

DIGITAL INSTITUTES OF KNOWLEDGE AND INFORMATION SYSTEMS MANAGEMENT IN SUPPORT OF HIGH-TECH PRODUCTION IN INDUSTRY 4.0

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This paper considers the current problems of knowledge and information systems management, which are solved with the help of digital institutes for the purpose of the development of high-tech production in the conditions of Industry 4.0. The paper identifies the role of knowledge in the innovative development of industrial production, characterises the specifics of the influence of digital technologies on the technological development of companies and production processes, and focuses on the sensitivity of high-tech production to the level of intellectual support of production processes. Emphasis is made on the necessity of using comprehensive digital institutes, which can expand the boundaries of production companies and use the potential of digital platforms and systems in full.

The research methodology combines traditional and new scientific directions and institutional theories in disciplines that study the research problem in the context of an increase in the intellectualisation of labour in the conditions of Industry 4.0. The research methodology covers general scientific methods of synthesis, analysis, the monographic method, observation, generalisation, and comparison.

The paper contains important thoughts regarding the features of digital institutes from the position of their formation and influence on knowledge management in high-tech companies. It considers the structure and functions of the digital institutes of knowledge and information systems management in the conditions of Industry 4.0 and characterises selected institutes in the context of their influence on the digital transformation of the economy and the improvement of the state of knowledge management.



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1. INTRODUCTION

The modern stage of the development of mankind is closely connected with digital transformation, which takes place in the conditions of the technological transition of the Fourth Industrial Revolution and Industry 4.0. Unlike the two previous technological revolutions, during which production processes were rethought through the implementation of new sources of energy and types of machines, the Third Industrial Revolution focuses on automatization and informatization of production processes. The fourth stage of large-scale technological transformations focuses on the processes of their digitalisation and autonomization, gradually expanding the spheres of their coverage.

Technological changes, which led to mass implementation into industrial production of sensors, artificial intelligence, and remote control, ensured stable competitive advantages and substantial increase in the productiveness and effectiveness of processes, as well as improvement in product quality and the level of technology. The growth of the technological level of production had an ambiguous effect on the processes of HR support. On the one hand, technological unemployment grew because of the replacement of human labour at certain stages of production, and, on the other hand, the complexity and variability of the applied technologies raised demands for the qualification of employees and formed a need for life-long learning.

Knowledge management and information systems became tools that can solve the problems of qualification and training of employees, as well as their intellectual development according to the production and economic processes. Penetration of digital technologies into knowledge management systems significantly raised the capabilities of implementing the outlined functions due to the improvement of access to knowledge and information, development of possibilities for search, systematisation, use, storing, and transfer of information, and support for conditions for joint intellectual work. Special opportunities for improving the quality of knowledge and information systems management in such conditions were created by digital institutes – special formations that emerged due to digital technologies' combination with socioeconomic institutes, which allowed joining traditional institutional influence with the capabilities of digital platforms and solutions.

2. EXPERIMENTAL SECTION

Industry 4.0 is a relevant research topic, which is studied in detail from different positions, depending on the context and purpose (Kovačić, 2023; Ryazantsev et al., 2024; Mutavdžija, 2023). This complexity leads to the necessity of using an interdisciplinary approach,

which is based on traditional general and new narrower scientific disciplines, such as informatics, cybernetics, operational management, and programming, on the one hand, and cyber-physical systems, systems of managerial decision-making, artificial intelligence, and data sciences, on the other hand (Meski et al., 2019).

A good methodological basis for the research is also offered by institutional theories, which go beyond simple information systems, setting the properties of such systems on public processes, which transform under the influence of digital technologies and new economic and technological paradigms. Therefore, information systems acquire a higher level of stability and strategic orientation, ensure the formalisation of internal rules and interaction with external elements, strengthen their social significance and adaptability, and acquire a certain regulatory function and symbolism.

From the position of knowledge management, the research methodology is disclosed in the context of educational sciences, management, and information technologies, which constantly strengthen their tools due to digital technologies. This is realised through remote training, cloud technologies, big data analysis, virtual reality, AI, etc. Thus, the development of Industry 4.0 is closely linked to the implementation of digital technologies in knowledge and information systems management, which is especially relevant for high-tech types of activities. In these conditions, digital institutes are assigned an important role in the formation of better conditions for using the potential of Industry 4.0 from the position of knowledge management. The main research methods have a general scientific character and include the methods of analysis and synthesis, the monographic method, observation, generalisation, and comparison. These methodological tools allow solving the research tasks and ensure a sufficient level of justification of the conclusions.

Theoretical substantiation of the research problem covers a wide range of scientific and expert works, which cover different aspects of the process of knowledge and information systems management in the conditions of the Fourth Industrial Revolution. Thus, conceptual provisions of the value of knowledge and its importance for the economy (Drucker, 1993) are combined with elaboration on the modern trends in the development of industry from the position of knowledge management (Roper and Love, 2018) and substantiate the necessity for the search for new methods and approaches to knowledge management and identification of their influence on production processes (Manesh et al., 2021). Identification of digital institutes as new forms of organisation which combine digital technologies and social processes (Jadaan, 2019), is agreed with the determination of their special role in the development of the digital economy and the formation of its effective models (Lanzara, 2009) and identification of different forms of these institutes in the

conditions of Industry 4.0 (Bem Machado et al., 2021). In addition, knowledge management is studied in the context of the management of production companies' quality (Akhmedova et al., 2023), an increase in their competitiveness (Arici et al., 2022), technological aspects of Industry 4.0 and digital institutes, which include smart production, virtual doubles, etc. (Haricha et al., 2023; Singh et al., 2022; Soori et al., 2023); study of the problem and advantages of the use of the Internet of Things in knowledge and information systems management (Wanasinghe et al., 2020), determination of the directions for integration and coordination of production processes due to development of universal frameworks for implementing a chain of digital technologies (Meski et al., 2019), and focus on inclusive development in the conditions of the use of AI and machine learning in systems of knowledge management (Popkova, 2024).

This research lies in the context of general scientific, economic, and technological processes, which focus on the resolution of the problem of an increase in the intellectual potential of production companies through knowledge and information systems management with the use of digital technologies in the context of Industry 4.0. According to this, the goal of this research is to substantiate and generalise the opportunities for the creation and use of digital institutes for knowledge and information technologies management with the maximum application of capabilities of Industry 4.0. Achievement of this goal involves several tasks, which include clarification of the key definitions, identification of historical and theoretical preconditions for the formation of digital institutes in the context of digital transformation, substantiation of their influence on high-tech production, and reflection of these institutes' structure and functions in Industry 4.0.

The task of this paper is to answer several questions, which are posed in the scholarly environment due to the increased attention to the systems of knowledge management: 1. Does Industry 4.0 really offer better opportunities for knowledge management in high-tech companies? 2. How exactly do the institutes of knowledge and information systems management influence the development of the digital economy?

3. RESULTS

The importance of knowledge for the development of the organisation and its innovativeness and competitiveness was justified by the classics of economic and managerial thought (Drucker, 1993; Schumpeter, 1999), who considered them the key economic resource of the organisation and factor of innovative development and competitiveness in the long-term. From the position of the resource approach, knowledge is considered as a production factor that requires corresponding actions for its management, to ensure the function of creation of cost and value.

In the conditions of quick technological development, it is leading decisions that form competitive advantages and ensure success. Search for new solutions to solve production problems is one of the preconditions of success. However, it requires constant support for the relevance of knowledge and access to it at all levels. The formation of Industry 4.0, which was implemented through digital technologies of big data analytics, the Internet of Things, cyber security, robotization, cloud computing, AI, etc., allowed manifesting such important advantages of new production systems as precision of information methods and effectiveness of communication technologies. This contributed to the development of innovative production concepts and systems of smart production, which improve the autonomy of production elements, their interaction, and the precision and effectiveness of production and related processes (Wanasinghe et al., 2020).

Industry 4.0 is treated as a futuristic paradigm, which uses intellectual systems that are combined with automatization and digitalisation. It is an effective tool which characterises a transition from simple machine production to production in which machines can interact and coordinate their activities for a common purpose (Oztemel and Gursev, 2020). A change in the paradigm of knowledge management in the conditions of Industry 4.0 determines new features of the generation of knowledge and information. According to this, a system of sensors that is used within machine interaction increases the volume of generated information, most of which is non-structured. This largely overloads information systems and systems of decision-making. Thus, knowledge management in the conditions of Industry 4.0 can be aimed at revealing significant information, structuring, and adapting it to the needs of production and management (Manesh et al., 2021).

Industry 4.0 is a tool and means of going beyond a production model. The main factor in ensuring results is the skilful application of machines that interact with each other or with humans or work autonomously according to the preprogrammed algorithms. Such processes predetermine the formation of large arrays of data and non-structured information, which requires preliminary processing, adaptation, and structuring before it can be used in the systems of knowledge management to transfer experience, ideas, and characteristics of processes and interconnections between the phenomena.

On the whole, digital technologies have a positive effect on high-tech production systems and knowledge management, creating new knowledge and transforming non-structured information into knowledge and ensuring its transfer and application, as well as the transformation of business models and infrastructure knowledge and information turnover (Table 1).

Table 1. The effect of digital tools on high-tech production and knowledge management in the conditions of Industry 4.0

| Digital tools | Effect of digital tools on high-tech production systems | Effect of digital tools on knowledge management |
|-----------------------------------|--|--|
| Cyber-physical systems | Integration of production processes and digital technologies, creation of smart production | Collection, analysis, documenting, and transfer of knowledge |
| Condition monitoring | Monitoring of the work of equipment, forecasting possible malfunctions, improvement of the level of technical services | Creation of knowledge, formation of data banks |
| Big data | Possibilities for deep analysis of production processes | Transformation of data into useful knowledge; creation, acquisition, and application of knowledge |
| Smart factory | Automatization and optimisation of production processes | Acquisition, creation, and transfer of knowledge; creation of information systems for knowledge management |
| Internet of Things | Unifies equipment and devices into one information network, forms constant data flow | Creation of a basis for transforming information into knowledge |
| Production | Ensure flexibility and effectiveness of production systems | Infrastructure for knowledge management, transfer of knowledge |
| Digital transformation | Transformation of business models and production processes | Transfer of knowledge |
| Cyber-physical production systems | Integration of production with digital technologies | Acquisition, creation, and transfer of knowledge |
| Process modelling | Optimisation of production processes | Creation and transfer of knowledge |

Source: Made by the authors using the materials of Manesh et al. (2021)

Given their diversity, digital tools ensure a wide range of activities, which facilitates the development of high-tech production systems and the transformation of the system of knowledge management. This is provided by the properties of digital technologies, which, due to integration with production processes, ensure a large-scale effect on the system of knowledge management. Such influence is manifested in an increase in the quality of collection and analysis of information due to the systems of monitoring, processing, and analysis of data, acceleration of decision-making, improvement of the infrastructure of knowledge management and growth of its effectiveness, and growth of the level of knowledge and professionalism of the employees of all levels and spheres of activities.

High-tech production is very sensible to knowledge. Large dependence on technologies determines the rareness and high cost of production operations that are conducted in the spheres of space and aviation technologies, leading computer developments, remote and autonomous control, etc. High cost of production and demands for quality form favourable conditions for the involvement of robotised and automatized systems of production and management in this sphere. Such a situation facilitates the reduction of human presence in the production chain and thus requires structuring and formalisation of knowledge, as well as its algorithmisation for teaching robots and automatic information systems (de Bem Machado et al., 2021). Active development of the knowledge management concept took place in the 1960s. An important stimulus for this became active attempts at codification and preservation of knowledge for the purpose of its transfer and further dissemination. This vision emerged based on the division of knowledge into explicit and implicit. Explicit knowledge is identified or structured

knowledge or knowledge materialised in the form of patents, trademarks, know-how, etc. Implicit knowledge is the knowledge that functions in the organisation without any formalisation and is inseparable from its carriers. This knowledge is often identified through the experience of the employee, his expertise, connections, etc.

Given the specifics of technical development of that time, the main problem of knowledge management was the complexity of formalisation of knowledge, its separation from carriers, and assigning a certain form to them, which is fit for usage, storing, dissemination, etc. (Roper and Love, 2018). This vision characterises the normative approach to knowledge, according to which knowledge is separated from the carrier in the form of printed text, tables, databases, or other types of coded information.

Industry 4.0, as a sphere of high-tech production, is the result of the application of knowledge. It is formed based on innovations and their successful combination in market conditions. According to this, it requires constant support through new ideas, talents, knowledge and information. The constant upgrade is one of the features of Industry 4.0, which is implemented in certain frameworks through the successful use of knowledge. On the other hand, Industry 4.0 is the driver of the process of knowledge management. It offers new opportunities for the creation and search for knowledge, its codification and structuring, storing and transfer, use and commercialisation. The main innovative technologies that are used within knowledge management are systems of managerial decision-making, databases and data banks, systems of generative AI, etc.

The influence of Industry 4.0 on knowledge management must be assessed critically. Undoubtedly, digital technologies offer completely new opportunities for operations with knowledge. It would be a mistake to limit the process of knowledge management by only operations with information. Such focus reduces attention to the main carriers and producers of knowledge – humans. Thus, when studying the process of knowledge management, it is important to take into account how technologies of Industry 4.0 influence employees. Here the focus is expanded due to consideration of opportunities offered by digital technologies and information systems for the selection of employees, organisation of their activities, adaptation and coordination, development and reward. The topic of knowledge management with the help of information systems requires expansion as well. In this context, the term "information ecosystem" is used more frequently; it is not limited by software and hardware support for the information processes management but also includes interconnections between different subjects which expand the potential of each element from the position of its implementing own peculiar functions.

A specific feature of digitalisation is its stable organisational basis, which is expanded to the macro-level and transforms other spheres of public life. It allows customers to purposefully influence the state of the provision of services, forms trends for economic and technological changes and creates platforms for dialogue and joint activities. In these conditions, each Internet user becomes an active economic actor involved in the process of development, production, distribution, and consumption of industrial products.

This vision of digitalisation transforms the sectorial and organisational structure of production, erases organisational boundaries, and changes values. This determines the complexity of processes, their interconnection, and mutual dependence. Thus, the effects from the implementation of some digital solutions are set on the effects from the implementation of other digital solutions, which increase transformation processes and accelerate changes. The described processes are very different from transformation with the help of IT technologies.

Active penetration of digital technologies in different public spheres and economic systems determines one of the key qualities of digitalisation – the formation of digital institutes. They appear due to digital technologies' penetrating the current public institutes and their merging. Such institutes form regulatory components (rules), normative provisions (values and standards), and cultural bases (types and schemes). This enables them to ensure the implementation of complex functions within government and production systems, market and public processes.

Digital institutes can be defined as a totality of legal, administrative, and cognitive tools of public influence,

which are closely integrated with digital technologies. According to this, digital institutes implement certain organisational functions and destroy the traditional boundaries, reformatting and expanding the institutional influence. Such institutes exist in the form of information systems, digital platforms, and ecosystems, which unify algorithms, programmes, and digital tools, which ensure the collection, processing, and use of data in the interests of the company or society (Jadaan, 2019).

Examples of digital institutes are stable information systems and ecosystems, which form completely new relations in traditional spheres of activities. They include online banks, e-government, social media, online libraries, virtual universities, cryptocurrency exchanges, etc. Each of these institutes ensured the transformation of traditional systems, such as bank services, education and sciences, communication means, information transfer, etc. Based on new systems, new qualities appeared, and they substantially expanded their functions and allowed them to obtain features that are not peculiar to traditional systems.

The general structure, functions, and effects that are ensured by digital institutes are shown in Figure 1. Their basis is formed by databases and knowledge banks, algorithms and systems of machine learning, including AI, digital platforms, and integrated information systems of production management.

The main functions of the digital institutes of knowledge management repeat standard functions of the systems of knowledge and information systems management, ensuring the work with data, their structuring, knowledge management, and optimisation based on production processes. The difference from the traditional systems of knowledge management lies in an increase in the level of autonomy and automatization of these processes. Systems of knowledge management, which were formed on this basis, are stabilised and developed more or less autonomously, without direct influence from humans. This is a sign of the institutional character of the studied systems in the conditions of Industry 4.0, which is implemented through specific properties of digital institutes, such as automatization, flexibility, adaptation, integration with the systems of monitoring, and the necessity for cybersecurity.

Effects that are formed due to the influence of digital institutes on production systems are aimed at an increase in effectiveness, speed of implementing innovations and bringing them to the market, support for the optimal management of resources, etc. All these functions, elements of the structure, and their properties and effects in the long-term can be implemented only due to continuous learning and knowledge management. In the conditions of Industry 4.0, high-tech production must focus on these aspects of the activities.

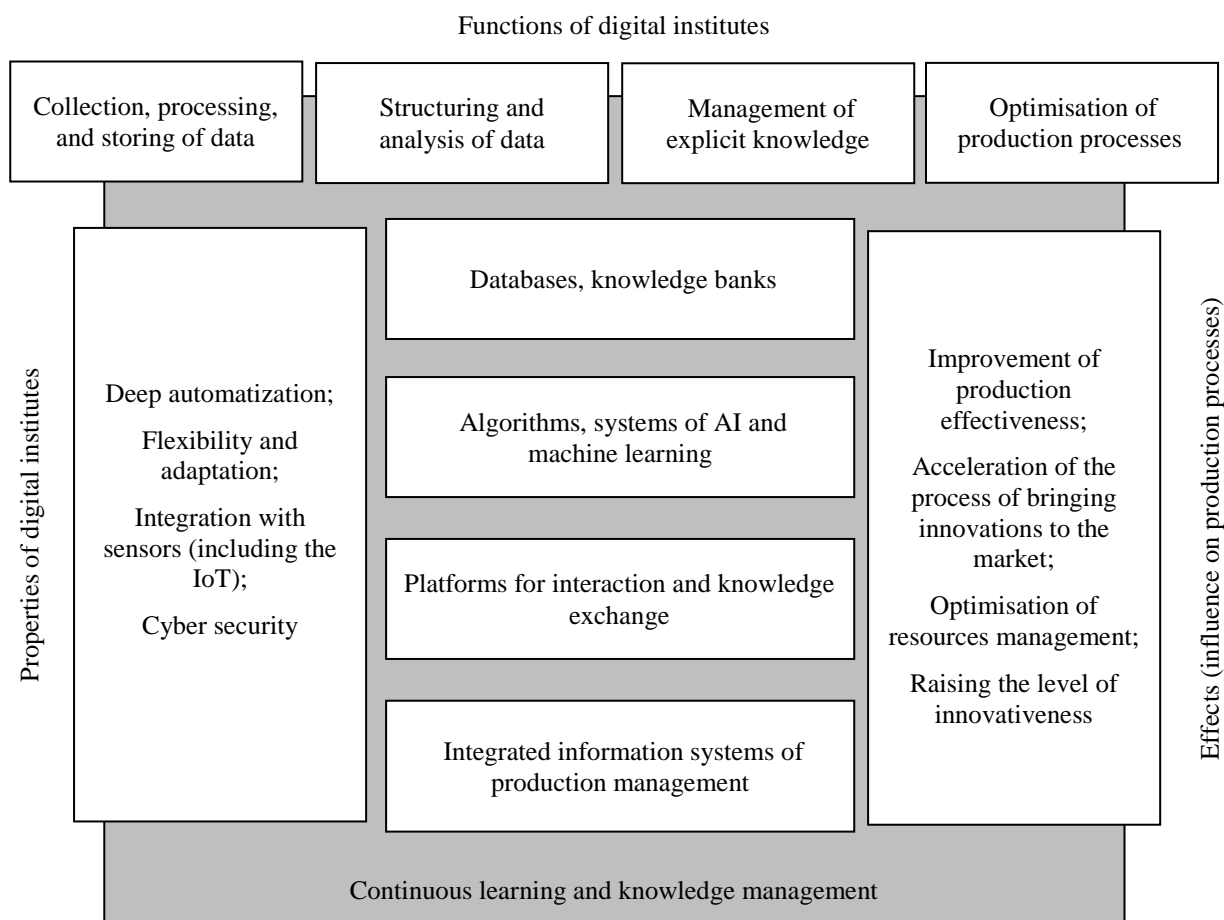


Figure 1. Structure and functions of the digital institutes of knowledge and information systems management in the conditions of Industry 4.0

Source: Made by the authors using the materials of Jadaan (2019) and Roper and Love (2018)

Despite the generally favourable influence of digital institutes on the quality of knowledge and information systems management, they are peculiar for substantial risks and advantages, which must be discussed and resolved. The main problems in this context lie in the complexity and inequality of the development of different elements of digital institutes. According to this, the compatibility of different information systems with knowledge management is often very low. Given an increase in the possibilities of active dissemination of information in the digital environment, the protection of rights for knowledge, including intellectual property rights, forms one of the key risks for the development of digital institutes in the studied sphere.

In the sphere of knowledge and digital systems management, digital institutes have become rather popular. Their expanding the qualities of traditional production systems in knowledge management allowed ensuring real transformation of not only information and educational processes but also forming new values and qualities of production systems. Varieties of digital institutes that have a large potential in the sphere of knowledge and information systems management are as

follows:

- Systems of digital knowledge management, such as SAP Digital Manufacturing (SAP, 2024), and Siemens: MindSphere (2024). They integrate a powerful operational system, sub-systems of data collection, quality management, production processes, and analytics;
- Information Systems for Smart Manufacturing, presented by educational and scientific digital ecosystems based on universities, such as Managing Digital Transformation (Industrie 4.0 Maturity Center, 2024) and MxD (MxD, 2024). They offer opportunities for the interaction of industrial-academic and government representatives for cooperation in the sphere of digital development, personnel training, etc.;
- Cloud-based Knowledge Management Systems – systems that use cloud technologies and analytics to collect information, structure it, and raise its value. This group includes GitHub (GitHub, 2024) – a digital platform for the joint development of software and knowledge

exchange, and the International Data Spaces Association (International Data Spaces Association, 2024) – a platform for the exchange of industrial data and knowledge.

The institutional character of these information systems and platforms is manifested through their ensuring a significant effect on the sectors of high-tech production. This effect is achieved due to the establishment of rules and norms, such as the development of protocols (Industrial Internet Consortium – protocol for the IoT devices); dissemination of information about the best practices (SAP Digital Manufacturing and Siemens MindSphere); creation of algorithms of implementing digital solutions (Digital Manufacturing and Design Innovation Institute); formation of standards in the sphere of data exchange and certification of cybersecurity tools and influence on government decisions through consultation bodies; creation of conditions for the cooperation of the digital market participants (GitHub); formation of the corresponding ecosystems (MindSphere); implementation of joint research projects; popularisation and promotion of innovations, etc.

Thus, digital institutes in the conditions of Industry 4.0 are active agents of changes and digital transformations, for they offer effective solutions and tools for the dissemination of information about successful experiences, joint activities and training, active knowledge exchange, etc. Such institutes transform the conditions of public interaction, changing interests and values and strengthening the economic and technological effectiveness of mankind's development at the modern stage.

4. DISCUSSION

The issue of creating digital institutes of knowledge management and information technologies, which are aimed at the development of high-tech production in the conditions of Industry 4.0, is rather complex. This is manifested in the presence of many issues that need discussion. The main discussion lies in the space of complex institutional processes, which require more detailed research and substantiation from the position of the integration of digital technologies into public and production processes. In this context, it is advisable to analyse the influence of different digital technologies on institutional capabilities of the systems of knowledge management and determination of the possibilities of combining them and using them within comprehensive high-tech digital ecosystems.

Another relevant problem is the identification of the impact of digital institutes on knowledge management in the sphere of high-tech production and production with a lower level of technology. Comparison of the influence of digitalisation on knowledge management in production systems of different levels of technological

development will allow for more precise modelling of mechanisms that ensure a sufficient level of intellectualisation of labour given the mentioned criterion. This model will allow selecting optimal parameters for intellectual development, which conforms to the level of technology, resource support, and market situation.

An important aspect of using digital institutes in the knowledge management of high-tech companies is solving the dilemma of compliance with ethical principles and the economic criterion. Here, further strengthening of digitalisation and its institutionalisation in the form of information systems of knowledge management will leave less space for human resources, in favour of programmes, algorithms, sensors, digital solutions, etc. In view of this, it is important to develop key values and limitations that can determine further development of digital institutes in the conditions of knowledge management in high-tech production.

5. CONCLUSION

Knowledge is the key factor of success in economic systems. It determines current results and prospects for the development of production systems. In the conditions of dynamic technological progress and digital transformation, the role of knowledge and the possibility of using it successfully grows constantly. This trend is especially relevant in high-tech production systems, in which precision, timeliness, and effectiveness are of the highest value. Industry 4.0 is an important factor in the harmonious development of high-tech production systems. This is connected with the properties of digital technologies and organisational tools of the Fourth Industrial Revolution: the Internet of Things, Big Data, virtual reality, deep automatization, robotization, etc. Their application offers completely new opportunities for production systems and, at the same time, requires a higher level of qualification for servicing digital processes and platforms.

Digital tools have a significant effect on high-tech production systems, rationally integrating digital technologies into production processes, forming smart production, raising the level of technological support and automatization, ensuring constant deep monitoring of production processes, and optimising and transforming business models and processes. These technologies have the maximum positive effect on the use of digital tools for knowledge management. This enables them to improve the state of collection, analysis, and formalisation of knowledge, its transfer, transformation, and effective use, as well as the development of the corresponding infrastructure and knowledge management systems.

Digital technologies play a dual role: they are a result of the application of knowledge and, at the same time, the driver of the processes of knowledge management. They

also produce an increasing volume of non-structured data and implicit knowledge, which complicates the process of knowledge management at production companies and requires the application of more effective tools. The key feature of digitalisation is the formation of digital institutes – structures that integrate digital technologies with traditional public institutes. Digital institutes do not just simply automatize the existing processes, they create completely new relationships and opportunities in the traditional spheres of activities. They form new rules, standards, and cultural models, ensuring the execution of complex

functions in government, production, market, and public processes. Different forms of digital institutes, such as systems of digital knowledge management, educational and scientific digital ecosystems, and cloud systems of knowledge management, actively transform high-tech sectors, establishing new standards, protocols, and practices of cooperation. This facilitates digital transformation of not only production processes but public interaction on the whole, changing values and raising the economic and technological effectiveness of development.

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