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DIGITAL TRANSFORMATION OF THE NETWORK MANAGEMENT SYSTEM FOR INNOVATIVE DEVELOPMENT OF TERRITORIES

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Keywords: digital economy; innovation networks; Internet technologies; technology transfer; commercialization of innovations; digital development rankings; intelligent system modeling.

ABSTRACT

The existing macroeconomic trends in the field of total informatization and digitalization of the world economy, a change in the sectoral structure of production, as well as economic challenges expressed in a change in technological orders, require a continuous revision of main approaches to organizing innovation. As international practice shows, the most effective interaction of all subjects of the national innovation system is carried out according to the network principle. The presented article studies the development trends of network innovation systems, reveals the content and retrospective features of network forms of interaction in technologically advanced countries. International ratings are used as a quantitative characteristic of the level of development of the digital economy. The study found that strategic partnership and interaction between the state, scientific communities and entrepreneurial structures creates preconditions for the creation of new breakthrough technologies and the expansion of network agents, increasing the productivity of research and development, effective commercialization of scientific research, and this is practically impossible without the use of virtual networks. The authors present a structural and logical model of an intellectual system for managing the innovative development of regions. This model prescribes the need to concentrate efforts for decision-makers in

determining the spatial reference points of scientific and technological development based on temporal databases. The proposed model makes it possible to solve problems in conditions of a lack of time, low reliability and inconsistency of initial information, and makes it possible to make a reasonable choice of an alternative among a variety of management models.

Keywords: digital economy; innovation networks; Internet technologies; technology transfer; commercialization of innovations; digital development rankings; intelligent system modeling.

INTRODUCTION

The modern market tends to expand the scale and diffusion of network structures in the economic space. In the network economy, a technological environment is formed; it is developing, reinforced by an innovative infrastructure, in which business entities have the opportunity to interact with each other regarding joint activities. The network form of interaction between the subjects of innovation (government, business and science) is one of the most common in world practice. Networks can be broadly defined as "a set of individuals and relational connections between them" (Yakobuchchi, 1996, p. 392). In this regard, the term "innovation network" is interpreted from the standpoint of expanding the concept of "network economy", and intelligent networks, as one of their directions in the development of innovation networks in the knowledge economy. In the most general interpretation found in modern specialized literature, the innovation network consists of the following subsystems: innovative; providing; financing.

Innovation networks include enterprises, research organizations, universities, and government working together to achieve common innovation goals. Many countries have recognized the importance of these networks for the development of innovation potential, international competitiveness and wealth (Rampersad, Quester, Troshani, 2010).

The emergence of a system of global Internet networks is the most significant man-made change in the world economy, with far-reaching consequences and creating unclaimed reserves for further spatial development in the field of innovation. Describing the stage of development of the Russian economy, L.A. Voronina and S.V. Ratner note that postindustrial society is "a network economy, consisting of network structures operating on the basis of networked electronics, in which the main emphasis is on the creation and dissemination of knowledge for the purposes of innovative development" (Voronina, Ratner, 2010, p. 12). The network economy, carried out using digital telecommunications, has a number of undeniable advantages over the traditional economy, while:

- factors of uniqueness and territorial exclusivity are destroyed;
- the cost of replication and delivery of digital products is sharply reduced and it becomes the same for all manufacturers;
- competitive differences in the cost of servicing additional orders are minimized.

The components of the network economy form a triad: network technologies – connections and relationships – network organizations. It has become an indisputable fact that the network economy is based on the use of Internet technologies. It is in connection with the formation of the information and economic space that the network economy has acquired ample opportunities to divide the innovation process among individual companies, both within the state

and abroad, while ensuring the unity of production and business science through modern telecommunication networks. The ICT sector lies at the heart of the information industry and remains a major driver of innovation, accounting for the largest share of R&D spending by enterprises in OECD countries and over a third of all patent applications worldwide. That is why it is especially important to analyze the development of information and communication technologies as the basis for the creation and functioning of the digital economy.

Experts have predicted the emergence of trends to transform the properties of the economic system as a whole and its individual elements through network forms of organization under the influence of changes in coordination mechanisms and market institutions (Parinov, 2002). One of the fundamental factors behind such changes is the recently emerging phenomenon of digitalization of the economy, which is gaining in importance.

The spread of digital technologies over a long period determines the directions of economic and social development and has repeatedly led to fundamental changes in people's lives. The formation of the digital economy is a priority for most technology leaders, including the UK, Germany, the USA, Japan, etc. Most often, they are characterized by a long period of implementation of the "digital development agenda" and the succession of priorities – from the creation of a basic infrastructure of information and communications technologies (hereinafter – ICT) before developing a coordinated policy in this area and programs to support the widespread adoption of digital technologies.
In recent years, another wave of transformation of business and social models has been unfolding, caused by the emergence of new generation digital technologies, which, due to the scale and depth of their influence, are called "end-to-end" – artificial intelligence (AI), the Internet of robotics, wireless technology (Wi-Fi) and others. According to some estimates, their implementation will increase labor productivity in companies by 40%. In the near future, nothing but the effective use of advanced digital technologies will determine the international competitiveness of not only individual companies, but also entire countries that form the infrastructure and legal environment for digitalization.Managing the spatial development of innovative activities is a complex process that requires the involvement of many participants in the management decision-making process. It should be borne in mind that in conditions of limited resources, it is required to find the optimal way to solve the set goals, taking into account alternative options for the development of the situation. In this regard, based on the management goals and information about the formed proposals in the field of innovative development, it becomes necessary to build a model that allows choosing the best alternative (scenario of innovative development) based on the assessment of effectiveness of the development of macroregions and national economies.

METHODOLOGY

The current stage of economic development at the territorial level is characterized by the expansion of areas of application of complex systems with a network structure. Improving the quality of preparation and implementation of management decisions requires the use of effective methods of structural analysis, based on the calculation of a number of indicators and modeling. The compositionally complex formulation of problems of this article requires a conceptual clarification of the actual interpretation of categories that characterize it. Modern network systems are considered only in close relationship, firstly, with

ICT technologies, secondly, with an innovative vector of development, and thirdly, with the digitalization of the economy.

This study is based on a combination of general scientific interdisciplinary and specialized economic methods, such as analysis, synthesis, scientific analogy, inductive, deductive methods, structural analysis, which is a methodological variety of system analysis, structural and logical modeling. The object of the research is network systems operating in an innovative economy. The subject of the research is the impact of digital transformation of the network system on innovative development on a national scale.

The authors provide a methodological overview of various approaches to defining the essence of the digital economy. So, in the version proposed by the World Bank, the emphasis is on the system of relationships between participants, according to which the digital economy is defined as "... a system of economic, social and cultural relations based on the use of digital information and communication technologies"1. The official Russian version considers the digital economy as an area of application of technological progress in various types of production, referring to the key factor of Big Data technologies, the processing and analysis of which, in comparison with traditional business models, help to manage the entire set of business processes, including equipment, storage, sale, supply of goods and services.2 In a broader context, the essence of the digital economy is presented in the state program for the development of the digital economy of the Russian Federation until 2035, where it is determined that the digital economy is a set of social relations and, in addition to a production focus, is aimed at increasing the level of socio-economic development of the state.3

The presented work identifies trends in the development of networked innovation systems at the international level, which became possible as a result of generalizing the retrospective features of the formation of networked forms of interaction in technologically advanced countries. International rankings are used as a quantitative characteristic of the level of development of the digital economy. First of all, it is the European Digital Economy and Society Index (DESI)4. The basis for using the DESI ranking is an integrated assessment approach that summarizes various indicators of the development of digital Europe and tracks the evolution of EU countries in terms of their digital competitiveness.

The digital transformation of the network management for innovative development is presented by the authors as an objective process. As a quantitative characteristic of the development of this process in the Russian economy, the authors used an assessment of the dynamics of statistical data on indicators of the share of the digital sector in GDP and the share of people employed in the ICT sector of the total number of employed.

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[1] World Bank (2016). Development of the digital economy in Russia. URL: http://www.vsemirnyjbank.org/ru/events/2016/12/20/developing-thedigital-economy-in-russia-international-seminar-1

[2] Decree of the President of the Russian Federation of May 9, 2017 No. 203 "On the Strategy for the Development of the Information Society in the Russian Federation for 2017-2030". URL: http://www.garant.ru/products/ipo/prime/doc/71570570/

[3] On the approval of the program "Digital Economy of the Russian Federation": Government order dated July 28, 2017, No. 1632-R

[4] Digital Economy and Society Index, DESI. URL: https://ec.europa.eu/digital-single-market/en/news/digital-economy-and-society-index-desi-2017

As part of the study, the authors have developed an intelligent network model for managing spatial development, based on the principles of timeliness, information security and sufficiency, synergy and managerial flexibility. The proposed model is multifaceted and includes subsystems associated with the stages of the innovation cycle and focused on the main groups of participants in the national innovation system.

RESULTS

3.1 Trends in international networking practice in innovation

The scientific literature mainly presents the issues of economic integration of organizations and its impact on the emergence and development of interorganizational network interactions, in particular, interfirm networks. In identifying the spatial forms of interorganizational networks, one should take into account various levels and types of economic integration: the interaction of organizations as economic entities, cooperation of research organizations with production companies, cooperation of socio-economic systems of regions, national economies of entire countries. So, in relation to the integration of organizations, interorganizational networks of the following types are formed: strategic alliance, value chain (network), focal supply network, dynamic focal network, virtual organization (Sheresheva, 2010).

In international economic integration, the forms of network interactions at the level of intergovernmental and interstate associations and agreements, including in the scientific, technical and innovation spheres, are to be studied (Boly`chev, Voloshenko, 2013). In interregional economic integration, the types of network interactions based on international cooperation of organizations and related to various types of interregional associations can be distinguished, including within the framework of existing agreements, programs and projects.

Innovation networks are associations of organizations whose activities are related to the transfer and commercialization of technologies, the creation and management of innovative projects, as well as the stimulation of innovative development. In defining networks, attempts are made to establish and classify the levels of formality of links in the network. Several authors have argued that different types of network formalities may require different management decisions. Moller and Rajala (2007) classify networks based on their value proposition. They define innovation networks as “relatively loose scientific and technological research networks involving universities, research institutes and research organizations of large corporations ... guided by ideas of scientific discovery” (Moller, Rajala, 2007, p. 900).

The beginning of the activity of innovation networks in international practice was the creation of the European business and innovation centre network (The European BIC network – EBN5) in 1984, which is the oldest organizational structure of this kind in Europe. EBN’s vigorous activity resulted in the unification under its leadership of about 140 certified innovation centers, incubators and accelerators, implementing measures to support innovative organizations and projects. The main focus of EBN’s work has become

[5] The official website of the European BIC network. URL: https://ebn.eu/

multilateral support for small and medium-sized innovative businesses through the creation of a number of organizations, such as:

- European Center for Innovation and Spin-off Companies (ECIS) to perform the function of business incubation and technology transfer to small and medium-sized businesses;
- International thematic network dedicated to entrepreneurship training, exchange of experience, knowledge and benchmarking (ENTRAIN.NET);
- RPE is a sustainable system of internationalization and support for innovative entrepreneurship, based on the continuous provision of services from EC-BIC and other intermediary organizations.

Further development of innovation networks followed the path of stimulating transnational technology transfer and promoting innovative services. For these purposes, since 1995, with the support of the European Commission, the first innovation relay centers (Innovation relay centers network – IRC6) were created. This contributes to the development of uninterrupted mechanisms for the transfer of technology from the scientific and technical sphere to the sphere of production of goods and services, which ensures the formation of a permanent innovation regime, acting on the principle of self-regulation.

In recent decades, technology transfer has become the main agenda of technologically advanced countries in innovation processes. In fact, in countries such as the United States, Australia, and the United Kingdom, innovation policies have shifted R&D funding and incentives towards rewarding diversified innovation networks (Corley, Boardman, Bozeman, 2006).

In international practice, there are many associative and network organizations that are focused in their activities on overcoming gaps in the intensity of R&D due to being embedded in the system of regional and global economic ties (Table 1).

Table 1. International associations and networks in innovation

Organization	**Year of creation, country/region**	**Characteristic and activities**
The European Association of Development Agencies — EURADA[7]	Headquarters: Brussels, Belgium 1992	EURADA unites, through an extensive network of regional agencies, highly qualified specialists from 22 countries of the European Union and beyond. Directions of the organization: • exchange of experience and best practices between members in the field of local and regional development; • participation in the development and implementation of territorial and development programs; • organizing and strengthening technical cooperation with development institutions, including the European Commission; • assistance to newly created development agencies and cooperation projects.

[6] The official website of Innovation relay centres network. URL: www.irc.cordis.lu
[7] The official website of the European Association of Development Agencies. URL: www.eurada.org

Organization	Year of creation, country/region	Characteristic and activities
World Technopolis Association — WTA[8]	Daejeon, Republic of Korea, 1998	WTA unites 30 cities with a highly developed scientific base from 15 countries. The goals of the association: • sustainable urban development; • improving the well-being of the population through the development of science and exchange of technologies, • creation of joint networks uniting various subjects of innovative activity in cities.
Association of European science & technology transfer professionals — ASTP[9]	Headquarters: Leiden, Netherlands, 1999	Today the non-profit organization ASTP unites 500 professionals from 35 countries. Mission: promotion and professional implementation of technologies and knowledge transfer between the scientific base and industry in Europe. Activities: • exchange of experience in the field of science and technological innovation; • exchange of ideas between representatives of various fields of science.
World Alliance for Innovation — WAINOVA[10]	Headquarters: Malaga, Spain, 2005	WAINOVA coordinates the activities of associations, science and technology parks and innovative business incubators around the world. Mission: to contribute to the economic and social development of the world by encouraging innovation, technology transfer and the creation of innovative companies.
World Business Angels Association — WBAA	Headquarters: Brussels, Belgium 2007	Formed by the leaders of 12 national business angel federations to create an international community of business angel networks to promote innovation around the world. Activities: · creating conditions for financing innovative activities with the support of business angels; · establishing partnerships between angel networks from different countries, including attracting international investment; · development of mechanisms for financing and supporting innovative entrepreneurship within the framework of public-private partnerships.
Enterprise Europe Network — EEN[11]	Geographically distributed network, 2008	Europe's largest network to support entrepreneurship and foster innovation, funded by the EU Competitiveness of Enterprises and SMEs (COSME) Program. The EEN network unites about 600 organizations from more than 60 countries of the world. EEN includes chambers of commerce and industry, technological innovation

[8]The official website of Association of European science & technology transfer professionals.URL: www.wtanet.org.

[9] The official website of Association of European science & technology transfer professionals. URL: https://www.astp4kt.eu/

[10] The official website of World Alliance for Innovation URL: http://www.wainova.org

[11]The official website of Enterprise Europe Network. URL: https://een.ec.europa.eu/

Organization	Year of creation, country/region	Characteristic and activities
		centers, research institutes, development institutes, it offers small companies access to the European market.
International Network for Small and Medium Enterprises — INSME[12]	Secretariat: Rome, Italy	The INSME international network operates within the framework of the Organization for Economic Cooperation and Development (OECD). Functional directions: • it is an intermediary in the creation of a public-private partnership; • it broadcasts information on the latest trends and ideas in the field of innovation; • it brings together stakeholders involved in innovation and technology transfer, including government agencies and international organizations.

As follows from the descriptions presented in the table, in many cases, the activity of innovation networks is expressed in the exchange of ideas, knowledge, experience, assistance to development, creation of necessary conditions, establishment of partnerships, expansion of networks, etc. As a rule, such formats of regulatory and management impacts only indirectly affect the development of innovation processes. However, the results of a study of the spatiotemporal impact of embeddedness in R&D networks for the production of regional knowledge in 229 European regions included in the Nomenclature of Territorial Units for Statistics (NUTS), conducted in 1998-2010, revealed positive effects arising from network integration (I. Wanzenböck & P. Piribauer, 2016).

In recent years, the positive influence of networked innovative interaction has found its manifestation in the stable consolidation of positions of a number of technologically advanced countries in the international innovation rating The Global Innovation Index, published by the International Business School INSEAD, Cornell University, and the World Intellectual Property Organization (Table 2).

Table 2. Ranking of countries by the level of innovation according to the Global Innovation Index

Country	2013		2018		2019	
	Rank	Index	Rank	Index	Rank	Index
Switzerland	1	66.6	1	68.4	1	67.2
Netherlands	4	61.1	2	63.3	4	61.4
Sweden	2	61.4	3	63.1	2	63.7
Great Britain	3	61.2	4	60.1	5	61.3
Singapore	8	59.4	5	59.8	8	58.4

[12]The official website of International Network for Small and Medium Enterprises. URL: insme.org

Country	2013		2018		2019	
	Rank	Index	Rank	Index	Rank	Index
the USA	5	60.3	6	59.8	3	61.7
Finland	6	59.5	7	59.6	6	59.8
Denmark	9	58.3	8	58.4	7	58.4
Germany	15	55.8	9	58.0	9	58.2
Ireland	10	57.9	10	57.2	12	56.1
Israel	14	56.0	11	56.8	10	57.4
South Korea	18	53.3	12	56.6	11	56.6
Japan	22	52.2	13	55.0	15	54.7
Hong Kong	7	59.4	14	54.6	13	55.5
Luxembourg	12	56.6	15	54.5	18	53.5
France	20	52.8	16	54.4	16	54.2
China	35	44.7	17	53.1	14	54.8
Canada	11	57.6	18	53.0	17	53.9
Norway	16	55.6	19	52.6	19	51.9
Australia	19	53.1	20	52.0	22	50.3

Source: The Global Innovation Index. URL: https://www.globalinnovationindex.org

In Table 2, 2018 was taken as the base year, on the basis of which the top twenty countries were selected in terms of innovative development. Switzerland became the absolute leader for all the years under consideration; in addition, the top five in different years included Sweden, the USA, Great Britain, the Netherlands, and Singapore. The change in the positions of countries in the innovation index (both their improvement and deterioration) indicates that despite the network interaction in the course of scientific and technological development as a manifestation of integration processes, there is a competitive struggle for innovation leadership and investment resources.

Some researchers are of the opinion that networks are unlimited and have no hubs (Ford, Hakansson et al., 2002). This is due to the fact that international network structures can be geographically "scattered" with no common boundaries. For example, the innovation network World Business Angels Association includes countries located on different continents, including Australia, Chile, China, France, Germany, India, Italy, New Zealand, Panama, Portugal, Scotland, Spain, United Arab Emirates, United Kingdom and the United States, etc. In such cases, fuzzy organizational and management structures with predominance of horizontal connections and in the absence of nodes in the form of specialized distribution centers or control centers are formed in the networks. Nevertheless, this circumstance is not an obstacle for successful cooperation of organizations to achieve results in the field of R&D and innovation.

In terms of common boundaries, a study of manufacturing plants in Quebec (Canada) found that geographic proximity between users and knowledge-

intensive business service (KIBS) providers does not offer any benefit in terms of innovation efficiency. It has also been found that service users are increasingly overcoming distance barriers through the use of the Internet and related communication devices (Shearmur, Doloreux, 2015).

Other researchers, including those in the field of strategic management, believe that subnets with certain boundaries can actually be defined (Gulati, Nohria, Zaheer, 2000). In particular, in Japan, two types of networks are distinguished – the "centralized type" with a limited number of cores and the "decentralized type" (R&D networks), which are dominant in the field of ICT and nanotechnology, more spatially concentrated (Yokura, Matsubara, Sternberg, 2013). In the innovation cluster of Silicon Valley, a complex network has formed, the nodes of which are companies, and the connections represent the various economic and financial structures that unite them (Ferrary, Granovetter, 2009). As Lee, Miller and others point out, the main difference between Silicon Valley and other high-tech clusters is the large number of venture capital companies, rather than the presence of large universities, companies or research laboratories (Lee, Miller, Hancock, Rowen, 2000). The system is designed in such a way that the creation and development of innovative start-ups is facilitated by law firms (Suchman, 2000), venture capital firms (Hellman, 2000; Kenney, Florida, 2000), consulting groups, recruiting groups and other service firms (Bahrami, Evans , 2000).

In world practice, the development of regional innovations has its own characteristics, not only depending on the countries implementing them, but also on the institutional affiliation of economic entities. As it was established as a result of studies of innovation networks in Japan conducted by Y. Yokura (Yokura, Matsubara, Sternberg, 2013), scientific and technical projects are more often involved in long-distance cooperation, and low-tech production is carried out by local partners. The role of the public sector is significant both in local and peripheral innovation processes. At the same time, inter-academic collaboration has a greater spatial scope than collaboration with the private sector.

One of the characteristic trends in the EU regions is an increase in participation in funded research networks, as a result of which there is an increase in activity in the field of knowledge production and patenting of intellectual activity. Regions with a lower level of knowledge, however, are more likely to benefit from positive effects and show higher marginal benefits from EU-funded R&D networks. However, this momentum may not be enough for the sustainable production of regional knowledge. In general, the expansion of interregional R&D networks in all European regions leads to a stimulating effect not only for the respective fields of knowledge, but also spatial spread to other areas. And this, in turn, will lead to a higher average level of knowledge production in a multi-regional system.

In Russia, the development of innovation networks is only gaining momentum, as a result, their scale compared to the European level is much lower, and the process of integration into international network structures is not yet active enough. There are several examples of such integration. First of all, it is possible to single out Novosibirsk, which was the first Russian city in 2001 to become a full member of the World Technopolis Association (WTA). Another example is the National Business Angels Association, established in 2009 by Russian business angel organizations with the support of Russian Venture Capital Association (RVCA) and JSC RUSNANO. Since 2011, the National Business Angels Association has been a full member of the European Business Angels Network (EBAN), which unites more than 150 organizations in more than 50 countries.

In general, Russian innovation networks, like many European scientific and technological network structures, are focused on the commercialization of science-intensive technologies and support for innovative business, primarily small and medium-sized businesses, and, moreover, on the formation of a national innovation system. These include:

- Russian Union of Innovation and Technology Centers (RuITC)13, established in 2000;
- Russian Technology Transfer Network (RTTN), created in 2002 and formed on the basis of innovation centers in Obninsk (Kaluga region), Koltsovo (Novosibirsk region), Yekaterinburg and Tomsk.

Since 2008, the Russian Union of ITC has been the coordinator of the Gate2 RUBIN (Gate to Russian Business Innovation Networks) project on the participation of Russian organizations in the European Entrepreneurship Support Network (EEN).

In Russia, innovative networking is most actively developing in the field of higher education. In accordance with the concept of "Three Spirals" by Henry Etzkowitz, it should be concentrated at the point of intersection of the interests of an educational institution with two main groups of influence: the business environment and the state (Eleneva, Elenev, 2014). The innovative activity spread to modern universities, which gradually began to turn into entrepreneurial universities. It is about network interaction not only with the aim of introducing into practice innovative educational technologies based on the joint use of resources, but also about the inclusion of higher educational institutions in the process of creating innovations.

3.2. Digitalization of the economy as a factor in the development of innovative network systems

The digital economy is a technological platform for an accelerated transition to an innovative development model, reflecting the transition from the third industrial revolution to the fourth, the so-called "Industry 4.0". According to most experts, the digital economy can be regarded as an industrial revolution that has no analogues in all previous experience, capable of fundamentally changing the socio-economic environment of mankind. Klaus Schwab in his book "The Fourth Industrial Revolution" pointed out the fundamental importance of a coordinated understanding based on the unity of goals and values of the influence of technology on the transformation of the economic, social, cultural and humanitarian environment of society (Schwab, 2016, p. 8). If the third industrial revolution resulted in a shift from analog electronic and mechanical devices to digital technologies, the fourth, in turn, is built on the foundation of the digital revolution, which involves the integration of computing resources into physical processes, where equipment and information systems are connected throughout the value chain, extending beyond the boundaries of a single organization or business.

Digital technologies are extremely diverse, which could not but affect the activities of network organizations in the innovation field. Digitalization has brought innovation networks to a technologically new level, changing the focus of scientific and engineering researches. Among the main directions related to global technological trends, which are focused on the innovation policy of Russia, are the following:

[13] The official website of The Russian Union of ITC. URL: http://ruitc.ru/

- Big Data technologies identified with information of a huge volume, often updated and created in various sources;
- neurotechnologies and artificial intelligence, created on the basis of the principles of the brain and nervous system, consider the brain as a neural network;
- distributed ledger systems (blockchain), the principle of which is the simultaneous launch of databases on multiple nodes distributed around the world between different users;
- quantum technologies that use the phenomenon of quantum entanglement on the basis of which quantum computers are created, capable of processing huge amounts of information and colossally superior to the capabilities of conventional digital computers;
- The Industrial Internet of Things – integration of computer networks and physical objects of industrial use with built-in sensors into a single system, which makes it possible to carry out remote control and management without human intervention;
- components of robotics and sensorics – programmable automated manipulators used for mechanical movement of objects and for performing various production operations;
- wireless communication technologies, coupled with the massive use of smartphones, tablet computers and netbooks, provide constant access to the Internet (Bluetooth, Wi-Fi, WiMAX, WWAN);
- technologies of virtual and augmented reality reproduce the world around a person through his sensations, influencing all organs of perception, are used in the fields of entertainment, education, science, microsurgery, architecture, design, etc.

As follows from the above descriptions, digital technologies in most cases have a network nature, being a logical continuation of the development of innovation networks. The variety of directions and fields of application of digital technologies confirms the position of a number of scientists, according to which the influence of the digital economy extends far beyond information technology (Kunczman, 2014) and its development will occur not linearly, but exponentially (Schwab, 2016, p. 9). At the same time, one cannot fail to take into account that the digital economy, although it is not limited to information and communication technologies, but, without a doubt, is precisely based on their use. In addition, some international rankings that assess the development of digital technologies in the world are focused primarily on Internet technologies.

First of all, it is the European Digital Economy and Society Index (DESI). According to DESI-2020, which measures the digital performance of Europe and monitors the evolution of digital competitiveness of EU member states, Sweden, Denmark and the Netherlands are ranked highest, followed by Malta, Ireland and Estonia. DESI is calculated as a composite index that summarizes various indicators of the development of digital Europe, has five main sub-indices, which are aggregated with different weights, and 31 indicators are used for scoring (Table 3).

Table 3. Structure of the Digital Economy and Society Index (DESI)

Individual	Weight	Number	Examples of indicators

DESI indicators	indicators	of indicators	
Connection	0.25	8	Proportion of households with fixed broadband Internet access; the share of households connected to the Internet; the share of broadband connections via mobile communications; the share of connections with 4G coverage, etc.
Human capital	0.25	4	The share of Internet users, the proportion of ICT specialists, professionals with science and engineering education, etc.
Using the Internet	0.15	7	The share of people using online news, music, video games, video subscriptions, video calls, social networks, internet banking, e-commerce, etc.
Implementation of digital technologies in enterprises	0.20	8	Electronic document flow, interaction with clients in social networks, the number of cloud consumers, the share of SMEs leading online trade, the share of online commerce in the total turnover, the share of electronic circulation of SMEs with other countries
Digital government services	0.15	4	The share of users of e-government services, the level of their complexity, the indicator of open data, etc.

Source: Digital Economy and Society Index, URL: DESI. https://ec.europa.eu/digital-single-market/desi

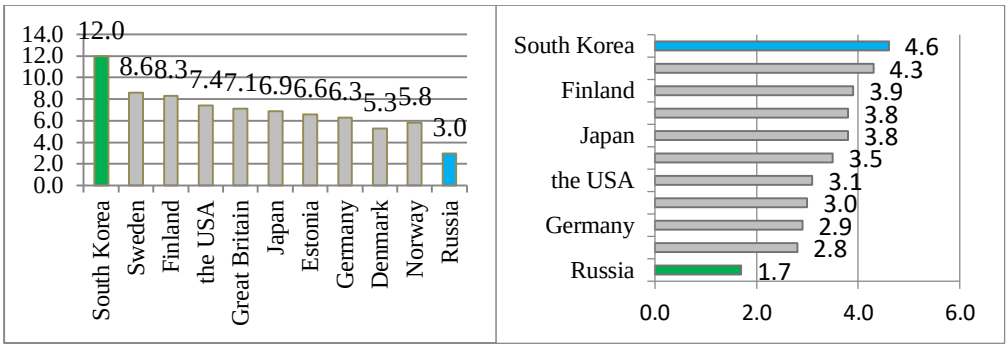
The content of indicators included in the DESI integral index indicates that the rating is of a pronounced social nature, taking into account the digitalization of business and industry to a lesser extent. In addition, the direction of digitalization implied in this rating is largely based on the use of Internet technologies and is not associated with such areas as neurotechnology, blockchain, industrial Internet, robotics, virtual and augmented reality.

Comparison of Russia with the EU average DESI index shows that the development of the digital economy in our country is comparable to the indicators of the countries of Central and Eastern Europe in the development of ICT infrastructure and human capital, but in terms of the level of Internet use by the population and business, and especially in the provision of public digital services. Russia lags slightly behind the EU average.

The closest thing to monitoring advanced digital technologies is the Global Connectivity Index (hereinafter referred to as GCI), published by Huawei since 2014 and based on the results of a study that assesses the progress of the largest

countries in the world in the field of digital transition. It was developed to analyze a wide range of metrics to comprehensively and objectively quantify digital transformation based on the four main components of GCI (supply, demand, experience and opportunities) and five advanced technologies (deployment of broadband communication networks, data center operation, cloud use, operations with big data and the development of the "Internet of Things"). The index ranks 50 countries based on 40 indicators that track the impact of ICT on a country's economy, its digital competitiveness and future growth. Collectively, countries rated on the GCI scale in 2018 account for 95% of global GDP. In 2018, Russia ranked 36th in this rating.

Judging by the indicators presented in Figure 1, the scale of the spread of the digital sector (production and trade of IT equipment, services, software development and digital goods, telecommunications) in the technological structure of national economies is not so significant – the digitalization process is obviously at the beginning of its journey.



a) The share of the digital sector in GDP (%)

b) The share of the employed in the ICT sector of the total number of employed (%)

Figure 1. The ratio of the digital sector's share in GDP (%) to the share of people employed in the ICT sector in 2018 among the technology leaders

Source: Eurostat; Rosstat; OECD; NRU HSE; Stolypina P.A. URL: http://stolypin.institute/wp-content/uploads/2018/09/issledovanie_tsifrovaya-ekonomika-14-09-18-1.pdf

The statistics presented in the graphs show that Korea is in some margin in terms of contribution to gross domestic product and the share of people employed in the ICT sector. Among the European countries leading in terms of these indicators, there is a scatter of values: for the first indicator, the range of variation was 3.8 percentage points, for the second it was less – 1.8 percentage points. The contribution of the digital sector to the Russian economy in 2018 is relatively small when compared to that of technologically advanced countries. This has its own explanation – the state program "Digital Economy of Russia" started quite recently, in 2017, and is currently a key priority of the country's economic policy. The target settings of regulators in relation to the development of the digital economy in Russia are set to create the necessary institutional and infrastructural conditions, to eliminate obstacles and restrictions in the development of high-tech business, while it is predicted that by 2030 the contribution of the digital sector to the country's GDP will approach 30%.

3.3. Model of an intelligent networked management system for innovative development

Along with the study of innovation networks for solving management problems, complex computer programs have recently been actively developed to help decision-makers (DM) in managing complex objects and processes of various nature using intelligent systems (Malykh, 2019; Smirnov, Levashova, 2019). For a decision-maker, an automated decision support system is important not only as advanced technical information and computing system corresponding to the modern scientific and technical level, but also as a means of increasing the efficiency of his labor (Tikhanychev, 2016; Logua, Khasanshin). With such a system, it is possible to perform in-depth analysis in a shorter time, allowing for more informed and better decisions.

Subjects of innovation, leading the development of new things, are associated with certain costs in promoting innovations, which are difficult to overcome due to existing financial constraints and consumer preferences, even in the context of globalization of the economic space.

For effective government regulation of processes occurring in the innovation system from the generation of new knowledge to their implementation in a specific product or technology, subject to cooperation between the state and the private sector, there is a possibility of a formalized description of an intelligent network management model. Within the framework of this model, the state, on the one hand, confirms its obligations to finance fundamental research and controls the spending of the invested funds until the stage of manufacturing the final product, on the other hand, creates conditions for the development of innovative processes, including:

- increasing the capacity of the flow of innovative knowledge due to the active transfer of technologies created in the areas of state responsibility;
- development of research centers and innovation clusters as the core of the scientific and innovation system;
- focusing the main efforts of the state on creating a research infrastructure integrated into a single network;
- active use of the latest information and communication technologies by enterprises making technological breakthroughs in the field of priority innovative areas;
- improving scientific developments by coordinating research and government programs, by building up scientific and technical potential, financial resources, taking into account the delimitation of the areas of responsibility of the state, business and society;
- creation of a network structure that ensures the exchange of knowledge and open access to new knowledge through electronic libraries, conferences, seminars, exhibitions;
- increasing the “openness” of the scientific space in the field of fundamental developments to meet the needs for innovative development with the necessary level of intellectual property protection of the investigated and developed product.

The structure of an intelligent network model for managing the spatial development of innovation in a macroregion in conjunction with the main

participants in the transfer of innovations is shown in Figure 2. To build the conceptual foundations of intellectual and information support subsystems, modern developments of Russian scientists and earlier ones that have not lost their relevance have been used (Zhozhikashvili , Stefanyuk, 1990; Popov, 1991; Dudnik and Petrochenkov, 2008; Mikryukov, 2018; Mukabenov et al., 2019).

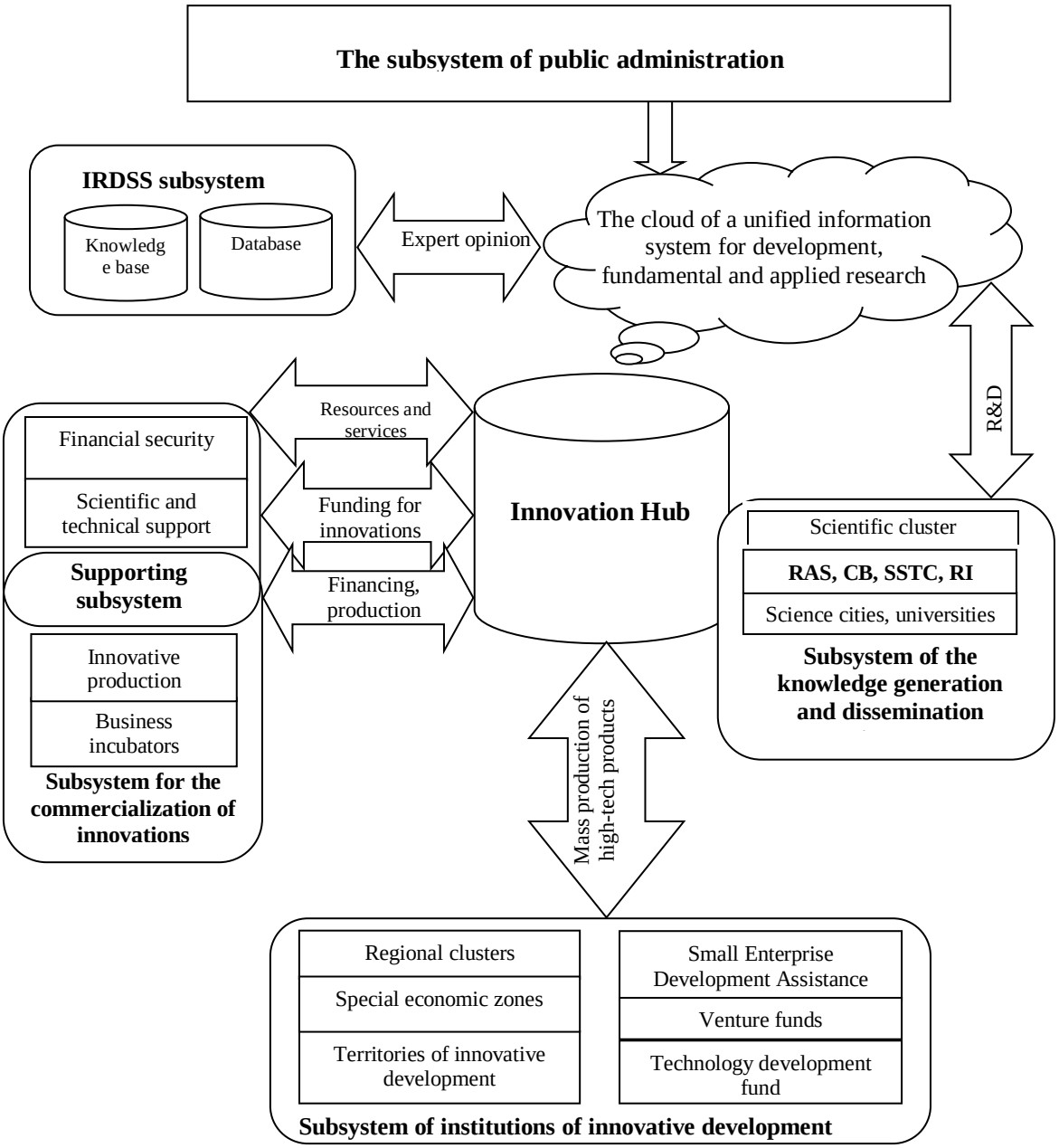


Figure 2. A model for managing the spatial development of innovation in the macroregion

The model for managing the spatial development of innovation in a macroregion, in conjunction with the main participants in the transfer of innovation, consists of the following subsystems:

- a subsystem of public administration of the national innovation system (NIS);
- a subsystem of an intelligent decision support system (IDSS);
- a subsystem of institutions of innovative development;

- a subsystem of the environment for the generation and dissemination of knowledge;
- a supporting subsystem;
- a subsystem for the commercialization of innovations.

The public administration subsystem forms a global system of strategic management of innovative development of regions in cooperation with science and private business through the formation of strategic programs aimed at stimulating demand for innovative products.

The intelligent decision support subsystem in real time is intended for management under conditions of severe time constraints and the presence of various kinds of uncertainties – incomplete information about potential investors, unclear information about a given volume of sales, selling prices, etc. The subsystem collects data on the state of economic entities in real time and signals the exit of certain parameters beyond the permissible limits.

The subsystem makes it possible to predict consequences of upcoming events based on the analysis of both information coming from outside and the expert knowledge embedded in the system. This necessitates updating and replenishing information directly in the decision-making process, and also ensures the ability of organizations to modify and adapt in the process of finding solutions in a constantly changing market environment for the near and distant periods in the temporal database system (TDS). A distinctive feature of the TDS is the ability to save information about the evolution of the control object during a given time interval $[t_{start}, t_{stop}]$, that is, all its states will be saved in the information system.

The subsystem of institutions for innovative development covers those types of activities and the corresponding financial and non-financial organizations that form and provide conditions for the accumulation and redistribution of financial, labor, intellectual resources for the production of science-intensive products and the provision of services for its creation.

The subsystem of the environment for the generation and dissemination of knowledge includes scientific organizations conducting fundamental and applied research, providing research in priority areas for the state and conducting research commissioned by a large corporate sector.

The supporting subsystem serves for the concentration of resources and a complex systematic renewal of economic resources of innovatively active organizations, including the fixed capital of the production sphere. The most important feature of the supporting subsystem is constant communication through partnership with economic federal institutions of the Russian Federation, large international companies, scientific institutions and innovation centers, venture investors, as well as with existing Russian development institutions.

The subsystem for the commercialization of innovations ensures the embodiment of research and development into industrial models, prototypes with their subsequent bringing to the creation of a market product. The innovative activity of organizations and investment attractiveness of the regional economy is facilitated by the transparency and sufficiency of information received by investors. In large cities, the unification of databases of leading research centers

will create commercial innovation trading networks with broad access. This network provides not only monitoring and notification of the decision-maker about abnormal situations before they lead to a malfunction of individual components or the entire network as a whole, but also provides the decision-maker with the choice of the optimal alternative from the set of feasible solutions available in the knowledge base.

The database in each of the subsystems consists of four main interconnected modules, namely: the Bank of Inventions, the Bank of Innovation Opportunities, Basic Knowledge, the Bank of Innovations and parts, distributed across all levels and collecting information about the operation of the network levels. Moreover, the network management processes are built on a hierarchical principle, and ensure the accelerated commercialization of scientific research results, which implement the search and selection of partners in a virtual unified information system for developments, fundamental and applied research based on information about their scientific and innovative activities.

Integration processes taking place in this network are expressed in the fact that corporations in the process of implementing large projects conclude agreements on fundamental, applied research and development (R&D) with research organizations, including small businesses, focused on the production of innovative products. This will ensure transparency of boundaries within the system of science and allows decision-makers to analyze the efficiency of spending money, to identify ways to achieve the originally planned results. At the same time, the system allows you to designate additional time stages in achieving the goal with a clearly defined system for reporting on the results achieved and create preconditions for the commercial implementation of the rights to an invention, prototype or pilot batch.

DISCUSSION

The concept of an innovative network model is relatively new in the economy. The analysis shows that there are many terms that imply different types of network interaction between participants in innovation. It should be noted that this term is not entirely accurate, since in the strict sense, any economy is networked and is based on the elements of the network and relationships between its participants. As experts point out, an important feature of the innovation network is the presence of cooperative interest, in contrast to the market, where each participant pursues, first of all, his own interests"(Rodionova, 2013). Nevertheless, the search for optimal forms of interaction between state, academic and corporate sectors in national economic systems is of particular relevance (Midler, 2010). This is due to the fact that the results of intellectual activity and the innovations created on their basis arise in both the private and public sectors.

A special place is occupied by network forms of interaction between territorial units, which are supported by the Innovative Regions in Europe Network (IRE), which is an association of regions implementing projects for the development of regional innovation strategies. However, the nomenclature of territorial units for statistics (NUTS) remains tied to the existing administrative-territorial division of the EU countries. The opposition to the established system is the World Alliance of International Financial Centers (WAIFC), which promotes international cooperation, sustainable investment and prevention of the impact of protectionism during a global health and economic emergency.

In some countries, governments can apply rigid approaches to innovation policy and introduce highly formal measures that require strong links between networks (Mani, 2002). This is a justified measure, since, in a sense, informal ties between participants in innovation networks based on declarations of cooperation, memoranda of understanding, etc. are unstable. An example is the innovation network International Network for Small and Medium Enterprises (INSME), which as of April 2020 can only count on the support of 61 members from 30 different countries.

The above thesis is confirmed by the fact that in world practice there are two types of organization of innovation networks:

- professional associations that arose as an initiative of the centers themselves (for example, ASTP). As a rule, these are self-governing organizations that independently establish the rules and forms of cooperation for new organizations.
- projects purposefully supported by the European Commission through special programs (e.g. FP6). Working and collaborating with such communities (IRE, IRC, EBN) is subject to contractual obligations and constraints.

The question arises of how digital technologies can affect organizational and managerial aspects and the system of relationships between participants in innovation networks. At first glance, since the emergence of trends towards digitalization of national economies, nothing has changed fundamentally in this regard. It seems that at the present time, the common goals, objectives and methodology formed by the existing innovation networks have remained unchanged, since the commonality of their formulations fits well into the framework of the ongoing digital transformation. It is possible to look at the issue of opportunities created by digital technologies in the future. One of these opportunities is created by the key advantage of the distributed ledger system, which guarantees cryptographic security and irreversibility of transactions, which, over time, will be used to protect the results of intellectual activity at the international level.

The American futurist Alvin Toffler, predicting changes in the social structure of society and based on the concept of three waves, predetermined the third wave as an era of synthesis in all branches of knowledge, which will result in large-scale thinking and generalizing theories (Toffler, 2009, p. 219). In the future, a similar trend may be embodied in the unification of currently operating numerous and multidirectional innovation networks. The development of neurotechnologies and artificial intelligence will inevitably lead to the improvement of translations into foreign languages and the overcoming of language barriers. This will significantly expand the boundaries of communication interactions and simplify the opportunities for scientists from different countries to participate in competitions for funding research and development, organized by international and intergovernmental organizations.

CONCLUSION

An innovation network is a structure for managing the innovation sphere of a region that connects the state and civil society and includes a variety of public and private organizations that have a certain common interest. The exponential growth

of mobile communications and the number of Internet users, the contribution of information and communication technologies to economic growth, the creation of new innovative jobs, the accelerated development of e-commerce – all these contribute to an active transition to a knowledge society.

The global economy is undergoing digital transformation, and this is happening at an accelerating rate. In the 1990s, economic changes were mainly associated with the emergence of the Internet, which remains the basis for the growth of the digital economy, but in the 2000s and 2010s a series of new information and communication technologies (ICT) accelerated economic change.

The digital economy requires expanding knowledge about new products and services, increasing the importance of learning and innovation, globalization and sustainable development. A wealth of information is changing the way markets work, allowing businesses to restructure and create new opportunities from the information that is available. The differences between the digital economy and the traditional one are in such characteristics as accelerated rates of development; breadth and depth due to paradigmatic shifts in the economy, business, society; systemic impact in the form of interconnection of internal and external transformations (Schwab, 2016, p. 9). The digital economy is defining a new level of governance with an emphasis on process transparency and governance in making decisions based on the accuracy and completeness of data.

Existing interpretations refer to digital information as a key production factor in the digital economy, and their beneficial use is possible through the introduction of processes and the use of information processing methods known as information and communication technologies. With this approach, it is the level of ICT development that obviously determines the potential opportunities and conditions for the emerging digital economy in any state. However, at present, the generally accepted understanding of the content of the digital economy is not completely settled; generally accepted approaches to technologies included in it have not yet been formed. This is evidenced by international rankings assessing the innovative and digital development of countries. In some cases, the indicators that form the integral indicator are related only to ICT technologies (DESI), in other cases, digital development is considered in a broader context (GCI).

The use of a virtual network is the most preferable from the point of view of maintaining a competitive environment in all types of markets – the innovation market, the technology market and the finished product market. The virtual network provides a real opportunity to launch science-intensive projects, which are also characterized by self-development according to the type of a chain reaction, since global information processes neutralize the importance of geographic proximity in the interactions of subjects and allow reaching a new level of development of innovative economic institutions. By developing scientific and industrial cooperation, ensuring the convergence of science and production, society actually brings production socio-economic relations in line with the changing conditions of the productive forces characteristic of a post-industrial society.

The mechanism of innovative development includes a set of interrelated economic resources “tuned” to perform certain functions of the innovation process (transformation of “input” into “output”), the interaction of which creates

incentives that ensure the transfer of knowledge, its distribution and transformation into pre-competitive technologies for the business environment. In addition, the stimulation of economic activity through feedback presupposes the orientation of the research environment towards meeting emerging needs and increasing the level of development of society in all spheres: economics, politics, culture, law, international relations, etc.

According to official statistics and expert and analytical information, Russia has been actively developing its digital economy over the past few years. Russia is a country with great potential, and the digital economy is one of the ways to unlock it. At the same time, at the global level, the country lags far behind economically developed countries: the country's digital sector is still relatively small, and there is a lag in such indicators as the number of knowledge-intensive enterprises and the share of the population employed in the ICT sector. The prevention and elimination of all the above challenges and risks and the achievement of the intended goals requires the implementation of the Digital Economy of the Russian Federation program, which creates the preconditions and conditions for improving the well-being and quality of life of Russian citizens.

For the state management of the spatial development of innovation in Russia at the regional level, it is necessary to create an interactive automated system that uses economic and mathematical models to develop managerial decisions when changing the system of indicators that measure the scale and effectiveness of innovation. The model allows public authorities to forecast the development of the situation in real time using temporal dependencies.

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