DOI: 10.17747/2618-947X-2022-4-376-383
УДК 338.36

A single digital space for the efficient functioning of industry

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Abstract

The article is devoted to the development of the concept of a single digital space for the effective functioning of the industry. A new model of industrial production organisation, the platform ecosystem are analysed. The analysis of the theoretical concepts of the world economy on its structure, the system of organisation of interaction between ecosystem participants, factors affecting its dynamic development is given. It is shown that digital technologies play an essential role in the organisation of the ecosystem. At the same time, digitalisation occurs in two directions: the creation of the digital space of the enterprise participating in the ecosystem and the creation of the digital space of the ecosystem of industrial production.

The analysis of the use of digital technologies in various industries is given. The rating of the use of digital technologies in industry is discussed. The analysis of the factors constraining the process of digitalisation of the industry of the Russian Federation is given. The concept of ecosystem, presented in the world literature, and its functional and organisational features are analysed.

The influence of institutional conditions on the functional characteristics of the ecosystem is discussed. The ecosystem management system affects the economic and technological efficiency of each ecosystem participant. The prospects for the development of ecosystems based on platforms are shown.

The ability of the Russian manufacturing industry to adapt digital technologies and the organisation of modern forms of production on their basis are analysed. It is demonstrated that the potential of modern production of complex multicomponent products is determined by the ability to scale based on industry 4.0 technologies. At the same time, most of the enterprises fulfill individual orders of consumers and do not participate in the production chains of such products.

The tasks necessary for the organisation of breakthrough development of manufacturing enterprises in Russia are formulated. For modern organisational forms of the manufacturing industry a non-departmental management body is proposed. Its structure and functions are discussed.

Keywords: digital technologies, Industry 4.0, digital platforms, digital space, industrial policy, industrial revolution, digitalisation levels, value chains, advanced technologies, industrial ecosystem.

For citation:

Bogachev Yu.S., Trifonov P.V. (2022). A single digital space for the efficient functioning of the industry. *Strategic Decisions and Risk Management,* 13(4): 376-383. DOI: 10.17747/2618-947X-2022-4-376-383. (In Russ.)

Acknowledgements

The article was prepared based on the results of research carried out at the expense of budgetary funds under the state assignment of the Financial University.

用于工业高效运作的的单一数字空间

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摘要

文章论述了为工业的有效运作发展单一数字空间的概念。分析了工业生产组织的新模式 —— 平台生态系统。作者分析了世界经济结构的理论洞察力，而且描述了组织生态系统参与者之间互动的系统以及影响其动态发展的因素。数字技术已被证明在生态系统的组织中发挥了重要作用。而数字化是在两个方面进行的：为参与生态系统的企业创建一个数字空间，以及为工业生产生态系统创造一个数字空间。

对数字技术在不同工业部门的应用进行了分析。讨论了数字技术在工业中的应用水平。对俄罗斯工业数字化的制约因素进行了分析。对世界文献中提出的生态系统的概念及其功能和组织特征进行了分析。

讨论了制度条件对生态系统的功能特征的影响。生态系统管理体制影响到其中每个参与者的经济、技术效率。

基于平台的生态系统的前景显示。作者分析了俄罗斯加工工业采用数字技术和在其基础上组织现代生产形式的能力。证明了，当今复杂的多部件生产的潜力是由基于工业4.0技术的扩展能力决定的，同时企业主体部分完成客户的个别订单，不参与此类产品的生产链。

制定了俄罗斯加工工业突破性发展的挑战。作者建议为加工工业建立一个非部门管理机构，并讨论其结构和功能。

关键词：数字技术、工业4.0、数字平台、数字空间、工业政策，工业革命、数字化水平、价值链、尖端技术，工业生态系统。

供引用:

Bogachev Yu.S., Trifonov P.V.（2022）。用于工业高效运作的的单一数字空间。战略决策和风险管理。13(4)： 376-383。DOI： 10.17747/2618-947X-2022-4-376-383。（俄文）。

本文是根据金融大学国家任务下以预算经费为代价进行的研究成果编写的。

Introduction

In the countries – digital leaders, there is an intensive process of digitalisation of the economy, including industry. Digitalisation processes in them are determined, among other things, by the reaction to crisis processes in the socio-economic space.

More than 20 years ago, in order to optimise costs, developed countries began to transfer manufacturing enterprises to developing countries, in which the level of wages and costs of organising production were at a rather low level (relative to their own indicators). Currently, geopolitical tensions have contributed to the generation of the sanctions regime in foreign economic activity. This led to a break in supply chains and contributed to the emergence of structural problems in the national economies of developed countries. Significant progress in production technologies, means of communication and data processing has created conditions for the reshoring of the manufacturing industry in these countries, so the problem of digitalisation of industry is relevant.

The technological level determines the potential for the development of the digital space at enterprises where production processes, business processes in the enterprise management system, logistics, jobs, their organisation and distribution, interaction with financial institutions, etc.[1] are significantly changing.

The theory of digital space makes it possible to optimise the costs of ordinary labour productivity, the efficient use of financial and human resources, quickly respond to external influences, and expand the clientele of product sales.

This is facilitated by the introduction of intelligent control systems for measuring instruments at various operating sections of the production line, cyber-physical systems, computerisation of workplaces, the creation of a unified system for the fleet of equipment and workplaces, and the development of information and analytical data processing systems.

1. Theoretical review

Digital technologies in modern conditions are the main tool that determines the functioning of the value chain. Currently, production networks unite independent economic market entities, taking into account the high level of coordination of interests and interdependence of participants based on the common goal of production [Digital transformation in Russia, 2020]. Within the

[1] The Decree of the Government of the Russian Federation of July 28, 2017 No. 1632 Program “Digital Economy of the Russian Federation”. http://static.government.ru/media/files/9gFM4FHj4PsB79I5v7yLVuPgu4bvR7M0.pdf.

network, a decentralised production model is being created, including management systems of independent companies.

According to K. Schwab, President of the World Economic Forum, industrial enterprises involved in digitalisation are on the verge of large-scale changes, in which production and business process models are a system of interaction with business partners and customers and with the environment as a whole [Schwab , 2017]. In the world literature, research is being actively carried out on the nature of the organisation of this system.

It should be noted that the following sections of economic theory were taken into account when forming the concept of ecosystems: organisational ecology, neoinstitutional theory, and the theory of dynamic abilities of ecosystems [Moore, 1993].

At the initial stage, the concept of ecosystems used the provisions of the theory of organisational ecology. However, subsequently, on the basis of these provisions, an independent section of the ecosystem concept was developed. The new institutional economic theory had a significant impact on the development of the theory of ecosystems. Indeed, in various studies of the model of interaction between participants in ecosystems, contracting models used in business, models of transaction costs are used. The theory of dynamic abilities stimulated researchers to substantiate the concept of ecosystems based on platforms. From the point of view of this theory, the organisational development of an ecosystem is considered through the dynamics of the development of a set of ecosystem organisations. This set of organisations, combining their competencies in the production process, has the goal of creating a multicomponent product. Summarising the results of these studies, it can be noted that this system is based on the modular organisation of the use of resources and competencies [Baldwin, 2008].

Modern industrial production is an ecosystem in which autonomous organisations complement the competencies necessary for the production of complex multicomponent products [Seiger et al., 2014]. For this reason, the architecture of the ecosystem is modular in nature, within each module a certain type of coordination is carried out [Roundy et al., 2018]:

– engineering, forming a single model of production at all its stages;
– informational, within the framework of which the interface of various elements of the technology implementation is carried out;
– resource, carrying out the exchange of resources between participants in the production chain.

To control the technological interaction, the leaders of the ecosystem set the structure, basic parameters, rules and methods of interaction of various modules. In each module, taking into account its functional features, mechanisms for interaction with partners are formed.

A characteristic feature of the ecosystem is the fact that the formation of the final product is carried out on the basis of technological coordination of intermediate products (components) of a complex product (multicomponent).

An important circumstance is the institutional conditions that determine the effectiveness of the ecosystem [Chepurenko et al., 2019]. From this point of view, it should be noted that in the theory of dynamic capabilities, the competitiveness of an enterprise is ensured by its ability to adapt its competencies to changes in the external environment [Winter, 2003]. In ecosystem theory, it represents the environment in which its participants must respond to changes. From this point of view, the theory of dynamic abilities introduces the concept of “platform-based ecosystems” [Teece, 2017]. Within its framework, the formation of the architecture of a multicomponent product based on technological competencies is carried out. In the process of formation, the opportunities of the process participants for the integration of competencies are highlighted. This creates an impulse for self-development.

A number of studies are devoted to modeling the process of absorption by corporations of small innovative enterprises during the formation of an ecosystem. However, conditions are possible (regulation of competition, tax regime, subsidies) under which exponential growth of both types of organisations (small and corporations) occurs.

The working hypothesis of the study is the possibility of organising an industrial production platform in Russia on the basis of a single digital space, taking into account the characteristics of the technological, production, economic, and financial potentials of the enterprise.

2. Methodology and results of the study

In this paper to substantiate the direction of development of the potential for digitalisation of industrial production in the Russian Federation, the following research methods are used:

1) a comparison method to obtain information about the directions and ways of digitalisation of industry in different countries;
2) a functional method for determining the tasks of digitalisation, taking into account the functional profile of the object’s activity;
3) methods of analysis and synthesis to determine the ways of interaction based on digital methods of various functional systems of the enterprise;
4) modeling methods for developing the concept of a single digital space of an industrial enterprise or groups of enterprises;
5) statistical methods that allow to obtain an objective description of the state of industry digitalisation in the world and in Russia.

Table 1
Information about the use of digital technologies and related goods and services in production
(% of the number of respondents surveyed)

Industry	Digital platforms	Big Data	AI technologies	Cloud services	IoT	Digital twin	Industrial robots / automated lines	Additive technologies
Mining	13.2	21.8	2.5	19.0	14.6	2.1	4.2	1.5
Manufacturing industries	16.0	26.5	3.6	27.1	15.8	3.3	17.2	5.2
Supply of energy, gas and steam, air conditioning	16.6	23.7	3.3	19.4	15.9	1.2	2.0	1.1
Collective classification grouping by types of economic activity "Industry" (based on OKVED2)	15.4	24.8	3.3	23.9	15.3	2.5	11.3	3.6

Note. Information on the use of digital technologies and the production of related goods and services units of measurement are given as a percentage of the number of respondents (representatives of industrial enterprises).

Source: Russian Statistical Yearbook (2021): stat. Sat. Moscow: Rosstat.

Statistical data show the distribution of digital technologies used by industry (Table 1).

Thus, digitalisation goes in two directions:

1) creation of the digital space of the enterprise;

2) creation of an ecosystem of industrial production.

In Russia, the leading companies in the digitalisation of industry are KAMAZ PJSC, Kalashnikov PJSC, RusAl OJSC, Petrozavodskmash JSC. At KAMAZ, the Digital Transformation Center has created: logistics planning systems, a system for monitoring and operational management of production (MRP-2), a cloud platform system, a system for interacting with customers, and robotisation. Currently, the number of systems accounts for 900. As a result of digital transformation, the company's sales volume increased by 21% [Digital technologies in logistics.., 2020].

The process of digitalisation is actively going on in high-tech companies such as PJSC Russian Helicopters and JSC UAC.

The introduction of digital technologies makes it possible to effectively solve the problem of industrial safety based on preventive technologies (Table 2).

Table 2
Rating of digital technologies in the industry in 2020

№	Technology	Significance Index
1	Industrial robots	1
2	Artificial intelligence	0.86
3	Machine learning	0.68
4	Digital Prototyping	0.56
5	Sensorics	0.42
6	Wireless connection	0.30
7	Blockchain	0.21
8	Big Data	0.20
9	Virtual and augmented reality	0.12
10	Product as a service	0.09
11	Computer vision	0.03
12	Smart contracts	0.03
13	Industrial Internet of Things	0.03
14	Digital Twin (BIM)	0.02
15	Smart factories	0.01

Source: Digitalisation: history, prospects, digital economies of Russia and the world. Manufacturing control. https://up-pro.ru/library/strategi/tendencii/cyfrovizaciya-trend/.

Digital technologies make it possible, in particular, to monitor the entire production process and timely register violations of safety rules.

It should be noted the factors hindering the development of digitalisation of Russian industry:

1) low-tech level of the production process;
2) lack of automatic control;
3) low level of production required for the digitalisation of equipment (processors, sensors, routers, etc.);
4) low level of production standardisation;
5) many processes at the state level are not structured;
6) lack of qualified specialists in the use of IT technologies;
7) insufficient level of training of IT-specialists in Russia;
8) the specific mentality of entrepreneurs – many strive for a quick income (while in developed countries a significant proportion of businessmen are engaged in projects with a payback period of 30 years).

Now, in accordance with the data [Korovin, 2019], in Western countries the share of the digital economy in the structure of GDP is 16-35%, while in Russia it is 5%, and even then in the service sector.

PwC conducted a survey of 1,155 manufacturing executives from various industries in 26 countries[2]. Four categories of companies were identified: digital newbies, digital followers, digital innovators, and digital champions. Only 10% of industrial companies are digital champions, of which 2/3 are in the early stages. Digital champions are companies that have implemented four ecosystems: operational, technology, human resources and customer. Overall, across all industries, Asian companies are leading (19% of surveyed companies have reached digital champion maturity), while in the automotive and electronics industries, 20% of respondents have reached this level of maturity. These companies are significantly behind enterprises from the sphere of production of consumer and industrial goods, as well as the processing industry. In the US, the least digitised are the traditional industries – oil, mining, chemicals, and pharmaceuticals.

In Russia, based on the analysis of big data in the 100 largest companies representing the metallurgical, oil and gas, banking industries, as well as the financial sector, it turned out that 68% of companies have begun to form tools for the digital economy. The main direction is the robotisation of business processes (Robotic process automation, RPA) and predictive analytics.

Unfortunately, domestic companies that have begun to digitalize their activities carry it out spontaneously, without an integrated plan. Only 35% of Russian companies have a ready-made digitalisation strategy, while the rest are only going to develop it [Gudkova, 2021].

Digitalisation means a transition to a fundamentally new technological level – not only the replacement of obsolete and obsolete equipment with the latest, but also the digitalisation of this equipment.

Russian companies, with the support of leading foreign companies, have begun training their employees in digital skills. However, at present, under the current conditions, it is necessary to mobilise efforts in leading universities that train specialists in information technology and programming, with the development of a set of training programmes for domestic IT companies. The low level of digitalisation is also facilitated by the weak development of high-tech industries.

A promising object of industrial digitalisation is value-added production chains [Russia in a new era .., 2020]. The theoretical foundations for organising production chains were formulated by D. Hopkins [Digitalisation of the manufacturing industry.., 2021]. Production chains are a system of independent enterprises that produce elements of multicomponent complex products.

Researchers believe that the essential difference between an ecosystem and a traditional market is the degree of cooperation and competition between participants in ecosystem relations.

3. Discussion of results

It should be noted that the ideas about the ecosystem have been developed in developed countries, in which a significant number of industrial enterprises have a high technological level of production organisation. These enterprises have a high potential for the formation of ecosystem associations based on digital technologies.

In Russia, even the leading branches of the manufacturing industry, such as mechanical engineering, have a low technological level of production. This feature limits the ability of enterprises to produce products in a wide range of products. As a result, enterprises have a low potential for organising large-scale production of multicomponent products. Thus, in the engineering industry, out of 40,000 enterprises, only 2,000 are able to organise large-scale production.

At present, the main sectors of the manufacturing industry in the Russian Federation (machine building and the chemical industry) are largely dependent on imported technologies and equipment. The needs of the Russian economy in industrial goods (engineering) were satisfied by 60% by foreign purchases. In sectors such as civil engineering, communication equipment, electronic devices,

[2] Connected and autonomous supply chain ecosystems 2025. https://www.pwc.com/sg/en/services/reimagine-digital/business-transformation/digital-supply-chain/connected-and-autonomous-supply-chain-ecosystems-2025.html.

the share of imports is approaching 90-100%[3]. It should also be noted that more than a quarter of machine-building enterprises are economically inefficient[4].

The analysis performed shows that Russian manufacturing enterprises have a low potential for organising modern production of complex products, especially in high-tech industries. Two tasks need to be solved:

1. To form the potential for breakthrough development of manufacturing enterprises.
2. To combine enterprises with breakthrough development potential into ecosystems.

4. Conclusions and suggestions for further research

Thus, in order to ensure the economic sovereignty of the country, it is necessary to develop a fundamentally new model of industrial production in the context of digital transformation. To do this, it is necessary to solve the following tasks:

1. To identify the main groups of goods that are a priority for the Russian economy.
2. To reveal the existence of enterprises with competencies in the production of these goods.
3. To monitor the technological state of the production of these products.
4. Based on the information received to engineer the possibility of creating a production chain, identifying and eliminating bottlenecks through interaction with friendly countries (China, India).
5. To monitor the personnel potential of the industry.
6. To coordinate with enterprises the needs of customers in the range of products, the scale of supplies, quality characteristics on a long-term basis.
7. To form stable logistics links between enterprises and consumers of industrial products.
8. To develop an after-sales service system.
9. Science and technology platforms define short-, medium- and long-term plans for the technological development of value chains. The implementation of these plans creates the conditions for solving the problem of technological sovereignty of the Russian industry. When organising scientific and technological platforms, the following circumstances must be taken into account: no company in the world has the full scope of competencies to create sustainable scientific and technological development. In this regard, conditions for coordination of leading scientists, engineers, and designers, regardless of their departmental affiliation, should be created on this platform.
10. To create a system of value chains, provide them with a modern system of interaction, which will allow, regardless of ownership, to increase labour productivity due to a high level of technological security, optimal use of resources and the scale of production. As a result, an industrial hub will be created, within which a wide range of complex multi-component products will be produced.
11. When creating an industrial hub, it is necessary to take into account the limitations of digital management models of individual enterprises.
12. In the value chain, production technology and management system should be digitally synchronised.

To implement the concept of an industrial hub, it is necessary to create a special development institution based on a public-private partnership with the participation of engineers and leading designers, representatives of the state in the format of a self-governing organisation. The development institution created by the state will manage the entire hub, and a branch of the organisation, empowered by the development institution, will manage a separate chain. The coordinating body will be the strategic development committee, which will include six state representatives. An advisory vote will be given to specialists - heads of the largest enterprises, leading scientists and experts in relevant subject areas.

[3] Digitalisation of industry. Overview of TAdviser. https://www.tadviser.ru/index.php/%D0%A1%D1%82%D0%B0%D1%82%D1%8C%D1%8F:%D0%A6%D0%B8%D1%84%D1%80%D0%BE%D0%B2%D0%B8%D0%B7%D0%B0%D1%86%D0%B8%D1%8F_%D0%BF%D1%80%D0%BE%D0%BC%D1%8B%D1%88%D0%BB%D0%B5%D0%BD%D0%BD%D0%BE%D1%81%D1%82%D0%B8._%D0%9E%D0%B1%D0%B7%D0%BE%D1%80_TAdviser.

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The article was submitted on 01.10.2022; revised on 15.12.2022 and accepted for publication on 18.12.2022. The authors read and approved the final version of the manuscript.
文章于 01.10.2022 提交给编辑。文章于15.12.2022 已审稿，之后于18.12.2022 接受发表。作者已经阅读并批准了手稿的最终版本。