centers of information automation will reduce time and costs of inventory and components in production, as well as quickly identify problems for prevention and corrective interventions and develop decision-making scenarios to ensure maximum production efficiency.

Big data, visualization and analytics provide a new level of knowledge, technical capabilities and tools to use all the data that may still be untapped, to obtain and anticipate results (predicting consequences and adjusting actions) from this production data. This data should be collected and categorized from disparate systems, devices, networks and people using open metadata standards. There is a need for new visualization and analytics models that capture data that is collected or stored at various stages of production and parts of operational equipment, in various applications and tools within end-to-end supply chains for more agile, real-time decision-making. This data must be properly linked with digital flows from design, modeling, simulation, prototyping, testing, as well as non-operational data such as energy and product management data to enable digital flows and digital manufacturing to improve efficiency of production. The widespread use of sensors and devices in the production process and supply operations will increase the need for improved management to effectively use the large volume of data. These large amounts of data need to be effectively managed throughout the product lifecycle using a data lifecycle management system. The data cybersecurity framework in the context of digital flows is key to enabling effective Big Data production and competitive advantage.

3. Digital Technologies and Innovations as Tools of the Industrial Revolution

Industry 4.0 involves the widespread use of advanced technological innovations that allow making effective and accurate engineering choices in real time by combining a number of information and communication technologies with existing production systems. Digital flows are a crucial component of Industry 4.0, and the combination of digital technologies and operations with manufacturing technologies enables vertical integration of intra-organizational systems and horizontal

integration of inter-organizational systems through the IoT, cloud technologies and computing services, as well as end-to-end balanced solutions along the entire value chain (Gilchrist, 2016).

Among the main technologies driving the industrial revolution today are CPS, blockchain, AI, digital twinning, IoT, big data and analytics, cloud computing, and additive manufacturing. A CPS integrates real-world physical processes with computers and communications infrastructure; the IoT provides the collection of information from physical objects using a computer network or the acceleration of a wireless connection; big data and analytics deal with the analysis of data generated by IoT networks to optimize the processing of information compared to the use of raw data; cloud computing provides software, infrastructure, and platform-as-a-service that enables real-time data exchange across the entire supply chain. In contrast to cloud computing, blockchain technology refers to pure digital ledgers of transactions programmed to record the value of any type of transaction and provide assets for secure and transparent forms for transaction data. AI technologies enable continuous learning and adaptive decision-making based on massive, sometimes unstructured data sets. Additive manufacturing, often called 3D printing, makes it possible to create three-dimensional objects by forming a layer of material under computer control (Fehmi and Ilker, 2019).

Today, industrial companies are at the epicenter of technological transformation. The world industry creates individual digital capabilities and intelligently connected products. Innovative processes such as connected manufacturing, predictive maintenance and innovative service models are increasingly being used in production. The use of modern digital technologies is becoming a necessity, which prevents the risks of losing relevance in the market of modern industry. Let's take a closer look at some prospective trends in the development of modern world industry today:

Nanoengineering — nanotechnology refers to the manipulation of materials at the smallest level. This rapidly growing industry offers ample opportunities for the development of industrial production. In the coming years, producers will use nanotechnology to produce stronger composite materials, develop and manufacture renewable energy storage systems, advanced biomedical devices, and more.

Biomechatronics — with the rapid growth of biomechatronics, the development of robotics in production has taken another step forward. This is a field that seeks to unite the body and the machine, involves the design and testing of complex architectures of devices imitating the skeletal-muscular structure of the body. Producers will primarily be involved in the design of mechanical sensors, controllers, and actuators for biomedical devices used in prosthetics and min-

ature medical implants. In addition to the medical field, research is also being conducted on the use of biomechatronics in the military industry.

AI will define the development of industrial production in the coming decade and continues to expand its impact on the software used in production. Generative design programs automatically optimize design and calculation systems to best match the functional purpose of the part — including how it will be manufactured. Software vendors are developing AI systems to advise engineers on material selection and compliance with established codes and standards. Meanwhile, workflow automation software allows AI to perform tasks such as verifying change orders, managing materials estimates, and finding opportunities to standardize parts across multiple products. AI is increasingly used to support the entire production chain of value creation, which provides a detailed quantitative assessment of current market data and allows to effectively solve strategic tasks. Also, AI is used in autonomous systems. These include vehicles and unmanned aerial vehicles, as well as robots — those that guide parts in factories and warehouses (they may one day replace conveyor belts) or those that deliver medicine and supplies to hospitals. AI makes possible the use of a wide range of complex products that autonomously respond to the environment or given commands (Gilchrist, 2016).

Intelligent quality control with the help of AI helps industrial companies to effectively use the capabilities of ML and advanced image recognition systems to automate the visual inspection and control of malfunctions of equipment and its small components. Dynamic process modeling and optimization will allow end users to plan their machine usage efficiently, plan material flow and dynamic supply, and predict possible stoppages.

Over the next decade, AI will become smarter, faster, and much more accurate. But it will still have to overcome one important barrier — trust. It will be at least a decade before anyone trusts a highway full of autonomous cars driven by AI, or a multimillion-dollar engineering factory making its own decisions about the production process without human support.

Expanding the use of online applications in industrial production opens up a whole set of advantages and is an important step in the direction of the development of Industry 4.0. For example, remote operations help manage devices from one central control center and provide machine support and maintenance. The data obtained from the machine can be used for monitoring and optimization. However, the increased use of online communications increases the vulnerability of engineering companies to cyber attacks. Cyber-attacks can have a devastating effect on the production, and therefore, ensuring cyber security plays an increasingly important role in ensuring the safety of industrial companies.

The use of «big data» and its quality in industrial production are growing nowadays. We are witnessing the growing proliferation of embedded IoT sensors that simplify and facilitate real-time information gathering. The spread of 5G wireless networks, which promise not only to increase the speed of data transfer by 5–100 times, but also to have much lower latency than existing 4G networks, also contributes to the quantity and quality of data.

The IoT today is a concept that is dynamically developing and its importance will grow in industrial production. The IoT technology makes it possible to earn higher incomes and increase margins in production. Also, the IoT technology is actively used in agricultural engineering. Today, there is an increasingly widespread use of digital technology in the development and implementation of new tools and machines. The wider spread of IoT will allow information to be collected from products in the field and be compared with their digital twins in production. In factories, this would allow manufacturers to track engineering equipment to optimize production or predict maintenance shutdowns. It will allow engineers to evaluate why some designs will not be able to extend the life of parts or machines in the future. Over the next decade, engineers and marketers will increasingly differentiate their products through intelligent use of the data they collect (Barna, 2021).

Thanks to Industry 4.0 and technological innovations, industrial design and production can be improved using the concept of a «digital twin». This concept involves displaying a physical asset on a digital platform and using sensors to monitor the performance, condition and status of the asset in real time. The concept of a digital twin is designed to help enterprises identify physical problems faster, predict their results more accurately and produce better products (Gilchrist, 2016).

Modern industry is highly dependent on equipment and it is important that machines and equipment work at full capacity as any malfunctions or breakdowns can affect operational results and product quality. Production using the concept of a digital twin allows manufacturers and specialists on production lines to receive rapid feedback and information about the ergonomics of a component, and therefore the possibility of operational 3D printing of an improved model within one or two days. Accordingly, manufacturers can instantly respond to new trends and customer challenges, as well as continuously implement incremental improvements in the design of machines and components based on the information obtained from the digital twin. The concept of a digital twin can significantly reduce the time to market and at the same time help to take into account the specific requirements of customers in production and achieve a competitive advantage.

Despite the increasing complexity of supply chains around the world today, many industrial manufacturers continue to rely on relatively simple means of

tracking and managing their supply chain processes. Current geopolitical and other global challenges have demonstrated the limitations of this approach. Instead, digital twin technology can be used to model supply chains and business processes, helping companies better understand the complexity of value chains, identify problems at early stages, and shape solutions. Given the vast amounts of data available in today's supply chains, digitalization has become a necessity to gain effective vision and perspective.

One of the key deficiencies in the decision making within supply chain management is the inability to provide context or situational awareness within the entire supply chain. A comprehensive digital counterpart of the supply chain, placed in an industrial meta-universe that leverages existing technologies, including AR/VR, can be used to create intuitive visualizations that are far easier to perceive than numbers on a table or points on a chart. The industrial metauniverse allows companies to harness the power of large-scale computing and deep visualization to analyze and interrogate a digital counterpart, providing a higher level of situational awareness on a global scale based on the availability of massive amounts of data. In turn, the integration of AI/ML into the industrial metauniverse platform can further increase the value of the digital twin. AI/ML is already doing great at sorting and classifying large data sets to help uncover the most useful information. When applied to supply chain management, this capability can help quickly sort and organize the vast amounts of data generated by today's global supply chain, making it easier to focus on the most important trends and patterns. Also, the more an AI/ML system is used, the better it is at recognizing patterns and predicting future supply issues before they occur (Fehmi and Ilker, 2019).

For the future development of industrial production, it is also important to find sustainable industries that will help companies become more efficient, more competitive and better prepared for today's challenges. Advanced digitalization technologies can facilitate the analysis and current practices of sustainable decision-making by manufacturers. Sustainability programs can benefit greatly from the power of AI and machine learning. For example, an AI/ML engine can help automate the aggregation of all the information a company needs to create collective intelligence without overwhelming employees with tedious information searches. This collective intelligence will help the company make an objective assessment of sustainability performance and create solutions to eliminate production and supply gaps.

Additive manufacturing, namely the method of building any objects according to their 3D model, is an important tool in promoting sustainable development. Casting and machining are processes that typically generate waste. The transition to additive processes can significantly reduce the material costs of parts, elimi-

nating the need for molds and the waste generated in the subtractive processing process. This method also benefits from the relative lack of design constraints compared to other manufacturing processes. As a result, designers can create components that are more efficient in several areas, including material use, thermal performance and strength-to-weight ratio, helping companies to be more energy and resource efficient (Gilchrist, 2016).

The rapid development of science and technology changes the requirements for the qualifications of employees. Simply investing in digitalization processes without intention or strategy risks is leaving many employees out of the labor market. For manufacturers, it is important to find a balance between modernization and attracting new talent, retraining and retention of current employees. The technology, which is intuitive and easy to master, will help both new and existing employees to master their work faster. Company employees can benefit from hands-on virtual training sessions that take place in the metaverse and offer a learning environment where mistakes are much cheaper than in a real production process. The industrial metauniverse will also change the way factories work, creating a virtual space to work on real projects that are more interactive and relevant.

4. Digitalization Shaping Future Industrial Revolutions

The active implementation of digitalization and advanced technologies of Industry 4.0 will contribute to increased labor productivity, more efficient and automated production processes, better quality and shorter product delivery times, the development of the world industry in modern conditions of globalization, geopolitical and pandemic challenges, lightning fast introduction of new digital technologies and growing competition in world markets. The rapid development of the latest technologies creates prerequisites for the development of the next industrial concepts of Industry 5.0 and Industry 6.0 already today.

Industry 5.0, also referred to as the fifth industrial revolution, is a new phase of industrialization that emerges when humans work together with advanced technologies and AI-based robots to improve work processes. Its focus is human orientation, as well as increasing the flexibility, resilience and sustainable development of the industry. This new phase goes beyond manufacturing, is based on the fourth industrial revolution and is realized thanks to information technology developments, which include such main components as AI, automation, big data analytics, IoT, ML, robotics, smart systems and virtualization. Industry 5.0 shifts priorities from a purely economic plane to a broader concept of social value and well-being. Although such a concept has already been mentioned in the past, for

example, in the form of corporate social responsibility, it was Industry 5.0 that cemented the idea of prioritizing social and environmental values over profits, establishing a new focus for industrial development. The concept of Industry 5.0 goes beyond industry and encompasses all organizations and business strategies to create a broader perspective compared to Industry 4.0. A comparison of the main characteristics of Industry 4.0 and Industry 5.0 is shown in Figure 1.

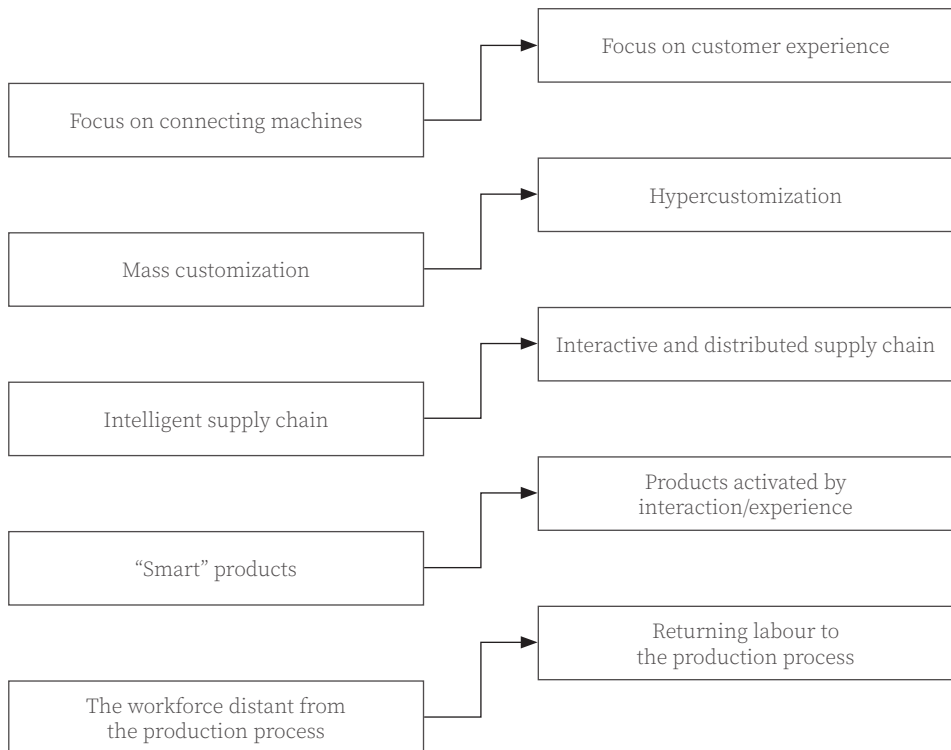


Figure 1. Comparison of the main characteristics of Industry 4.0 and Industry 5.0
Source: i-Scoop (2023)

Thanks to personalization and close cooperation with collaborative robots (cobots), employees can concentrate on performing additional tasks within the framework of Industry 5.0 with a focus on the client. This concept goes beyond manufacturing processes and includes increased sustainability, a human-centered approach and an emphasis on sustainability. Therefore, the main benefit of Industry 5.0 is the creation of workplaces with the possibility of generating higher value, which provide greater personalization for customers and improved design freedom for employees. Automation of production processes allows employees to

focus more on providing improved individual services and creating customized products (adapted to specific consumers). At the same time, increased attention to sustainability means that businesses are becoming more flexible and have a positive impact on society, rather than simply mitigating any negative effects of production processes (i-Scoop, 2023).

While the concept of Industry 5.0 refers to the personalization and synergy between the work of people and machines, the world's leading scientists are already predicting what Industry 6.0 will be like in order to prepare the foundation for the effective implementation of its mechanisms. Industry 6.0 will be an era of renewable energy, total machine independence, aerial manufacturing platforms, anatomical improvements and quantum control. Already today, certain research topics are relating to specific industries and lying directly on the path to the next industrial revolutions. There are several areas being driven by today's product markets that hold the potential for the next industrial revolutions, namely drone delivery, Ddx (differential diagnosis) portable medical kits, bionic organs, quantum computing, AI for automated driving, the use of neuroscience and AI for consumer research etc. (Duggal et al., 2021).

Industry 6.0 is the next step in the latest technologies and processes, the foundations of which are being laid today. For example, drone research is a familiar topic, but combining drones with other devices to realize a new service/product opens up new possibilities that have not been explored before. Drones can be used in industrial logistics to reach places where conventional methods are inaccessible due to uncontrollable external factors such as temperature, electrical hazards, chemical hazards, etc. Portable medical diagnostics is another vivid example of a research direction paving the way for the sixth industrial revolution. In particular, in order to expand the research, the medical profile of the user can be connected to the smart technologies of health care systems, creating even more personalized solutions in this field. Also, 5D printing technology, which allows you to print objects not from one point upwards, but from five axes, is already starting to develop today. The printer's print head moves at 5 different angles during printing. These movements allow the printer head to enter at different angles that cannot be achieved with 3D printing. With these new angles, the print head can follow the contour of the mold and the contour of the object, and printed parts can be created using curved layers instead of flat layers. These curved layers allow you to print stronger parts with complex designs. So, using several examples, we have illustrated the birth and development of many new technologies that will determine the next industrial revolution. Therefore, despite the long-term prospect of the active implementation of Industry 6.0 in industry, it is advisable to start researching its technologies today in order to lay the foundation for ef-

fective strategic planning of the industrial development based on innovation and competitiveness (Duggal et al., 2021).

Modern global studies of the next industrial revolution highlight robots as a key role in the production process, which will become the industrial norm. The likely outcome of previous revolutions focused on digitalization, technical automation and personalized manufacturing will be monolithic manufacturing centers where machines will be connected to multiple AI algorithms to perform specific tasks that will work together to produce based on customer requirements. The sixth industrial revolution is predicted to use the following technologies in order to improve various aspects of production and the general quality of life: multidimensional printing, robo-medicine, home robotics, neuroscience technologies using AI. It is worth noting that forecasts and visions of the development of Industry 6.0 differ depending on the specific industries under investigation. However, the common denominator of such forecasts is a complex, customer — and human-oriented production with a high level of digitalization, innovation, sustainability and virtualization, extensive collaboration with robots, a high level of connections between various industries, mass customization (adaptation and customization of a product for a specific audience), and personalization services and products with the addition of the concept of dynamic supply chain management, highly specialized thinking on one lot size, and rapid global information exchange.

5. Conclusions

According to global forecasts of economic development, many of today's challenges and their consequences will be relevant in the future, namely, geopolitical crisis, pandemics, disruptions in supply chains, the need to implement innovative technologies, changes in the labor market, etc. Therefore, the timely mastering and implementation of digital technologies will help manufacturing companies to develop cooperation, efficiently collect and process data, and explore innovative solutions, saving time and money. Digitalization and automation of manual processes can help increase labor productivity and ensure resource savings, as well as improve interaction with customers, detect changes in customer needs in a timely manner and adapt to changing market conditions. An important challenge for enterprises is to ensure the speed and flexibility of their digitalization programs, and to choose the optimal level of management and control that enables, not inhibits, these programs. Digitalization as an important component of Industry 4.0 is a prerequisite for ensuring competitiveness in an industry environment

that is constantly changing. It is important to implement innovative technologies within the framework of Industry 4.0 and to involve more computerization and flexible decision-making processes in production regarding software and intelligent systems.

Despite the increasing complexity of supply chains around the world today, many industrial manufacturers continue to rely on relatively simple means of tracking and managing their supply chain processes. Current geopolitical and other global challenges have demonstrated the limitations of this approach. Given the vast amounts of data available in today's supply chains, digitalization has become a necessity to gain effective vision and perspective.

The post-pandemia and post-crisis recovery and effective development of the world industry depends on the introduction of the latest technologies and the activation of industrial development within the framework of Industry 4.0. With the evolution of manufacturing, science, technology and the Internet, the implementation of so-called "smart" manufacturing will be a strong response to the rising cost of labor and changing consumer habits, supporting the development of the industrialization of the economy. At the same time, it is expedient to continue researching evolving innovative industry trends in order to ensure the development and competitiveness of the economy. And the study of the latest concepts of Industry 5.0 and Industry 6.0 are relevant already today with the aim of forming a knowledge base and future support on the way to the implementation of the latest technological achievements and transformation of business and production processes in accordance with the latest models of industry development.

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Znaczenie cyfryzacji i innowacji w ramach rewolucji przemysłowej w kontekście wyzwań współczesnych

Streszczenie. W artykule przeprowadzono analizę głównych trendów cyfrowych w ramach Przemysłu 4.0 i następujących po nim — Przemysłu 5.0. i Przemysłu 6.0. Przeanalizowano koncepcję cyfryzacji jako warunku rozwoju innowacyjnych technologii. Udowodniono, że cyfryzacja i automatyzacja mogą pomóc w zwiększeniu wydajności pracy i zapewnieniu oszczędności zasobów, usprawnić interakcje z klientami, wykrywać zmiany potrzeb klientów w odpowiednim czasie i skutecznie reagować na aktualne wyzwania związane z pandemią i geopolityką. Wyniki badania wyraźnie pokazują potrzebę dalszego rozwoju cyfrowego i innowacji w celu wspierania transformacji przemysłowej i przyszłej rewolucji przemysłowej. Zalecono globalnym producentom przemysłowym, aby aktywnie pracowali nad rozwojem strategii cyfryzacji i wykorzystywali analitykę, analizę procesów i zrobotyzowaną automatyzację procesów jako kluczowe technologie, na których można budować dalsze innowacje.

Słowa kluczowe: rewolucja przemysłowa, Przemysł 4.0, Przemysł 5.0, Przemysł 6.0, cyfryzacja, innowacja, zaawansowane technologie, produkcja cyfrowa