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Knowledge management strategies in companies: Trends and the impact of Industry 4.0

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Abstract. The existing business models essential for the creation of consumer value and, consequently, business competitiveness are now undergoing a transformation. Brand-new technological developments based on network integration, intelligent technology and flexible automation are becoming increasingly relevant: additional competitive opportunities appear, and knowledge management and intellectual capital management are becoming key business processes. When developing a strategic vision, it is important for companies to pick the relevant data out of the information flow about the external and internal environment and convert it into organizational knowledge, which is a core management resource. The paper analyses the experience of Russian and foreign companies in the introduction of scalable models focused on the widespread use of Industry 4.0 and establishes the principles and strategies of knowledge management that allow these companies to maintain their competitive positions in a strategic perspective. The theory of knowledge management and resource approach constitute the methodological framework of the present study. The general scientific methods of logical-structural analysis and systematization, as well as the contingency case study method were applied. The information base encompasses the case studies of six companies, retrieved from publicly available sources. The findings of the empirical research prove the feasibility of applying a situational approach to knowledge management: companies use different strategies for accumulating and sharing knowledge according to their maturity level and the area of implementation of Industry 4.0. Based on the results obtained, the authors develop a situational approach to the strategic knowledge management of companies that successfully apply the technologies of the Fourth Industrial Revolution. The theoretical and practical significance of the study lies in identifying common approaches to knowledge management under various conditions, which can be used to create the strategic vision of managers involved in the key decision-making process in companies.

Keywords: Industry 4.0; knowledge management; strategic management; situational approach; business process; business model.

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INTRODUCTION

The advances of the Fourth Industrial Revolution widely debated by managers and academics around the globe exert an increasing impact on the transformation of traditional business models and necessitate the use of new management approaches in order to maintain companies' sustainable competitive advantage. The values of the traditional linear economy are gradually being replaced by the principles of a circular economy, which consist in the formation and maintenance of a sustainable cycle of creation, consumption and processing of resources for their most efficient use and elimination of waste-generating production processes [Rajput, Singh, 2019, p. 2]. Analysis of technological changes and their impact on the process of global economic development shows that the concepts of intellectual capital and knowledge management developed at the end of the 20th century are acquiring greater practical significance [Bordeleau, Mosconi, de Santa-Eulalia, 2020, p. 173; Bezginova, 2018, p. 28; Vorobyov, 2018, p. 33]. Approaching the edge of technological development, companies more frequently face the need to search for intellectual resources – structural capital and human talents to maintain and improve their market position.

The widespread implementation and use of the accomplishments of Industry 4.0 has become one of the priority avenues for the global economy development in the period from 2020 to 2030. According to Hermann, Pentek and Otto [2015, p. 16], transformation of manufacturing is based on such processes as flexible automation, network integration and smart technologies. Recent years have witnessed a dramatical increase in the number of companies that use the Internet of Things (IoT) technologies; process and analyze big data using cloud computing; and implement advanced cyber-physical systems based on smart robotization, additive manufacturing, and augmented reality [Müller, Buliga, Voigt, 2018, p. 2; Mohammadpoor, Torabi, 2019, p. 3]. Awareness of these achivements and of their striking investment accessibility undoubtedly transforms business representatives' consciousness (primarily of those making strategic decisions) and changes their strategic vision. Consequently, the strategic goals of business tend to change as well, and there is a shift in the understanding of the major resources used by companies to gain strategic advantage.

A number of researchers emphasize that knowledge management is of special importance in the process of technological transformation [Buenechea-Elberdin, Sáenz, Kianto, 2018, p. 1758; Song, Sun, 2018, p. 1166; Fakhar Manesh et al., 2020, p. 2; Vorobyov, 2018, p. 35]. Knowledge is acquired information that, along with other strategic resources, is used by companies to get a competitive advantage. Knowledge is gained by businesses when performing their own independent activities and through experience exchange through cooperation [Nonaka, Toyama, Hirata, 2008, pp. 23–24]. Depending on the prevailing conditions, managers should apply certain rational approaches to knowledge management that can lead the company to success [Kim et al., 2014, p. 403]. This topic is of particular interest due to the fact that the technological capabilities of Industry 4.0 make it possible to strengthen cooperation and integration while providing the inflow of relevant data to be further processed and transformed into organizational knowledge. This, in turn, will reduce the informational-economic burden on individual companies and support their sustainable development.

The *purpose* of this article is to reveal the theoretical patterns in approaches that affect the choice of knowledge management strategies in companies developing under the influence of Industry 4.0. The primary *objectives* of the research are:

1) to analyze the approaches to strategic knowledge management based on a contingency perspective and their impact on the transformation of traditional business models prevalent in the markets for goods and services;

2) using the data from open sources, to examine the experience of international and Russian companies that have introduced Industry 4.0 technology guidelines;

3) to identify significant factors influencing the choice of a certain knowledge management strategy.

In the context of the economic availability of Industry 4.0, the massive introduction of its technologies in certain sectors of economy becomes a matter of time. Most experts assume that the main consequences of the transformation will become apparent in the period from 2020 to 2030[1]. Based on this thesis, the authors of the current study suggest that this is the stage of strategic planning, at which managers should establish the technological niche and the position of business in the future economic development of local and regional economy. Managers should also analyze the available strategic resources by specifying the strategic role of companies: whether they will be followers or drivers of economic growth.

The paper is structured as follows. Section 1 provides an overview of knowledge management strategies and highlights the viability of a situational approach. In Section 2 we perform a theoretical analysis of the impact of Industry 4.0 on business models, make assumptions about factors affecting the choice of knowledge management strategies, such as the scope of Industry 4.0 introduction (cyber-physical systems or data mining systems), as well as the level of companies' maturity in terms of readiness to use Industry 4.0 (initial level, follower, "beacon" company). Then, in Section 3 we scrutinize the case studies of six companies that use the advances of Industry 4.0 as the basis for their business models and show the practical importance of the assumed factors. In Section 4 we design a matrix for choosing a knowledge management strategy according to the effects of the proposed factors. In conclusion, we discuss the limitations of the proposed approach and the avenues for further research.

KNOWLEDGE MANAGEMENT STRATEGY: A LITERATURE REVIEW

In the past two decades, theory and practice of knowledge management have gained in popularity in the literature on management as the proposed models direct managers' attention to hidden resources of companies and enhance their performance in the long run [Takala et al., 2007, p. 327; Baxter, Roy, Gao, 2009, p. 184; Yang, 2010, p. 216]. Oluikpe [2012, p. 864–865] highlights that the knowledge management strategy should provide an understanding of the sources of organizational knowledge, emphasize its role in value creation, and support the internal business processes of the company. From the standpoint of the resource-based approach, knowledge is a unique resource of an organization utilized within the business cycle to gain a competitive advantage [Barney, 1991, p. 101; Raudeliūnienė, Davidavičienė, Jakubavičius, 2018, p. 544]. At the same time, strategy is a process of establishing the mission, vision and functional goals of the company for the effective allocation of resources, such as knowledge for achieving organizational goals [Buenechea-Elberdin, Sáenz, Kianto, 2018, p. 1758].

A number of researchers note that in the modern literature there are two main perspectives on strategic knowledge management in companies [Joia, 2007, p. 204; Oluikpe, 2012, p. 867; Wong et al., 2013, p. 241]. The approach to strategies classification developed by Hansen, Nohria and Tierney [1999, p. 2] is based on the analysis of leading companies operating in various sectors of economy, the business models of which underwent a radical transformation under the influence of technological changes. The first perspective is revealed through *knowledge codification* and implies that strategic management focuses on identification, classification, preservation and dissemination of explicit knowledge in the forms corresponding to organizational goals. Companies use codified knowledge as a universal multiple-use tool for resolving business problems. Hence, such companies attract significant investments in the IT infrastructure and training of employees, who usually possess only basic qualifications. The second perspective lies in *knowledge personalization*, that is, to intensify the flows of internal implicit knowledge based on the strengthening

[1] McKinsey & Company. (2019). The Fourth Industrial Revolution. Targets for the development of industrial technology and innovation. World Economic Forum. January. Available at: http://www3.weforum.org/docs/WEF_Четвертая_промышленная революция.pdf. (In Russ.).

of networks and internal interaction. This perspective allows increasing the dynamism of the internal knowledge management system and avoiding complex processes of knowledge formalization. Employees, as a rule, are highly qualified and come up with unique solutions for each business case. Hence, investments in human capital are aimed at maintaining the process of creative communication and continuous knowledge exchange [Hansen, Nohria, Tierney, 1999, p. 3].

Traditional knowledge management strategies were refined with respect to the principles of the situational approach: particular knowledge management strategies can be applied according to the conditions prevailing in the environment, in which companies operate. Managers should select relevant factors exerting a decisive effect on the choice of the management strategy that should be sensitive enough to react promptly to the environmental shifts. Becerra-Fernandez and Sabherwal [2001, p. 27] show that strategies are dependent on content orientation (goal- or process-oriented) and focused domain (broad focus typical of service companies or narrow focus typical of manufacturing companies). Other variables for the analysis of knowledge management are processes (storage, use, creation of new knowledge) and types of knowledge (accumulated knowledge or innovative knowledge). We suppose that such approaches are difficult to apply in practice, since they do not take into account the *content of knowledge* and their *utility for certain groups of users and business* at large. Kim, Lee and Chun [2014, p. 403] attempt to overcome this limitation. Among the factors affecting the decision-making processes in strategic knowledge management, the authors single out the *source of knowledge* (external or internal), which determines its relevance for solving routine or innovative tasks, and the *intensity of knowledge changes* in the industry, which establishes the requirements for knowledge and its update rate under the influence of changes in the external environment. Thus, companies are able to apply strategies of external and internal codification or personalization depending on the conditions of the external and internal environment. External codification concentrates on adapting the formalized experience of other companies operating in the industry, for example, through the analysis of technical reports, patents, and commercial journals. Internal codification is aimed at finding knowledge within the organization and providing favorable conditions for knowledge formalization. External personalization allows employees to contact external experts and partners, whereas internal personalization focuses on maintaining the knowledge exchange environment in the process of employees' communication [Kim, Lee, Chun, 2014, p. 404].

We assume that, within the framework of the situational approach, companies should take into account technological development trends specific for the next decade. They should also choose the strategy of knowledge management that is optimal for them depending on their maturity level when implementing Industry 4.0 technologies and on the content of organizational knowledge peculiar for the area, where it emerges. To confirm this hypothesis, we firstly examine the impact of Industry 4.0 on the transformation of business models and knowledge management strategies, and, secondly, analyze the experience of some companies based on a representative case study to identify the fundamental principles influencing the choice of knowledge management strategies.

TRANSFORMATION OF TRADITIONAL BUSINESS MODELS AND KNOWLEDGE MANAGEMENT STRATEGIES IN INDUSTRY 4.0

Global technological trends of the Fourth Industrial Revolution allow us to conclude that national economies are on the verge of widespread adoption of circularity principles to guarantee sustainable development of production systems [Rajput, Singh, 2019, p. 2; Zozulya, 2018, p. 2; Proshkina, 2019, p. 92]. In their activities, traditional industrial enterprises rely on linear supply chains and manage to maximize their revenues using vertically integrated business models. With the global environmental and socio-demographic problems aggravating each day, the concept of a closed economic cycle, based on the idea of recycling, circulation of materials and their reuse, has become increasingly relevant [Ing et al., 2019, p. 1181]. The technological platform of Industry 4.0 allows introducing the solutions that improve the environmental efficiency of production, provide information gathering, manage the consumption of physical resources, and also have a significant social effect by transforming the existing markets for intellectual labor [Jacobs, 2012, p. 25]. The external environment of enterprises is changing in response: to survive and develop, companies need to cooperate in the distribution and joint consumption of rare resources, thereby creating sustainable technological clusters. Cooperation, knowledge exchange and task distribution between different companies allows ensuring the most efficient use of resources [Xu, Xu, Li, 2018, p. 2941].

In a broad sense, Industry 4.0 is the convergence of industrial production and information and communications technology. It is premised on the principles of self-regulation, intellectual support and the interconnection of the production process's individual elements through the Internet of Things, which is the core element of the entire concept [Rajput, Singh, 2019, p. 2; Sony, Naik, 2019, p. 2]. To comprehend the strategic importance of Industry 4.0, this concept should be regarded as an example of deep integration of ERP systems into existing business processes by building a local cyber-physical network (that is, a network consisting of digital elements and physical objects). The primary advantages of the Industry 4.0 technologies are their investment attractiveness, versatility and relatively low introduction costs. According to Müller, Buliga and Voigt [2018, p. 2], the average cost of cyber-physical systems introduction in German companies does not exceed 2,000 euros per unit. At the same time, McKinsey & Company experts forecast that the introduction of the Industry 4.0 technologies will allow pioneering industrial companies to increase cash flows by 130% in the next 10 years compared to traditional development scenarios[1]. Moreover, the implementation of cyber-physical systems requires equipment to be only partially modernized at the level of 40–50% of the corporate fund.

Most researchers agree that the technological advantages of the Fourth Industrial Revolution seriously affect *business models*: these are value creation mechanisms within an organization, interconnected into a single system that provides a supply of goods and services in the market [Sniderman, Mahto, Cotteleer, 2016, p. 2; Yadav et al., 2020, p. 21]. Based on a meta-analysis of the academic literature, Foss and Saebi [2017, p. 216] define business models as complex systems that create value, as well as deliver and distribute it through certain mechanisms. The elements of such systems are value proposition, consumer interaction mechanisms, key resources, and the profit formula. A *process model* is one of the possible ways of describing business models: the process model is optimal for strategic analysis, since it allows tracing the entire logic of value creation – starting from logistic inflows (physical and intellectual resources) to the functioning of intra-organizational processing and distribution of outflows of information, goods and services (see Figure). The elements of Industry 4.0 gradually complement such models, as well as transform their individual elements, for example, by outsourcing some typical technological operations or creating a new logic of distribution channels. Next, we investigate the impact of Industry 4.0 on business models and companies' approaches to knowledge management.

Robotization and additive technologies. The physical infrastructure of an enterprise is transformed through the use of *advanced robotization* and *additive manufacturing technologies* [Fakhar Manesh et al., 2020, p. 2]. The main peculiarity of Industry 4.0 robots is their ability to collaborate and learn from humans using artificial intelligence technologies [Müller, Buliga, Voigt, 2018, p. 3; Rajput, Singh, 2019, p. 2]. Modern collaborative robots, or cobots, are able to perceive, memorize and analyze elementary patterns of physical movements and human behavior to simulate them especially when performing monotonous, repetitive or dangerous elements of the production process. Such cobots are becoming more affordable and can be utilized within the existing infrastructure with minimal investment needed. Additive manufacturing has gained an increasing amount of attention over the past five years: 3D printing is one of the key drivers for the development of Industry 4.0, since it allows reducing the labor intensity of the production of complex parts made from a variety of materials [Ghobakhloo, 2018, p. 911]. On the one hand, companies do not need to purchase expensive special-purpose equipment to manufacture different parts. On the other hand, companies are able to exploit opportunities of digital design technologies to scan real objects and shorten the prototyping cycle, as well as produce the required limited number of prototypes and parts for further consumption in the production process.

Visualization and *augmented reality* technologies, which can be used at all stages of the production cycle, also exerted a significant impact on traditional business models [Sniderman, Monika, Cotteleer, 2016, p. 3]. Visualization technologies are sometimes called digital twins as they create an image of a real physical object or process in a virtual environment, which ultimately allows one to better understand, analyze and optimize their work in real time [Ghobakhloo, 2018, p. 911].

From the perspective of knowledge management strategies, the introduction of robotization, additive technologies and virtualization, in our opinion, will require considerable investment in human capital; enterprises will need to apply a *strategy of external codification of knowledge* and provide employees with new technical training based on best practices and models of strategic benchmarking. Firstly, some of the routine and non-creative work can be terminated. Secondly, existing jobs are subject to a qualitative transformation; therefore, training will become an integral part of any knowledge management strategy. Thirdly, the Fourth Industrial Revolution causes novel specialties and jobs to emerge. This will result in a significant transformation of the training system and the search for talents to fill new positions [Kitaygorodskiy, 2018, p. 291]. Among the key trends that positively affect the transformation of the job market and human capital in business models are the increasing availability of data and technologies for their processing, as well as the growing potential of cutting-edge technologies to organize the work of cyber-physical systems.

The Internet of Things. The network integration of individual production and administrative business processes are the next element in the development of physical infrastructure. The Internet of Things is a system of physical devices connected to each other in a digital network that allows communicating and exchanging information via the Internet [Meski et al., 2019, p. 94]. The devices that can be part of this system vary from individual sensors attached to industrial equipment and machines to personal smartphones utilized by employees on a daily basis to remotely control physical objects and perform data analysis. In terms of knowledge management, the Internet of Things is a technological platform that allows establishing knowledge exchange processes in real time, as well as integrating this process to the operational production cycle. The elements of the Internet of Things have become the essential components of the leading companies'

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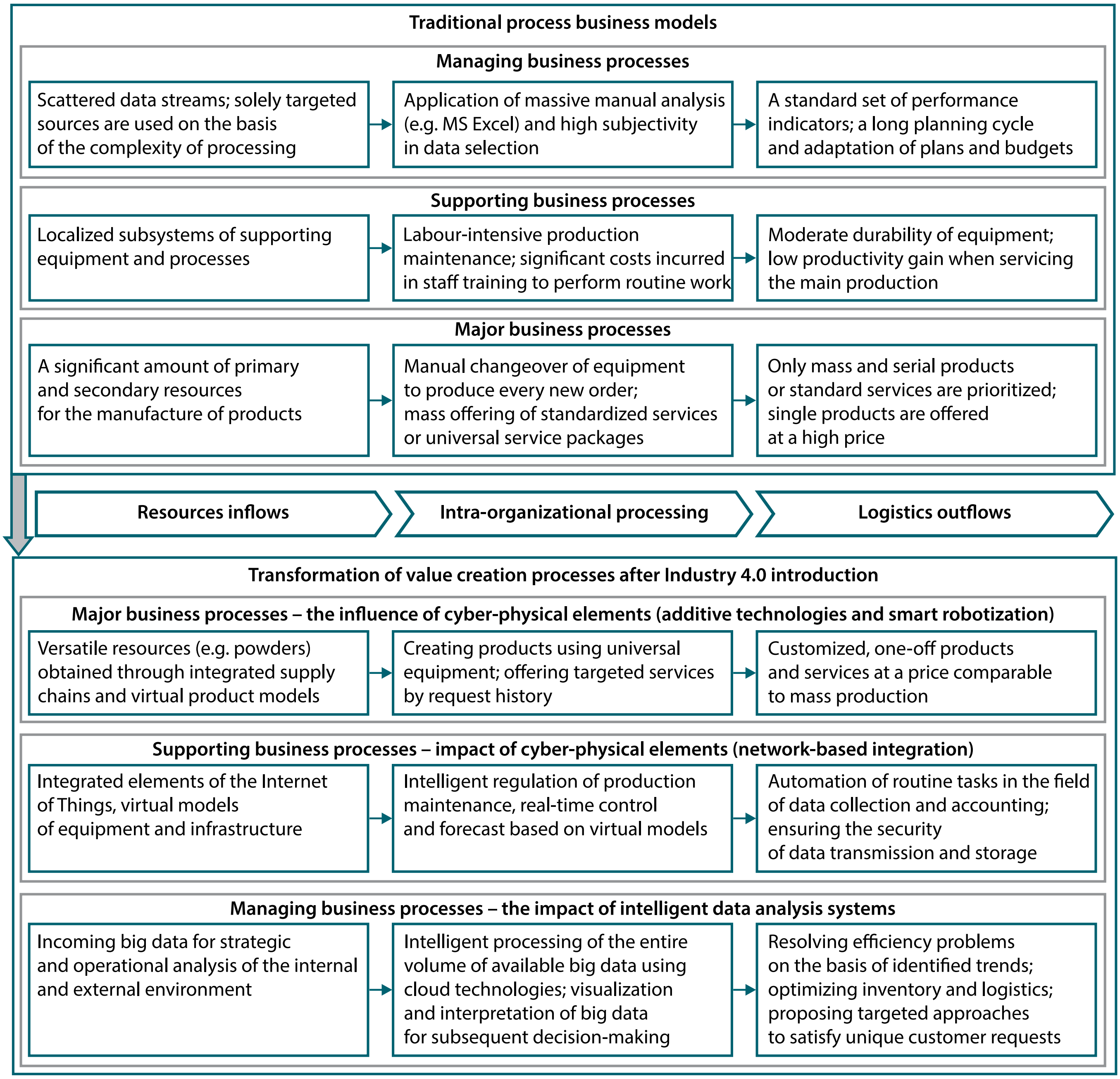

The process model of a traditional company compared to the process model of Industry 4.0
Сравнение процессной модели традиционной компании и компании Индустрии 4.0

infrastructure, allowing them to tackle such problems as production and inventory management, order flow regulation, order structure optimization and production planning.

The massive impact of the Internet of Things on traditional business models implies reducing the labor intensity, controlling the main business processes and generating a continuous data flow about the enterprise's internal environment. At that, these are not only production resources we are talking about, but also human capital. For example, these systems can be configured to receive timely signals from the employees to improve particular business processes, which can underlie the procedure of the company's strategic transformation. We believe that in this context companies need to follow a *strategy of internal personalization of knowledge* and, relying on the expertise of the company's specialists, concentrate on finding patterns in production and logistics business processes, for example, in order to design models for efficient production or distribution of material flows.

Big data and cloud computing. Intelligent technologies, including those for collecting, analyzing and interpreting data, play an essential role in supporting administrative business processes. The system of the IoT integrated physical devices generates large volumes of sophisticated data, the so-called *big data*, that can be used to analyze the internal environment [Sniderman, Monika, Cotteleer, 2016, p. 2; Khan, Vorley, 2017, p. 18]. To explore the strategic opportunities of the internal and external environment in dynamics, analysts within the company apply various mathematical models. Big data is an unstructured, large-scale representation of high-quality information that requires special approaches to be applies to analysis. In contrast to traditional companies using the advances of the Third Industrial Revolution (automation and robotization), companies relying on big data are able to investigate previously isolated datasets within a single model, for instance, to analyze production efficiency with respect to the emerging bottlenecks or to identify the patterns of consumer behavior [Kosacka-Olejnik, Pitakaso, 2019]. Numerous researchers claim that big data analysis is one of the key methods of turning information into knowledge, which can be employed for operational and strategic planning of company development[1].

Most of this data is generated not only within the company, but also in the process of supplier-consumer interaction, thus increasing the relevance of cyber-physical security while applying and processing sensitive personal data. For a company engaged in the service sector of economy, processing big data from external sources (social networks, company websites), among other things, helps build up an in-depth customer profile in order to develop new marketing strategies [Sniderman, Monika, Cotteleer, 2016, p. 2].

Knowledge management has a great influence on administrative business processes: in industrial companies, big data analysis can be applied when learning details about the machinery life cycle so as to reduce failures and costs for unpredicted repairs, as well as to design the life cycle of the very product and implement an effective recycling and reuse strategy. The volume of the collected data is incomparable with the volume of data processed using traditional methods. To process them, therefore, cloud technologies are utilized that make it possible to rent computing power and digital storage without diverting a significant amount of resources to the information infrastructure [Ghobakhloo, 2018, p. 910]. A qualitative change in the data obtained through data mining is due to the comprehension of individual characteristics of each consumer or the internal production process, and to the development of customized offers or models of equipment performance with a unique accuracy. Under such conditions, it is reasonable to employ the strategies of *external codification* to analyze the data gathered from the *external environment*, e.g. from customers or supply chains, as well as external personalization to determine the most tried-and-tested methods for processing the collected big data.

Analyzing the abovementioned achievements of Industry 4.0 from the perspective of traditional business models transformation and knowledge management strategies, we distinguish between two essential elements of the company's infrastructure, i.e. two Industry 4.0 implementation areas:

1) *cyber-physical systems* (additive technologies, cobots, and the Internet of Things) that support key manufacturing business processes;

2) *data mining and decision-making systems* (systems for collecting, analyzing and interpreting big data) that maintain administrative business processes, including strategic management.

Based on the analysis of the Industry 4.0 technologies, we arrive at the conclusion that these implementation areas are characterized by different content of knowledge: cyber-physical systems generate operational knowledge that is useful to specialists and developers, whereas data mining systems can turn data into strategically important organizational knowledge that will be of use for managers making long-term decisions.

Company maturity. We believe that business models and knowledge management strategies are also affected by the level of companies' maturity in terms of Industry 4.0 implementation. Despite significant technological challenges and shifts in the market for goods and services, the general logic of positioning companies on the "scale of success" remains unaltered: there are leaders introducing the state-of-the-art technologies; followers; and underperformers receiving only a marginal effect from the introduction of Industry 4.0.

According to McKinsey Report[2], there are several types of organizations regarding the concept of Industry 4.0: "beacon" companies are the most efficient at applying this concept and successful at using the global trends of the Fourth Industrial Revolution to their own advantage. "Beacons" ensure the extensive implementation of Industry 4.0 within their business models at all levels of production and distribution, which is their key difference from traditional companies. Among "beacons" are the largest actors in the market of industrial technologies and innovations, as well as local companies leading in particular regions. McKinsey Report also distinguishes between followers, i.e. companies aiming to introduce Industry 4.0 technologies in the next 10 years, and lagging companies that do not plan to do it at all.

According to Müller, Buliga and Voigt [2018, p. 10], there are four categories, designed to help managers to evaluate their own company's positioning towards Industry 4.0: craft manufacturers following traditional pathways; preliminary stage planners that have not yet introduced the Industry 4.0 technologies, but thinking of doing so; Industry 4.0 users applying this methodology to organize specific business processes; and full-scale adopters that have introduced these technologies to all their work processes. Ganzarain and Errasti [2016, p. 1124] propose a three stage maturity model, which consists of the stage of strategic vision (analysis of op-

[1] McKinsey & Company. (2019). The Fourth Industrial Revolution. Targets for the development of industrial technology and innovation. World Economic Forum. January. Available at: http://www3.weforum.org/docs/WEF_Четвертая_промышленная революция.pdf. (In Russ.).

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portunities and resources to be introduced); the stage of roadmap (development of the implementation plan); and the stage of action building (attracting investments and introducing Industry 4.0 projects into particular business processes).

We assume that the level of maturity will also have a significant influence on knowledge management strategies. Combining the three approaches developed in the literature, we can differentiate between three maturity stages of companies in terms of implementation of the Industry 4.0 paradigm:

1) the initial maturity level: Industry 4.0 elements are not introduced in manufacturing; there is only a strategic vision of the implementation process or a roadmap under development;

2) "followers": the elements of cyber-physical and data mining systems are introduced in particular business processes;

3) "beacons": organizations that have fully introduced the Industry 4.0 concept and integrated its key elements into all major business processes.

EXPLORING THE IMPACT OF INDUSTRY 4.0 ON BUSINESS MODELS AND KNOWLEDGE MANAGEMENT STRATEGIES THROUGH CASE STUDY

To confirm the assumptions about the effect of (1) the Industry 4.0 implementation area and the nature of organizational knowledge, as well as (2) the company maturity level, we address several case studies of companies operating in Russia and abroad. To explore the assumptions made, it is reasonable to use a qualitative analysis implying a targeted detailed inquiry into some characteristics of certain companies. This analysis is performed on the basis of a representative, or *typical case study* [Yin, 2009, p. 48]. This method is acceptable, since the companies under examination are considered homogenous in terms of introducing and maintaining the Industry 4.0 technologies into their production processes, but they are different in maturity levels and positioning towards Industry 4.0 and employ different approaches to implementing knowledge management strategies. The selection of the companies was carried out according to whether they were involved in the full-scale Industry 4.0 implementation projects or introduced the methodology to individual business processes only. Another selection criterion was the transparency and availability of the data about their internal environment. The information about the companies was retrieved from open web resources provided in Appendix.

Company A is involved in the German chemical industry and is one of the world's leading manufacturers of silicone prototypes and spare parts based on additive technologies. The company's maturity corresponds to the "beacon" level as it has its own innovative solutions and developments in the field of raw materials production and equipment modification for working with such a complex material as silicone. Expertise in this field is one of the company's central competitive advantages. Silicone prototypes are widely used in automotive industry, healthcare, electronics and lifestyle goods. The strategic goal of *Company A* is to enhance the availability of silicone parts for a broad variety of industries. The current business model is oriented towards receiving orders via the company's website. Once the registration is completed, users upload technical drawings of the necessary parts to the website. After that the production time and cost will be calculated. All drawings of 3D models are uploaded to the client's profile in a universal CAD-file format. Information solutions are integrated into the SAP system. The data from the website is processed by the system; afterwards the order is confirmed and the necessary resources (computed machine time and the amount of materials) are set aside. The engineering team also takes part in assessing the feasibility of the project and, if necessary, delivers additional opinions.

The case study of *Company A* shows that a number of routine knowledge exchange operations typical of the traditional business model for one-off orders are excluded from the operational flow. The company's engineers are only involved in project consulting and analyze if the original parts need to be finalized, whereas all the functions of knowledge exchange with the client are automated, and the machine workload is calculated based on the data from the integrated network of 3D printers. The company is able to track its projects online and establish communication with the client according to the analysis of the current data. Strategically, the effectiveness of such a business model depends on the scale of operation and the complexity of orders received.

Company B is a medium-sized British company that also specializes in the application of additive technologies in manufacturing, including non-standard materials. Due to the high availability of technology, the 3D printing industry is growing at an extremely fast pace. The company specializes in the manufacture of complex carbon parts based on selective laser sintering. The company's major problems are to plan the inflow of orders and to distribute the workflows between the existing equipment units in sequential processing. This is a "beacon" company, since the Industry 4.0 technologies are deeply integrated into its business processes. Firstly, modern solutions have allowed the company to introduce cyber-physical systems for material flows automation into its main business processes and minimize the level of human control and manual operations. Secondly, quality management operations in the field of measuring digital models of workpieces were automated followed by a subsequent analysis of their wall thickness and strength properties. Thirdly, the company heavily invests in employees training and focuses on teaching the existing materials processing approaches to improve the quality of work. Thus, the company seeks to manage information about the current workload and its customers by offering unique solutions for each.

Company C is a private university in Norway. This is a "beacon" company that uses the achievements of Industry 4.0 to organize the educational process. As a high school of architecture, the university seeks to speed up the design processes by producing 3D models in a short time. The main problem comes down to not only the capacity of university equipment, but also to the laborious analysis to identify projects' errors. The introduction of the Internet of Things allowed the university to speed up business processes and reduce the percentage of errors in the production of project layouts. This freed up some time for the staff to advise students on the conceptual design of projects. The strategic goal of the university is to develop human capital: the introduction of the Industry 4.0 technologies reduced the processing cycle of a project in the university's architectural laboratory and optimized the amount of time spent on interaction with major customers, thus increasing the satisfaction of teachers and students.

Company D is among Russia's largest retailers operating in the foodstuffs and medicine market. One of the development avenues of the company is to understand customers' needs within the low and medium price segments. The strategic objective is to manage stocks and coordinate supply chains to stimulate cooperation with local manufacturers, which enjoy some benefits due to brand recognition and relatively low logistics costs. In this case, the company chose the path of improving the information technology infrastructure in order to use the big data flow in planning based on predictive analytics. The company corresponds to the "follower" level of maturity due to local solutions and the scale of implementation. Daily physical transactions with a large number of customers generate a significant flow of data, which is processed by the company, turned into knowledge and then used for offering more attractive prices. According to the company's specialists, the introduction of this system will allow designing the layout of stores, expanding the availability of goods and improving shelf display. In addition, the company plans to strengthen interaction with distributors – representatives of manufacturing companies: based on the analysis of consumer behavior, the company alters the frequency of promotions (sale price tags) in order to ensure the greatest attractiveness of goods for consumers. Thus, using the Industry 4.0 technology, the company seeks to decentralize decision-making and introduce a customer-oriented operating model in order to be more flexible and prompt when deciding on the product range and pricing policy.

Company E. The mission of a Russian high-tech manufacturing company is to turn fiber lasers into a tool for mass production, providing superior performance, reliability and usability at a lower total cost compared to other types of lasers, which allows final users to increase productivity and reduce costs. The company's maturity corresponds to the "follower" level, since the Industry 4.0 concept is introduced to only fundamental business processes. Integrated solutions are created in manufacturing, which is a self-regulating operating system based on the IoT technologies. Through interaction with reliable suppliers, the company strives to minimize the level of defects in products. Judging by the company's history, it actively uses its employees' knowledge to build a primary infrastructure corresponding to the level of the Industry 4.0 technologies in operating activities to improve the quality of manufactured products. The lasers are used in the next production cycles so as to develop goods with high value added – additive laser sintering plants.

Company F manufactures and introduces automation, digitalization and additive technologies to the activities of production companies. This is a "beacon" company that conveys its experience to other market participants for developing their infrastructure. This is an international organization supporting technology solutions in other firms that introduce Industry 4.0-based platforms, provide a steady supply of equipment and machinery, offer consulting services and train employees. In line with the corporate motto "Collaboration supports innovation", the company's partner program is designed to make its global network available to selected partners. This cooperation strategy in knowledge management creates benefits for exclusive partners representing industry and the service sector. As opposed to the aforementioned case studies, the company develops the human capital of its partners by offering training for the client company's employees and additional consulting services on field-specific issues.

RESULTS AND DISCUSSION

Having analyzed the companies' experience, we suppose that all of them try to transform their current business models through the introduction of the Industry 4.0 technologies (Table 1). On the one hand, despite the fact that all the companies are at different implementation stages and operate in various sectors of economy, they all receive economic and social effects from the use of cyber-physical systems, data mining and analysis of big data. On the other hand, by adopting a particular solution, each company seeks to gain competitive advantages in the market. For example, manufacturing companies benefit more from the integration of additive technologies, while companies in the service sector use the advances in Industry 4.0 to analyze, study and support their customers.

Companies applying the Industry 4.0 concept do not aim to form a "stronghold" of universal knowledge, but transform their business models and strategies in the process of value creation, and flexibly respond to the needs of their customers depending on the prevailing conditions. In our opinion, the experience of the companies' under consideration implies primarily an extensive use of the situational approach to implementing a particular knowledge management strategy. In the course

Table 1 – Industry 4.0 implementation areas, the level of companies' maturity and their impact on the knowledge management strategies in the companies under review
Таблица 1 – Области применения индустрии 4.0, уровень зрелости компаний и их влияние на стратегии управления знаниями в компаниях.

Company	Industry 4.0 implementation areas creating value / Their influence on the business model (element involved in value creation)	Maturity level / The industry, in which the company is engaged	Impact on knowledge management strategy based on [Kim et al., 2014, p. 404]
A	Cyber-physical systems / To eliminate routine manual operations when processing a flow of one-off orders to enhance quality	Beacon / Chemical industry	Internal codification. The network integration of the equipment allowed creating value from the formalized knowledge of customers (models uploaded to the site) to minimize manual operations
B	Cyber-physical systems / To introduce a quality management system based on the integration of the Internet of Things into the order processing system	Beacon / Laser 3D printing	Internal personalization. The internal knowledge of employees was processed to optimize production business processes and create sustainable production models while minimizing the human factor
C	Cyber-physical systems / To reduce project cycle times and improve employee performance	Follower / Education	External codification. The university receives orders from its partners and students in the formalized format and implements their automated processing
D	Data mining / To strengthen the relationships with buyers and suppliers by using the Industry 4.0 advantage, i.e. Big Data in sales planning	Follower / Retail	External codification. The company uses the data obtained to analyze consumer behavior. It sets up a database of external consumer conduct to generate knowledge about their buying habits, support customized sales and optimize stocks
E	Cyber-physical systems / To use a self-adjusting manufacturing system to produce laser products applied in additive manufacturing	Follower / High-tech mechanical engineering	Internal codification. The company uses the data and employees' knowledge to ensure self-regulation of the internal environment and search for alternative ways of using laser products
F	Data mining / To share and exchange knowledge with the company's clients to transform their internal environment in accordance with the principles of Industry 4.0	Beacon / Consulting and technology implementation	External personalization. The company trains its clients' employees so as to maximize the performance of the Industry 4.0 solutions introduced within their infrastructure

of the analysis carried out by the method of a representative case study, we have demonstrated that the implementation areas of Industry 4.0 and the level of companies' maturity were relevant factors in pursuing a certain knowledge management strategy. Thus, our assumptions were confirmed. Based on the findings of the analysis, we propose a matrix (Table 2) for choosing a strategy corresponding to the prevailing factors.

Table 2 – Contingency models of knowledge management strategies according to the company's maturity level and the implementation area of Industry 4.0
Таблица 2 – Типичные ситуационные стратегии управления знанием в зависимости от уровня зрелости компании и области внедрения Индустрии 4.0

Implementation area / Maturity level	Business process dominated by influence of network integration and cyber-physical systems	Business process dominated by influence of data mining
Initial level (elements of Industry 4.0 are not adopted or only the introduction roadmap is developed)	*External codification:* gaining external formalized knowledge about the technologies acceptable for the company's industry and comprehending standard methods for adopting these technologies	*Internal personalization:* realizing the potential value of big data and cloud analytics in the company's activities on the basis of employees' knowledge about the development potential of individual business processes
Followers (Industry 4.0 is adopted at the level of individual business processes; the objective is to ensure the stability of the system)	*Internal and external codification:* using formalized internal knowledge to build a primary cyber-physical infrastructure that is optimal for the existing technology; using the formalized customer data to include it in the cyber-physical environment (for example, virtual models uploaded to company websites and utilized for the analysis and production of individual parts)	*External codification:* following best practices of the industry in processing and interpreting big data, applying time-honored methods and areas of analysis; applying knowledge of leaders in the industry to find similar patterns in consumer behavior, optimize supply chains using big data and data mining technologies
Beacons (full-scale implementation at the level of the entire business model; the objective is to provide innovative solutions for the development of advanced niches in the market)	*External codification:* using well-tried solutions to improve the existing infrastructure of Industry 4.0 *Internal personalization:* applying non-formalized knowledge of employees to upgrade cyber-physical systems; building the internal environment	*Internal and external personalization:* using the pioneering expertise of the employees to analyze patterns and trends in the data, digital goal-setting, training services; applying non-formalized data from customers and partners for strategic analysis and search for weak signals (shifts in consumer behavior or supply chain)

At the initial level, in order to decide on the company's contingency strategy, it is necessary to identify the current stage of the company's development and establish its maturity level in terms of readiness for the full-scale application of the Industry 4.0 technologies. The approach developed by the authors is based on the analysis of the extent to which the companies are ready to introduce the Industry 4.0 elements into their business models. The approach emphasizes the importance of the system sustainable functioning and the support for advanced technologies entering the market, which reduces the riskiness of investments in Industry 4.0 and requires managers to be highly qualified. After that, it is necessary to specify the technologies implementation area, their relations with operational activity and the cyber-physical environment or the processes of big data mining and employee training.

The initial level of maturity. In our view, at the early stage of contingency strategies application it is required to develop a *transformational strategic vision* among the company's top managers, which is based on the understanding of certain types of technological, material and human resources exploited in the company's activities. Given the characteristics of managers as users of data mining results, the initial steps are likely to be taken in interpreting and benefiting from the big data generated by companies and the external environment. When forming a strategic vision, it is necessary to identify what drives changes in the external environment, and forecast the company' position in all resource markets, including the job market. For doing so, external codification is applied in order to analyze the formalized knowledge about the existing technologies of Industry 4.0 and their potential when transforming the current business model. All data can be later used to create a new Industry 4.0 implementation roadmap or revise the existing one.

Followers face the challenge of *cyber-physical adaptation*. At this stage, enterprises that have introduced the elements of Industry 4.0 as part of particular business processes improve and optimize the current infrastructure, since some of the business model's elements need to be integrated according to the latest technological advancements. Cyber-physical adaptation is about optimizing the company's internal physical and network infrastructure in line with the capabilities of the existing supply chains and geographic markets. Internal and external codification of knowledge helps such companies lay the groundwork for a sustainable and developing system that enacts a "catching up" development scenario. At the same time, they can effectively process the accumulated formalized data and knowledge to optimize the existing technology and search for alternative ways to employ it. As indicated above, *Company E* uses the acquired knowledge to find new ways to apply laser technologies in mechanical engineering and metallurgy. Changes in such companies are expected to influence not only production systems, but also human resource management strategies, since adding a variety of creative tasks and enhancing the performance of remote and brain work are coming to the fore.

In case if data mining is a dominating business process, companies-"followers" are guided by digital goal-setting, which involves strengthening the organizational culture in the field of data processing and interpretation. Vierhaus et al. [2014, p. 194] claim that in the nearest future companies should invest more resources in employee training and human capital, and involve experts in big data analysis. It is advisable for companies to use the experience of industry leaders and apply the available formalized data. The implementation of this strategy also suggests assessing technological risks that a company is more likely to face in the period from 2020 to 2030.

"Beacon"-companies are industry leaders that adopt the advances of Industry 4.0 to gain a competitive advantage through innovative knowledge. Normally, such companies implement strategies of internal and external personalization. As shown in the abovementioned cases, such companies endeavor not only to train their clients within the framework of operational business processes, but also to learn from them by analyzing their partners' actions. In such an environment, knowledge quickly becomes obsolete; therefore, for most "beacons", deep codification strategies are ineffective and limited in application.

The Industry 4.0 technologies implemented by "beacon"-companies involve a rethinking of a number of operations, some of which can be distributed within strategic partnerships in a single supply chain. For example, if a company does not possess sufficient knowledge in a particular business activity, it will be more profitable for it to acquire certain resources from specialized suppliers; therefore, it is not necessary to develop formalized and codified knowledge about a given resource in such an area. Modern companies also do not have to design a vertical supply chain and ensure a full production cycle. In any markets, there are opportunities to focus only on those areas, in which the company has a sustainable technological advantage in terms of knowledge and business understanding. In addition, such strategies, if followed by "beacon"-companies, can affect the localization of the main production, if the company's management makes a decision to distribute business units among specialized regional clusters.

Owing to personalization strategies, "beacons" are able to *position Industry 4.0* in the external and internal environments. Companies attract more investment due to the fact that, when communicating in the business environment, they disclose information about their technological advantages to potential investors, thereby attracting additional capital and expanding the network of suppliers.

CONCLUSION

The literature review and the analysis of the "beacon"-companies' practices demonstrate that the knowledge management strategy is a system-forming factor in the internal environment of all types of companies – those embarking on the implementation of the Industry 4.0 methodology, and those already enjoying its substantial benefits. The next decade will witness a distribution of actors in the markets for goods and services according to their technological advantage. Therefore, managers feel the urgent need to forecast their position in a rapidly changing environment. The shifts in priorities will require managers to revise their strategic vision of the existing business models. The concept of Industry 4.0 creates a number of opportunities for organizing efficient production, raising the quality of intra-firm human capital, sharing knowledge with customers and creating a common image of a successful business to achieve sustainable competitive advantage.

The issues of strategic knowledge management within Industry 4.0 receive scant attention in the management literature. We believe that a situational approach to strategic knowledge management shows significant promise and can be applied to help companies flexibly adapt to intense technological changes. The present study has demonstrated that Industry 4.0, as a global trend, transforms the current business models: it attracts highly qualified employees and eliminates routine operations, shortens planning and decision-making cycles, makes it possible to identify new patterns in consumer behavior to provide complete satisfaction with products and services, and creates realistic models to optimize supply chains. All this is possible due to big data mining. In contrast to the previous stage of industrial development, the focus of knowledge management is on people's intellectual activity, their adaptability, individual performance and personal involvement in corporate management. Hence, decision-making should be aligned with the specific trends of Industry 4.0.

In the course of the study, we identified the significant factors that affected the choice of a particular knowledge management strategy by a company. Firstly, this is the maturity level. At each stage of development, companies face essentially different tasks and have the need for different types of knowledge: from creating a strategic vision and planning a roadmap for the Industry 4.0 implementation to developing winning knowledge personalization strategies for effective knowledge exchange with potential investors and successful positioning of leadership qualities in existing conditions. Secondly, we identified two key areas of Industry 4.0 implementation – cyber-physical environment and data mining. They, in turn, can be used to determine the type of organizational knowledge (operational and strategic) and potential users (specialists, developers or managers). Based on the factors influencing strategies' application, we have designed a matrix for choosing a knowledge management strategy while introducing the achievements of Industry 4.0.

The proposed situational approach to establishing typical strategies has a number of limitations inherent in conceptual modeling of social processes. First, the revealed distinction between the cyber-physical environment and data mining should be considered along with the properties of the generated knowledge and potential users. In the first instance, we are talking about the physical "shell" of production generating streams of operational data and information, which are transformed into knowledge by the appropriate infrastructure (here, users are represented by specialists and developers). In the second instance, we emphasize the strategic importance of big data in transforming the fundamental business model and making long-term decisions (here, users are represented by managers). Second, the companies' activity was disintegrated and its individual elements were identified, which limited the integrity principle of the companies' internal environment. In fact, companies are exposed to a large number of hidden factors that can also exert a significant impact on the choice of the knowledge management strategy. Third, the proposed approach focuses on technological factors, and, if put into practice, it should be supplemented with social variables with respect to the accumulated level of human capital, social and environmental responsibility.

In the coming years, companies should prepare themselves for a marked increase in the volume of quantitative and qualitative data that need to be processed into organizational knowledge. Companies need to find new and effective ways to acquire organizational knowledge and encourage employees to seek autonomous solutions, while avoiding the traps of bureaucratic centralization to shorten the management decision-making cycle. In such conditions, it becomes increasingly relevant to analyze accumulated data in the context of managers' strategic vision transformation. In addition, most researchers conclude that Industry 4.0 will have the greatest impact on the transformation of the job market and, above all, on the competitive strategies of employers, which are subject to change due to the emergence of new professions and high-tech jobs. Against this background, research studies on special human capital determined by the trends of Industry 4.0 are especially promising. Obviously, companies seeking to derive strategic benefits from flexible technology solutions need to attract significant investment in human capital and opt for data analysts and engineers who are able to implement technology solutions. ■

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Appendix

The official website of Company A. Available at: https://www.aceo3d.com/.
The official website of Company B. Available at: https://paragon-rt.com/.
The official website of Company C. Available at: https://aho.no/en.
The official website of Company D. Available at: https://magnit-info.ru/about/strategy/Magnit%20strategy%20summary%20-%2004Oct18%20v1.pdf.
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Стратегии менеджмента знаний в компаниях: тенденции и влияние Индустрии 4.0

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Аннотация. Современные компании переживают трансформацию привычных бизнес-моделей, на основе которых рождается потребительская ценность и, следовательно, конкурентоспособность бизнеса. Актуальность приобретают новые технологические ориентиры, основанные на сетевой интеграции, интеллектуальных технологиях и гибкой автоматизации. Появляются новые конкурентные возможности, ключевыми управляющими бизнес-процессами становятся менеджмент знаний и управление интеллектуальным капиталом. При формировании стратегического видения компаниям важно отобрать релевантные данные из потока информации о внешней и внутренней среде, превращая их в организационное знание, являющееся ключевым ресурсом. Статья посвящена анализу опыта работы российских и зарубежных компаний по внедрению масштабируемых моделей, ориентированных на широкое применение Индустрии 4.0. Также определяются принципы и стратегии управления знаниями, которые позволяют таким компаниями поддерживать конкурентоспособность в стратегической перспективе. Методологическая база представлена теоретическими положениями менеджмента знаний и концептуальными положениями ресурсного подхода. Методами исследования являются логико-структурный анализ и систематизация, а также ситуационный метод кейс-стади. Эмпирическую базу составляют кейсы шести компаний, сформированные из открытых источников. Полученные результаты показали целесообразность применения ситуационного подхода к менеджменту знаний: компании используют различные стратегии накопления и обмена знаниями в зависимости от уровня зрелости и области внедрения Индустрии 4.0. Предложен ситуационный подход к стратегическому менеджменту знаний тех компаний, которые успешно применяют технологии четвертой промышленной революции. Теоретическая и практическая значимость исследования заключается в выявлении общих подходов к управлению знаниями в различных условиях. Статья может быть полезна менеджерам, принимающим ключевые решения в компаниях.

Ключевые слова: Индустрия 4.0; управление знаниями; стратегический менеджмент; ситуационный подход; бизнес-процессы; бизнес-модели.

JEL Classification: I10, I12, M31

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