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Digital transformation of industrial production in the context of Industry 4.0

The article explores the key components of the digital transformation of industrial production in the context of Industry 4.0, in particular: the introduction of IT technologies, which involve the using of Big Data, Blockchain technologies in production, robotics, computer-aided design systems, resource planning of industrial cluster enterprises, product life cycle management, and also process of the control systems of the production processes. An in-depth analysis of the number and content of scientific papers devoted to the research of the digital and innovative potential of the industrial cluster, indexed on the bases of Web of Science, Scopus, the Russian scientific citation index, has been carried out. This analysis revealed the relevance and depth of research, the definition and modern approaches to assessing the digital potential. The approaches, main indicators, and indicators for assessing digital potential proposed by Russian scientists A.V. Kozlov, A.B. Teslya, N.V. Gorodonova and A.A. Peshkova, Yu.A. Kovalchuk, I.V. Alekseyev and others. The author's definition of the concept «digital potential of an innovative-active industrial cluster» was given, the possible ways of its functioning were highlighted: provided that the traditional production process can be implemented, as well as with the active formation and development of digital potential. The concepts of the digital economy were also characterized and the directions of technology application in industrial production were defined: the «Internet of Things», «Big Data», «Blockchain» and «Cyberphysical Systems».

Keywords: Industry 4.0, digitalization, digital transformation of industry, industrial enterprises, industrial clusters, digital potential, approaches to assessing digital potential, digital factories.

In the context of modern economic development, the digitalization of industrial enterprises and especially industrial clusters is given the special attention, since the development of the Internet and its wide distribution, the emergence and using of a variety of cloud technologies and digital platforms, the active and almost universal using of additive technologies by the enterprises, and the development of digital factories has ensured the emergence global industrial networks that go beyond the usual understanding of «industrial enterprise».

Today we are talking about the innovative-active industrial clusters that can actively create, implement and commercialize innovative products, using all the advantages of industrial automation, thereby ensuring the transition of all industrial production to a new fourth stage of industrialization (Industry 4.0), which involves widespread digitalization, due to than the research of the digital potential of industrial enterprises and in particular clusters, operating on digital platforms (backbone innovative-active), is of particular relevance.

The analysis of the sources showed that in the modern scientific literature insufficient attention is given to the research of the concept of «digital potential» (Table 1). It is important to note that when searching in English databases, we used the phrase «digital potential», because, using the mask «digital potential of the industrial cluster / enterprise», no suitable scientific papers were found; in Russian-speaking — «digital potential of an industrial enterprise / cluster»; sorting of scientific articles was also carried out according to the following parameters:

1) years of publication: 2015–2019;
2) sources of information: scientific articles, books (including monographs), conference proceedings;
3) field of science: economics, management, business

Table 1

Number of scientific papers devoted to the research of the digital potential of the industrial cluster and indexed by WoS* databases, RSCI

Years	Number of publications in WoS	Share of publications,%	Number of publications in the RSCI	Share of publications,%
1	2	3	4	5
2015	52	9.5	1	2.2
2016	103	18.9	1	2.2
2017	112	20.6	6	13.0

1	2	3	4	5
2018	150	27.5	17	37.0
2019	128	23.5	21	45.7
*For searching process of the information used the section «Web of Science Core Collection».				

Note. The table is compiled by the authors according to the databases WoS, Scopus, RSCI.

As can be seen from Table 1, the number of scientific papers, indexed in WoS on digital potential over the past 5 years is small. At the same time, as a qualitative analysis shows, about 95–98 % of all published articles are mainly devoted not to studying «digital potential», but to such scientific areas as: digital economy, digitalization of industries, digital transformation, digital communication, digitalization of the public services sector, cryptocurrencies, digital social media marketing, big data, the using of digital technologies in the innovative development of economies of countries and regions, company websites, etc. *Complex works reflecting the concept, structure and analysis of approaches to assessing digital potential have not been identified.*

As for the RSCI database, for the analyzed period (2015–2019), the number of scientific articles found relating directly or indirectly to the research topic was 46, of which only 4 of them disclosed the essence of digital potential, including an industrial enterprise.

No scientific publications covering aspects of the digital potential of industrial clusters in both databases over the past 5 years have been found, which once again confirms the relevance of the research conducted by the authors.

As before, many scientists identify the «digital potential» with the «innovative potential», introducing only some elements of digitalization into the structure of the latter, or considering the «digital potential», on the contrary, without reference to the main financial and economic indicators of the enterprise / cluster. Therefore, the number of publications considering the innovative potential of an industrial enterprise and cluster is much larger (Table 2). This is partly due to the fact that the concepts of «digital economy, digitalization, digitalization, digital infrastructure» have been introduced into the scientific circulation relatively recently [1].

Table 2

Number of scientific papers devoted to the research of the innovative potential of the industrial cluster and indexed by the basis of WoS *, Scopus, RSCI**

Years	Number of publications in WoS	Share of publications,%	Number of publications in the RSCI	Share of publications,%
2015	11	11.8	27	18.6
2016	17	18.3	30	20.7
2017	28	30.1	43	29.7
2018	19	20.4	26	17.9
2019	18	19.4	19	13.1
* To search for information, the «Web of Science Core Collection» section was used. ** Search in WoS was carried out by the mask «innovative potential of the industrial enterprise»; in RSCI — «innovative potential of the industrial cluster».				

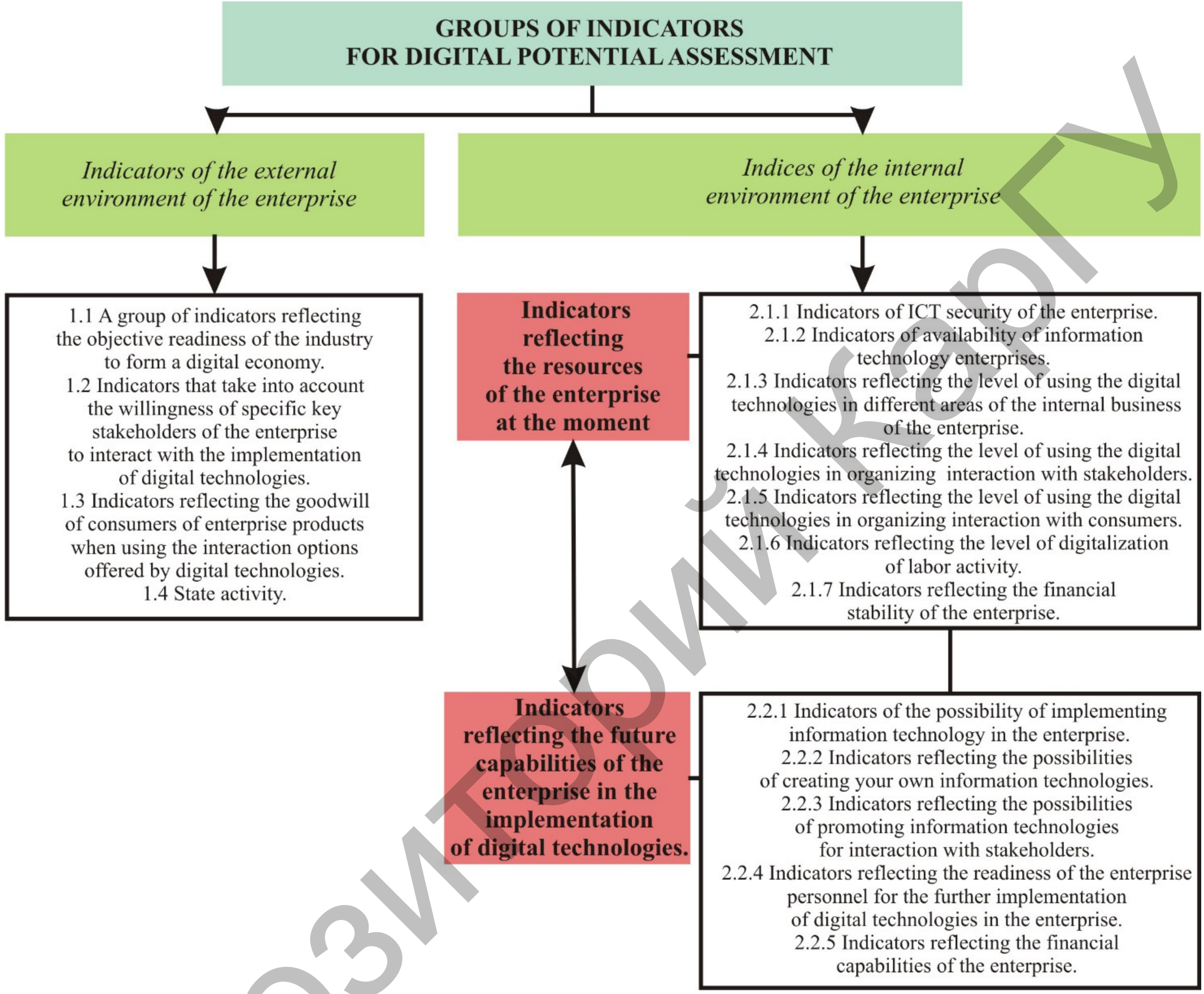
Note. The table is compiled by the authors according to the databases WoS, Scopus, RSCI.

However, it should be noted, that there is no generally accepted definition of the concepts of innovative cooperation as economic categories. The analysis showed that the structure of innovative cooperation has not been fully explored. Currently, there are several options for the structure of innovative cooperation and mutually beneficial cooperation. The economic potential of an industrial enterprise cannot be equal.

The digital potential of an innovative-active industrial cluster is a multifaceted system, includes many different factors that determine it, and therefore, analysis of approaches and methods for its assessment requires careful study and detailed consideration. Speaking about the analysis of approaches for assessing the digital potential of an industrial enterprise and cluster, in addition to the works described above, no others were found, which greatly complicates the analysis and identification of the most suitable approach, which at present would most accurately allow for the assessment of digital potential.

In this regard, we consider in more detail the existing approaches to assessing digital potential and, based on them, we outline its structure.

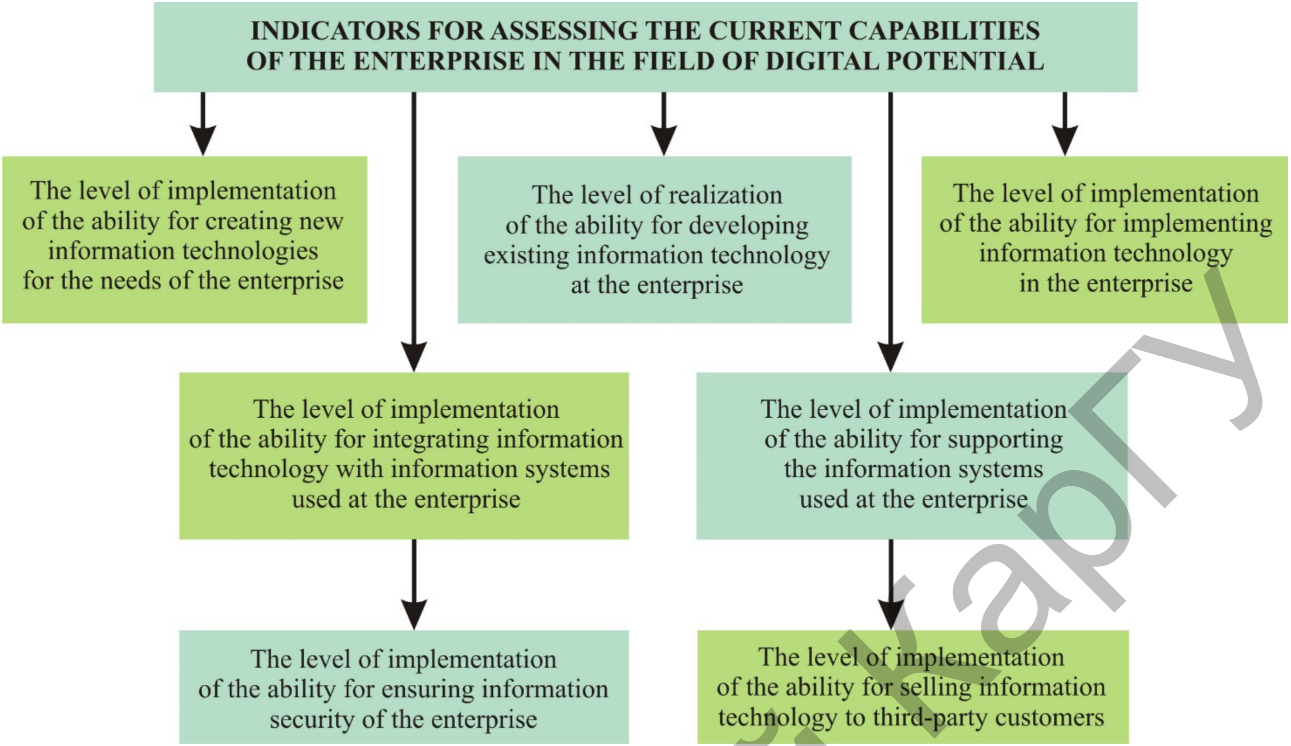
1. A.V. Kozlov, A.B. Teslya in the work «Digital Potential of Industrial Enterprises: Essence, Definition and Calculation Methods» they propose to evaluate the digital potential of an enterprise as a kind of integral assessment, which includes indicators of the external and internal environment (Fig. 1).



Note. The figure compiled by the authors based on the source [2].

Figure 1. A set of indicators for assessing digital potential, proposed by A.V. Kozlov, A.B. Teslya

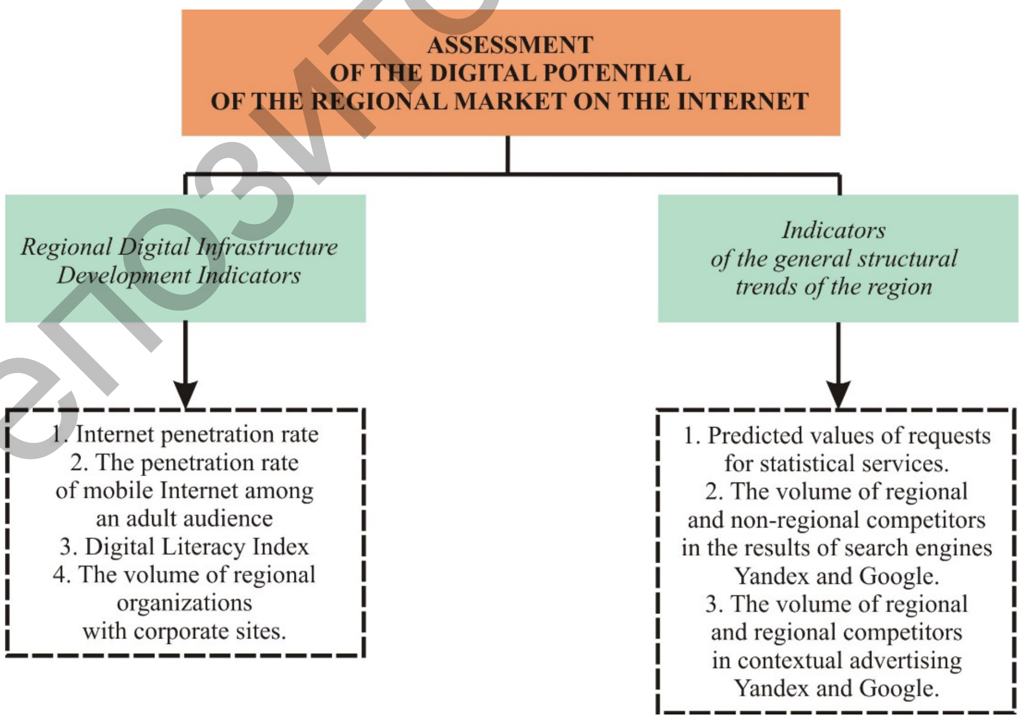
2. At the same time, N.V. Gorodonova and A.A. Peshkova in the scientific article «Development of the theoretical foundations of assessing the digital potential of an industrial enterprise» propose to evaluate the digital potential, taking into account the indicators of providing organizations with advanced hardware and software systems, the level of automation of certain business processes of the enterprises, the amount of costs for the development of the IT sphere (Fig. 2). At the same time, the authors note, that such an assessment is a determination of the current capabilities of the enterprise in the field of digital potential. N.V. Gorodnova and A.A. Peshkova in their work in addition to the proposed author's methodology for assessing digital potential pay special attention to existing ones, including: a society informatization index, an ICT development index, a readiness index for a network economy, a methodology of the international McKinsey & Company, and Systemic Economic Analytics of the Defense Industrial Complex (developed by experts of the Institute of Economic Strategies of the Russian Academy of Sciences).



Note. Figure compiled by the authors based on the source [3].

Figure 2. Digital capacity assessment system developed by N.V. Gorodonova and A.A. Peshkova

3. Yu.A. Kovalchuk, I.V. Alekseyev in the framework of the publication «Digital Potential of Regional Markets as a New Strategic Factor for the Development of Franchised Enterprises» propose to evaluate the digital potential in the context of two groups of parameters: indicators of the development of the digital infrastructure of the region and indicators of the general structural trends of the region (Fig. 3).



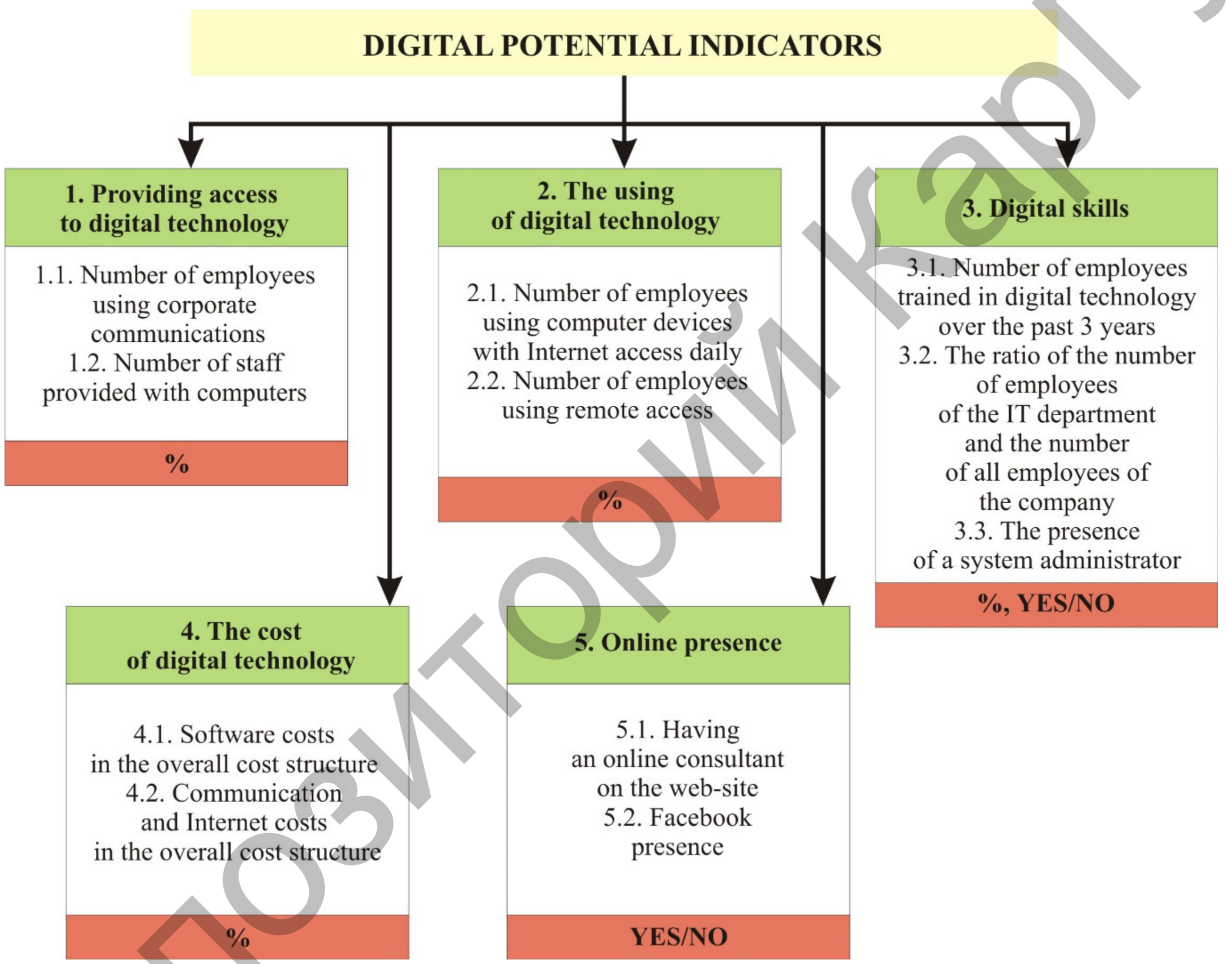
Note. Figure compiled by the authors based on the source [4].

Figure 3. The system of indicators for assessing the digital potential of the regional market on the Internet, created by Yu.A. Kovalchuk, I.V. Alekseyev

4. Y.V. Popov, K.A. Semyachkov, Yu.A. Moskalenko in the work «Comparative Assessment of the Digital Potential of Enterprises», the digital potential is estimated based on the digital readiness index developed by the WEF and the INSEAD international business school. Moreover, the authors distinguish the following groups of assessment parameters:

– providing access to information and communication technologies (includes 2 subparameters);
– application of information and communication technologies (includes 2 subparameters);
– skills in the application of information and communication technologies (includes 3 subparameters);
– costs of information and communication technologies (includes 2 subparameters);
– company presence in the network (includes 2 subparameters) (Figure 4).

According to the authors, the assessment carried out on the indicated groups of parameters allows us to see how efficiently and competently the company / individual enterprise uses digital resources.



Note. Figure compiled by the authors based on the source [5].

Figure 4. The main indicators and factors for assessing the digital potential
proposed by Y.V. Popov, K.A. Semyachkov, Yu.A. Moskalenko

The analysis showed that the most of the scientific works today are mainly focused on conducting cross-country, cross-industry analyzes of the digitalization process, digital transformation, and the development features of digital economies, while no approaches to the analysis of the digital potential of an innovative-active industrial cluster have been found.

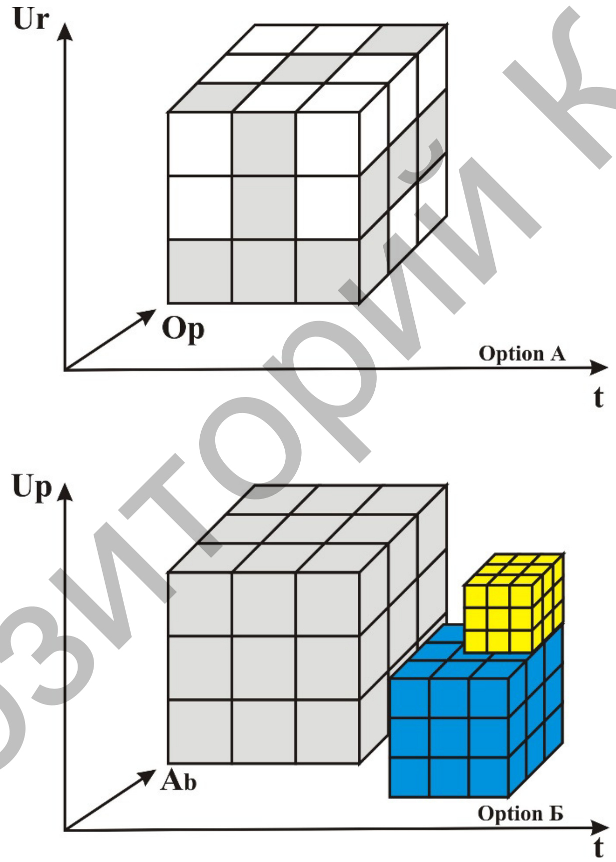
It should also be noted, that the existing approaches to assessing digital potential are built, practically, on the basis of factors that are directly related to the possibility of introducing modern ICT tools to the enterprise, while components that characterize the economic, financial, production stability of the enterprise are often overlooked, which, in turn, are part of the innovative and economic potential, in the research and understanding of which there are also certain discrepancies.

In 2013, as part of the publication «Measuring the full impact of digital capital», McKinsey introduced the concept of digital capital, which should be understood as a combination of traditional (servers, routers, software, etc.) and intangible assets: unique developments that contribute to the development of digital technologies; opportunities provided by digital technology; human capital; new business models built taking into account the requirements of the market, a functioning digital economy [6].

In essence, «digital capital» and «digital potential» are related and similar concepts. Analysts at the company determine that digital capital is a key factor in economic growth and population welfare.

However, we believe that «digital potential» should be understood as a combination of various sub-potentials (material, technical, scientific, organizational and managerial, infrastructure, financial and economic, human resources and information and communication), which should reflect two aspects of the enterprise / cluster: opportunities and his abilities.

This definition allows us to identify 2 possible ways of functioning of an innovatively active industrial cluster: the first — taking into account only its capabilities in the case of choosing traditional production methods without the active introduction of digital technologies; the second — with the maximum using of their abilities, which, coupled with a variety of digital technologies, will enable the industrial cluster to ensure efficiency in all its functioning systems (Fig. 5).



Note. The figure is made by the authors.

Figure 5. Variants of the functioning of the innovative-active industrial cluster under the condition of the traditional production process (option A), as well as with the active formation and development of digital potential (option B)

The characteristic of the axes in the figures presented is as follows:

– x-axis — t — time factor (long-term planning);

– y-axis: option A (Ur) — current level of resource using without digitalization elements (or with the presence of some of them); Option B (Up) — the maximum using of the resource capabilities of an innovative-active industrial cluster after the introduction of modern IT technologies in all cluster management systems: information, logistics, production and management;

– z-axis: option A (Op) — possibilities of an innovative-active industrial cluster; Option B (Ab) — the ability of an innovative-active industrial cluster.

What in this case should be understood as the active introduction of modern IT technologies? It's no secret, that the main «force» in the formation and dissemination of the concept of Industry 4.0 was the concepts of the Internet of Things, Big Data and Cyberphysical Systems, a brief description of each of which is presented in Table 3.

Table 3

Brief Description of Digital Economy Concepts

Name of concept	Characteristic	The direction of technology application in industrial production
Internet of things (IOT)	Equipping a variety of physical objects and systems with IT technologies to reduce their interaction with humans in the process of industrial production. The industry introduced the concept of IIOT — industrial Internet of things	Actively introduced in energy supply systems, in the transport industry. Successful implementation examples: jet engine prevention (used by General Electric); dry vacuum pump monitoring (used by Taiwan Smiconductor Manufacturing Company), etc.
Big Data	A set of methods and approaches for processing structured and unstructured data of a large volume and of various types	Improving energy efficiency, alarm management, data analysis technologies for quick DNA decryption, customer loyalty management, etc.
Blockchain	This is a continuous system of blocks containing information, built according to certain algorithms, capable of building relationships with decentralized databases	Prevention of cybercrime in various industries; active using in the industrial industry for the production of diamonds, allowing to have a historical database of all ever mined gems; digital identity; authentication; confirmation of access rights to resources
Cyberphysical systems	A concept that provides for the process of interaction of sensors installed at different objects of the production process, equipment of the industrial cluster and information systems (including digital platforms) for forecasting, self-tuning and adaptation to changes in production in the shortest possible time	Intelligent power grids, increasing transparency and manageability of supply chains, production of customized personal goods, etc.

Note. The table is compiled by the authors based on sources [7, 8].

Summing up all of the above, it should be noted, that the concept of «Industry 4.0» has become a driving force in the formation and development of digital economies around the world. Therefore, by analyzing the key components of Industry 4.0, by the active introduction of IT technologies we mean the using of Big Data, Blockchain, robotics, computer-aided design systems (CAD / CAM / CAE), industrial cluster enterprise resource planning (ERP) systems, and management systems in production product life cycle (PLM), production process management systems (MES), BPM business process management systems, an increase in the share of personnel capable and willing to work with high-tech equipment, introduction high-performance computers, active presence on the Internet (the presence of the site, pages in social and professional networks), and many others.

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Л.В. Ташенова, А.В. Бабкин, Д.Г. Мамраева

Индустрия 4.0 контекстіндегі өнеркәсіптік өндірістің цифрлық трансформациясы

Мақалада Индустрия 4.0 контекстіндегі өнеркәсіптік өндірісті цифрлық трансформациялаудың негізгі компоненттері қарастырылған, атап айтқанда: өндірісте Big Data, Blockchain технологияларын, робототехника, автоматтандырылған жобалау жүйелерін, өнеркәсіптік кластерлік кәсіпорындардың ресурстарын жоспарлауды, өнімнің өмірлік циклін басқаруды, сонымен қатар процестерді басқару жүйесінің қамтитын IT-технологияларын енгізу. Web of Science, Scopus және ресей индексі бойынша ғылыми дәйектемедегі негізінде индекстелген индустриялық кластердің цифрлық және инновациялық әлеуетін зерттеуге арналған ғылыми еңбектердің саны мен мазмұнына терең талдау жасалды. Бұл талдау зерттеулердің өзектілігі мен тереңдігін, цифрлық әлеуетті бағалауға анықтама мен заманауи көзқарастарды анықтады. Ресей ғалымдары А.В. Козлов, А.Б. Тесля, Н.В. Городонова және А.А. Пешкова, Ю.А. Ковальчук, И.В. Алексеев және басқалар ұсынған цифрлық әлеуетті бағалау тәсілдері, негізгі индикаторлары және көрсеткіштері көрсетілген. «Инновациялық белсенді индустриялық кластердің цифрлық әлеуеті» ұғымына авторлық анықтама беріліп, оның жұмыс істеуінің мүмкін жолдары көрсетілген: дәстүрлі өндіріс процесі жүзеге асырылған жағдайда, сондай-ақ цифрлық әлеуетті белсенді қалыптастыру және дамыту жағдайында. Сонымен қатар цифрлық экономика ұғымдары сипатталған және өнеркәсіптік өндірісте технологияны қолдану бағыттары анықталған: «заттар интернеті», «үлкен деректер», «блокчейн» және «киберфизикалық жүйелер».

Кілт сөздер: Индустрия 4.0, цифрландыру, өнеркәсіптің цифрлық трансформациясы, өнеркәсіптік кәсіпорындар, өнеркәсіптік кластерлер, цифрлық әлуеті, цифрлық әлеуетті бағалау тәсілдері.

Л.В. Ташенова, А.В. Бабкин, Д.Г. Мамраева

Цифровая трансформация промышленного производства в контексте Индустрии 4.0

В статье исследованы ключевые компоненты цифровой трансформации промышленного производства в контексте Индустрии 4.0, в частности: внедрение IT-технологий, подразумевающих использование на производстве технологий Big Data, Blockchain: роботизация систем автоматизированного проектирования; планирование ресурсов предприятий промышленного кластера, управление жизненным циклом изделия, а также системы управления производственными процессами. Проведен глубокий анализ количества и содержания научных работ, посвященных изучению цифрового и инновационного потенциала промышленного кластера, проиндексированных по базам Web of Science, Scopus, российского индекса научного цитирования. Данный анализ позволил выявить актуальность и глубину исследований, определил и современные подходы к оценке цифрового потенциала. Раскрыты подходы, основные индикаторы и показатели оценки цифрового потенциала, предложенные российскими учеными А.В. Козловым, А.Б. Тесля, Н.В. Городоновой и А.А. Пешковой, Ю.А. Ковальчуком, И.В. Алексеевым и другими. Дано авторское определение понятию «цифровой потенциал инновационно-активного промышленного кластера», выделены возможные пути его функционирования: при условии осуществления традиционного процесса производства, а также при активном формировании и развитии цифрового потенциала. Также охарактеризованы концепции цифровой экономики и определены направления применения технологии на промышленном производстве: «интернета вещей», «больших данных», «блокчейн» и «киберфизических систем».

Ключевые слова: Индустрия 4.0, цифровизация, цифровая трансформация промышленности, промышленные предприятия, промышленные кластеры, цифровой потенциал, подходы к оценке цифрового потенциала.

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