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Evaluating Digital Ecosystems in Russia's Regions*

Vera V. STEPANOVA
Northern (Arctic) Federal University
Arkhangelsk, Russian Federation, 17, Northern Dvina Embankment, 163002
E-mail: nirvvs@mail.ru

Anna V. UKHANOVA
N. Laverov Federal Center for Integrated Arctic Research, RAS
Arkhangelsk, Russian Federation, 23, Northern Dvina Embankment, 163000
E-mail: karmy-anny@yandex.ru

Aleksei V. GRIGORISHCHIN
Northern (Arctic) Federal University
Arkhangelsk, Russian Federation, 17, Northern Dvina Embankment, 163002
E-mail: grigorishchin@mail.ru

Dilmurad B. YAKHYAEV
Northern (Arctic) Federal University
Arkhangelsk, Russian Federation, 17, Northern Dvina Embankment, 163002
E-mail: dilmurad-92@mail.ru

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Abstract. Successful establishment and functioning of the digital economy is possible only in an adequate digital ecosystem, but the semantic and structural content of this system has not been defined adequately yet. Such uncertainty can be found at different levels (federal, regional and local) and in various aspects: subject-related, branch, segment, technical and others. At the same time, the need to implement effective measures for the development of regional digital ecosystems requires not only an understanding of their qualitative content, but also an accurate quantitative assessment. Our paper analyzes conceptual approaches to the definition of a digital ecosystem, provides our own understanding of its full content, which allows us to build a sufficiently verifiable assessment of digital ecosystems development at the regional level. We present a technique for assessing the development of regional digital ecosystems; according to this technique two integrated indices are calculated, and on this basis we carry out an analysis on 82 constituent entities of Russia over the period of two years. The study reveals the existence of significant differentiation between the regions according to the level of development of digital ecosystems; it also helps identify a number of characteristic types of regions in this context. Our assessment has shown that, along with the majority of the regions where the development of digital ecosystems is defined as average, some regions show opposite trends. There are regions, for example, the Belgorod and Kirov oblasts, in which the conditions for the digital environment are below average, but the level of ecosystem development in them is average or higher. There are regions where the situation is the opposite, i.e. the conditions are quite high, but the level of development of the digital ecosystem as a whole leaves much to be desired. Such a negative example is the Moscow Oblast. We also identify leading regions and problem regions. We hope that a reliable assessment of development of digital ecosystems using our technique will help work out effective solutions for successful promotion of the digital economy in Russia.

Key words: digital economy, ecosystem of the digital economy, index of activity of the subjects of digitalization, digitalization conditions index, assessment of the level of development of digital ecosystems, regions digitalization matrix.

Introduction

2017 was a breakthrough year for the development of the digital economy in Russia. The digital economy has become a key topic of the Russian President's speech at the Saint Petersburg International Economic Forum 2017; in his speech the President pointed out that Russia needed to increase its technological, personnel and intellectual advantages in the field of the digital economy. The President said it was necessary to create a flexible regulatory framework to introduce digital technology in all spheres of life, taking into account the information security of citizens, businesses and the state. Russia's policy aimed at digitalization was confirmed by the establishment of the Digital Economy Development Fund "Digital Platforms". The Fund promotes industry-specific digital platforms, the research on directions and technologies of the digital economy, participation in the elaboration of state and professional development programs, etc., and participates in the approval of two important strategic planning documents in mid-2017: the strategy for the development of the information society in the Russian Federation for 2017–2030[1] and the program "Digital economy of the Russian Federation"[2]. Both

[1] Strategy for the development of the information society in the Russian Federation for 2017–2030: approved by the Decree of the President of the Russian Federation of May 9, 2017 No. 203. Available at: http://kremlin.ru/acts/bank/41919 (accessed: 26.05.2018)

[2] Program "Digital economy of the Russian Federation": approved by the Resolution of the Government of the Russian Federation of July 28, 2017 No. 1632-r. Available at: http://static.government.ru/media/files/9gFM4FHj4PsB79I5v7yLVuPgu4bvR7M0.pdf (accessed: 27.05.2018).

strategic documents pay great attention to the formation of the digital economy ecosystem. However, we can name only a few currently existing definitions of this new phenomenon, due primarily to its lack of maturity and insufficient scientific elaboration. In addition, modern Russian scientific literature contains virtually no works on the assessment of the digital ecosystem development in Russia, taking into account the existing features and realities. In this regard, the goals of our study are as follows: to identify the nature and content of "digital ecosystems", to develop and test their assessment methods and to carry out pilot analysis of their development in Russia's regions. At the same time, the high level of socio-economic differentiation of the territory of the Russian Federation makes it necessary and highly relevant to assess the formation of ecosystems of the digital economy at the regional level; the information obtained will help elaborate recommendations for their development.

Review of conceptual approaches, and research methodology

At the state level, the term "digital economy ecosystem" is understood as a partnership of organizations that provide continuous interaction of their technological platforms, applied Internet services, analytical systems, information systems of public authorities of the Russian Federation, citizens and organizations. This definition is given in the strategy for the development of the information society in the Russian Federation for 2017–2030. A similar definition is proposed by representatives of the Center for Macroeconomic Analysis and Short-Term Forecasting: according to D.R. Belousov, the digital economy ecosystem is a system of "subjects that are interacting, exchanging digital resources and transforming their kinds into different ones" [1, pp. 6-17]. The subjective approach to understanding the ecosystem of the digital economy focuses on the actors that promote digitalization, but does not pay attention to the conditions in which they operate. From this point of view, a scientific article headlined "Digital economy: Conceptual architecture of a digital economic sector ecosystem" is of particular interest; in it, the authors give the following definition of the digital industry ecosystem: "It is an environment that provides conditions for the innovative development and distribution of digital services, digital products, applications and devices in a particular sector of the digital economy" [2, pp. 17-28]. As we can see, the emphasis in this definition is already shifted toward the conditions of digitalization, but it remains unclear who ensures the development and distribution of digital products and services. Another definition of the ecosystem is formulated in a research conducted by the Russian Association of Electronic Communications (RAEC) – a non-profit organization that unites more than 150 vendors of the Russian electronic communications market. In the presentation of the report on the results of the 2017 study, the digital economy ecosystem is presented as "those segments of the market where value added is created with the help of digital (information) technologies". RAEC proposes to consider the digital economy ecosystem through its decomposition into seven hubs: 1. State and society; 2. Marketing and advertising; 3. Finance and trade; 4. Infrastructure and communications; 5. Media and entertainment; 6. Cybersecurity; 7. Education and human resources[3]. This approach reduces the digital economy ecosystem to digital segments of

[3] *Annual report of RAEC "The economy of Runet 2017".* Available at: http://raec.ru/upload/files/de-itogi_booklet.pdf (accessed: 20.05.2018).

the market, while in reality the subjects of the digital economy interact with other sectors (in particular, science, energy, innovation sector, etc.). The level of digitalization of the economy is no less dependent on the development of these segments. In our opinion, it is necessary to get a broader interpretation of the concept of the digital economy ecosystem, the interpretation that follows from the generally accepted definition of "ecosystem" in the natural sciences. The term "ecosystem" was coined by ecologist A. Tansley to refer to jointly living organisms and their conditions of existence, which are in a natural relationship with each other [3].

Using the method of analogy and the subject, environment and segment approaches, we put forward an idea that the digital ecosystem should include the subjects of digitalization and the digital environment that creates conditions for the development of the digital economy and digital society. In our opinion, "digital ecosystem" is a multi-structural relationship between the main actors of the digitalization of the economy (population, state, business) and the basic conditions of their functioning.

Based on the objectives of the program "Digital economy of the Russian Federation", the digital economy ecosystem, in which data in digital form is a key factor in production in all areas of socio-economic activity, is intended to ensure effective interaction of business, academia, educational community, government and citizens. Thus, business represented by entrepreneurs, and people and government represented by public authorities are those who act as major subjects of the digital economy [4]. Often the interests of these actors are determined in opposition to each other and are in conflict. In order to eliminate and smooth the contradictions, science proposes many concepts, including sustainable development [5; 6], corporate social responsibility [7; 8, pp. 87-90; 9, pp. 81-84], the theory of stakeholders [10; 11, pp. 418-422] and others. In our opinion, the concept of shared value is of the greatest interest in the context of our study. M. Porter and M. Kramer, the founders of the concept [12, pp. 72-86; 13, pp. 62-77], define it as a system of policies and operational practices that enhance a company's competitiveness while improving the economic and social conditions of the communities in which it operates. Regarding the development of the digital economy, the concept of shared value helps ensure a balance of interests of business (using new software and information tools to increase the productivity of companies; online sales of goods and services, all this contributes to the reduction of costs, etc.), authorities (electronic document management that helps reduce material and time costs of management; reducing communication costs, etc.) and people (using information technologies that provide new opportunities for training and communication; receiving services in electronic form, contributing to the minimization of time costs, etc.).

On the basis of the concept of shared value and having identified the main stakeholders, we propose to include the following areas in the assessment of the level of digitalization of Russian regions:

1. Digital activity of the population [14, pp. 295-304].

Citizens who have access to the Internet and the necessary skills to use it can participate in a wide range of online activities. This may involve the use of online content (such as news, music, video or games, multimedia content, or interactive social events) through modern communication activities (such as social media, e-mail, Skype) or through digital opportunities

for e-commerce. People who use the Internet to order banking services, money transfers, insurance services, to carry out operations with shares and other securities save their time and money significantly.

2. Digital activity of organizations [15, pp. 218-229].

Digitalization is the main factor in competitive advantage of organizations and in promoting their economic indicators. The introduction of digital technologies can improve the efficiency of production of goods and services, reduce costs or provide closer interaction with customers, employees or business partners and becomes a mandatory requirement of competitiveness. This, along with the possibility of using the Internet as a sales point, makes a significant contribution to the modernization of business.

3. Digitalization of the state [16, pp. 221-236].

Interaction of organizations and citizens with the public sector can be simplified and raise its quality with the use of digital technologies. Public authorities can use digital technologies to cope more efficiently with the increasingly complex needs of business and citizens, while significantly reducing costs. And thanks to the more efficient and streamlined public services, citizens and organizations receive public services of a better quality and with minimal time costs.

In our opinion, in addition to the interaction of the subjects of digitalization (business, people and government), the digital ecosystem includes six most important conditions for the existence of the digital economy and digital society; these conditions form a kind of "digital environment". Let us consider each of the six conditions in more detail.

1. Digital infrastructure is considered one of the most important conditions for the digitalization of the economy and society; this idea is contained in the state program "Digital economy of the Russian Federation" and in the Information Security Doctrine of the Russian Federation approved by the Decree of the President of the Russian Federation of December 5, 2016 No. 646. Scientists [17; 18, pp. 907-932] and specialists of the information industry also point out special importance of the development of digital infrastructure. For instance, Andrei Vorobyov, director of the Coordination Center for TLD RU/.РФ, notes that a stable and sustainable operation of the infrastructure plays a key role in the digitalization process: "Like it was two centuries ago, when economic development of the region depended on the roads that were suitable for horse-drawn vehicles, and a century ago – on railroads, nowadays communication plays a key role. Only in the digital way of life the place of railways and motor roads is occupied by information dissemination channels". Thus, the deployment of a unified system of telecommunication channels, providing digitalization of the telephone network and the access to high-speed broadband Internet services, is one of the most important factors in the digitalization of the economy and society.

2. Digital competences of the population. These, according to the HSE Institute for Statistical Studies and Economics of Knowledge, include people's skills in the use of personal computers, the Internet and other types of information and communication technologies, as well as people's desire to acquire ICT competencies, knowledge and experience[4]. Digital competencies range from the basic skills people need to use digital technologies effectively for personal,

[4] HSE Institute for Statistical Studies and Economics of Knowledge. Available at: https://issek.hse.ru/news/207284687.html (accessed: 30.05.2018).

educational and work purposes, to the advanced or professional skills required to develop and create new digital goods and services and increase productivity through the use of digital technology. At the same time, the basic competencies that allow a person to become part of the digital society, learn new knowledge swiftly and adapt to new non-standard activities remain crucial. Thus, basic digital competence of the population, expressed primarily in the skills of using a personal computer and the Internet, are now a necessary condition for human competitiveness in the digital economy.

3. Digital education. Digital competences of the population are particularly dependent on the level of development of the educational system. Today, Russia is to achieve an ambitious national goal – to establish universal digital literacy. The most important role in this process belongs to higher education, since nowadays an individual simply cannot obtain it (unlike other levels of the educational system) without possessing at least basic digital competencies. Higher education also plays a crucial part in increasing the number of specialists in the field of digital economy. From all the above it follows that the development of the digital economy in our country largely depends on the effective operation of the higher education system, including the implementation of digital education programs and the availability of the necessary equipment, resources and facilities.

4. Spatial and territorial structure. The development of the digital economy is also significantly influenced by the spatial and territorial structure, in particular the level of urbanization and development of the territory. The importance of urbanization of the territory is explained by fact that at present the cities concentrate major technological, information and intellectual resources. The state program "Digital economy of the Russian Federation" provides for the implementation of a number of measures to create "smart cities", in which the central place will belong to the digital technologies for managing energy, water resources, public transport, etc.

Much attention in the development of the digital economy and society should be paid to the development of the territory. In terms of population density and land availability, Russia is an underdeveloped country. We should note that the well-developed and densely populated areas of North Caucasus and the Moscow agglomeration contrast with the undeveloped expanses of the North, Siberia and the Far East [19, pp. 85-91]. This greatly complicates and increases the cost of development of the digital infrastructure, makes it impossible to include the population of remote and inaccessible areas in the information society. The solution to these problems can be found in the accelerated (with governmental participation) formation of information infrastructure: the development of this infrastructure will form IT-frameworks, which are likely to be somewhat different from the territorial and spatial framework of the current settlement systems; this fact can provide an incentive for their development. Subsequently, the integration of digital technologies that emerge and function in "smart cities" will form a "smart settlement system" [20, pp. 68-74; 21, pp. 9-20; 22].

5. Development of science and innovation. In addition to legal regulation, personnel and education, information infrastructure, and information security, the five areas of development of the digital economy that the state program "Digital economy of the Russian Federation" defines as basic ones include the formation of research competencies and technological capacities. Research and innovation is one of the main drivers of economic development in the modern world.

Thus, innovations in the field of computer technology, which have transformed the sphere of telecommunications, provided the opportunities for creation and development of e-mail, social media and messengers, which, in turn, have become a powerful impetus to the formation of the digital economy.

6. Availability of resources. Energy is one of the most important resources for the development of the digital economy. Powerful computers, transactions of payment systems and other digital processes require significant energy costs. In this respect, the territories characterized by energy surplus have certain competitive advantages in the development of the digital economy. Financial resources are another important resource, crucial to the development of any sphere of society. The transition of the Russian economy to digital technologies will require significant investments. The significant costs for creating a digital infrastructure, the high rate of obsolescence of digital equipment, and long terms of training highly qualified personnel – all this necessitates considerable amount of expenditures on the part of both the state and business.

Research methodology

We have analyzed the existing approaches to the assessment of the digital economy. As a result, we have selected four international methodologies on the basis of which we carry out a cross-country comparison:

1. The Digital Planet 2017[5] methodology developed by Bhaskar Chakravorti and Ravi Shankar Chaturvedi at The Fletcher School of Law and Diplomacy. Within its framework, the authors assess the state and pace of development of the digital economy in the world. The Digital Evolution Index they have developed includes 170 indicators grouped into four main drivers:

- supply conditions (Internet access and degree of infrastructure development);
- demand conditions (people's demand for digital technology);
- institutional environment (governmental policy, legislation, resources);
- innovation and change (investment in research and start-ups).

In 2017, having calculated the Digital Evolution Index for 60 countries, the authors created the DEI Chart that classifies countries into four distinct trajectory zones: Stand Out (both highly digitally advanced and with a high pace of digitalization), Stall Out (with a high state of digital advancement while exhibiting slowing momentum), Break Out (low-scoring in their current states of digitalization but evolving rapidly), Watch Out (face significant challenges with their low state of digitalization and low momentum).

2. The European Commission methodology for calculating the Digital Economy and Society Index[6]. The DESI is composed of five principal policy areas which regroup overall 34 indicators: Connectivity (fixed broadband, mobile broadband, fast and ultrafast broadband and broadband prices), Human capital (basic skills and internet use, advanced skills and development), Use of internet service (Citizens' use of content, communication and online transactions), Integration of digital technology (Business digitisation and e-commerce), and Digital public services (eGovernment and eHealth).

[5] *Digital Planet 2017. How competitiveness and trust in digital economies vary across the world. Report*. The Fletcher School, Tufts University. Available at: https://sites.tufts.edu/digitalplanet/files/2017/05/Digital_Planet_2017_FINAL.pdf

[6] *The Digital Economy and Society Index (DESI). Final Report*. European Commission. Available at: https://ec.europa.eu/digital-single-market/en/desi

Table 1. Analysis of techniques for assessing the digitalization of the economy (information society) at the regional level

Name and authors of the technique	Brief description	Advantages	Disadvantages
Technique for assessing the level of development of the information society in constituent entities of the Russian Federation (Institute for Development of the Information Society; Ministry of Digital Development, Communications and Mass Media)*	The aim is to monitor the level of development of the information society in constituent entities of the Russian Federation and to build a rating of regions on its basis. The integral index of development of the information society consists of two components: "Drivers of development of the information society" and "Use of ICT for development". Includes 58 indicators.	The first comprehensive attempt to assess digital ecosystems (not only ICT, but also information society development factors). The use of indicators in international rankings. Easy interpretation of the results.	The complexity and cost of methods (too many indicators, difficulties in the collection and calculation of the individual indicators). Insufficient substantiation of the applied reference values. Information society development factors are limited by human, scientific, and educational potential and by the development of digital infrastructure; Duplication of a number of indicators (e.g. "Share of households with a personal computer (PC)" and "Number of PCs per 100 households, units"). The use of outdated indicators that do not reflect the level of development of the information society (for example, "Proportion of households with the landline"). The fact that the rating includes federal cities with "extreme" values for most indicators, which leads to distortion of the results. Lack of substantiation of the weighting factors for calculation of the integral index.
Technique for assessing the results of development of information and communication technologies in regions of the Russian Federation (M.Yu. Karyshev) [23, pp. 74-82]	The aim is to assess the results of development of information and communication technologies in regions of Russia and to arrange them into groups depending on the values of composite indices. The ICT Development Index calculating technique, which was adapted and supplemented in accordance with the specifics of statistical accounting in the Russian Federation, is taken as a basis. It includes two composite indices: the ICT Development Index, which includes the sub-index of ICT access, the sub-index of ICT use and the sub-index of core skills, and the Information Economy Development Index, which includes the sub-index of computerization of workplaces, the sub-index of network access, the sub-index of software applications, and the sub-index of energy security.	Adaptation of ICT Index (ICT Development Index – IDI) to Russian realities. Cost-effectiveness in the collection of statistical data for the calculation of the indices. Assessment of individual factors that influence the development of the information society through the calculation of the Information Economy Development Index (energy development, access to the Internet). The ranges of the indices from 0 to 1. that are understandable for the interpretation of the results	Lack of consideration of the whole range of factors that influence the development of the information society. The use of outdated indicators that do not reflect the level of development of the information society (for example, "Number of landline telephones per 100 people", "Number of centers for collective use of the Internet, units per 10 thousand people").

* Technique for assessing the level of development of the information society in constituent entities of the Russian Federation. Institute for Development of the Information Society; Ministry of Digital Development, Communications and Mass Media. Available at: http://minsvyaz.ru/ru/documents/4949/ (accessed: 27.05.2018).

Source: own elaboration based on the technique for assessing the level of development of the information society in constituent entities of the Russian Federation developed at the Institute for Development of the Information Society, Ministry of Digital Development, Communications and Mass Media and on the research by M.Yu. Kartashev "Statistical technique for measuring the information economy: finding the integral indicator".

3. ICT Development Index – IDI[7] (International Telecommunication Union). Goals: to measure the status and level of development of information and communication technologies (ICT) in the world.

The ICT Development Index is a comprehensive indicator consisting of 11 indicators combined into three sub-indices: infrastructure development and access to ICT (Access Index), ICT use (Use Index), and ICT skills (Skills Index).

4. Networked Readiness Index – NRI[8].

This index can be used as a tool to analyze and build comparative ratings that reflect the level of development of the information society in different countries. It measures the information capabilities of 129 countries included in the index by 67 parameters arranged into three main groups: the environment for ICT development; the readiness of citizens, business and public authorities to use ICT; and the usage of ICT in the non-governmental, commercial and public sectors. The methodology for calculating the index is based on three main factors: environment, readiness and use of ICT. Each index factor is an aggregated sub- and micro-index indicating the weight of the criteria calculated on the basis of statistical and expert indicators and the number of indicators of each sub-index.

However, in our opinion, these methods have a number of disadvantages:

a) the indicators used by these methods are not available in regional statistics;

b) the indicators cannot be applied to the Russian Federation, since Russian statistics do not keep records of a number of indicators;

c) index values are non-comparable with the values of previous years (calculation methods are constantly changing);

d) the methods do not take into account the differences between countries in their area and geography, the features essential for the development of ICT.

Speaking about digital ecosystems of the territories, we should note the lack of methods for their integrated assessment that allows us to compare regional ecosystems. Possible analogues of such techniques, their pros and cons are presented in *Table 1*.

Our research has allowed us to develop a methodological framework for assessing digital ecosystems of Russia's regions. With the help of this technique it is possible to differentiate constituent entities of the Russian Federation both by the level of activity of the subjects of digitalization and by the degree of favorable conditions for its development. For these purposes, we propose two indices: the Index of activity of digitalization subjects of the region (Id), which determines the pace of digitalization in the subjects of the ecosystem, and the Index of digitalization conditions in the region (Idc). Thus, these two indices make it possible to assess the level of development of regional digital ecosystems as a whole.

The index of activity of digitalization subjects of the region is calculated on the basis of 17 indicators selected in accordance with the areas of digital activity of the population, digitalization of organizations and the state. In turn, the index of digitalization conditions in the region includes 14 indicators that characterize the most important conditions of digitalization *(Tab. 2)*.

[7] *ICT Development Index. Report.* United Nations International Telecommunication Union. Available at: https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2017/MISR2017_Volume1.pdf

[8] *Networked Readiness Index, NRI. Global Information Technology Report.* World Economic Forum. Available at: http://reports.weforum.org/global-information-technology-report-2016/networked-readiness-index/

Table 2. Classification of indicators to calculate the indices

Indicators within the Index of activity of digitalization subjects of the region (Id)		
Digitalization area	Sub-area	Indicator
1. Digital activity of the population	1.1 Access to broadband Internet	1.1.1 Number of active subscribers of fixed broadband Internet access, units per 100 people
		1.1.2 Number of active subscribers of mobile radiotelephone communication using broadband Internet access, units per 100 people
	1.2 Purposes of using the Internet	1.2.1 Downloading movies, music, images; watching videos; listening to music or radio, %
		1.2.2 Finding information about products and services, %
		1.2.3 Phone calls or video conversations via the Internet, %
		1.2.4 Participation in social media, %
		1.2.5 Sending or receiving e-mails, %
	1.3 Transactions on the Internet	1.3.1 People who use the Internet to order banking services, money transfers, insurance services, transactions with shares and other securities, % of the total population aged 15–72 who use the Internet to order goods and services
2. Digital activity of organizations	2.1 Electronic document flow	2.1.1 Use of electronic document management in organizations. Organizations using electronic data exchange between their own and external information systems, according to the exchange formats, %
	2.2 Use of broadband Internet and software	2.2.1 Organizations that use broadband access to the Internet, %
		2.2.2 Organizations that use special software, %
	2.3 Availability of the website and digitalzation of jobs	2.3.1 Organizations that have their own website, %
		2.3.2 Number of personal computers with access to the Internet per 100 employees, units
3. Digitalization of the state	3.1 Digital government services	3.1.1 People who use mobile devices to receive state and municipal services, % of the total population aged 15–72 who receive state and municipal services
		3.1.2 People who receive information through official websites and portals of state and municipal services, %
		3.1.3 People who interact with public authorities and local self-government via the Internet, by type of interaction "Implementation of mandatory payments (payment of duties, taxes, fines) online", % of the total population aged 15–72
	3.2 Quality of services	3.2.1 People's assessment of their level of satisfaction with the quality of public and municipal services provided via the Internet, fully satisfied, %
Indicators of the Index of digitalization conditions in the region (Idc)		
Digitalization condition	Factor	Indicator
1. Digital infrastructure	1.1 Internet	1.1.1 People who use the Internet, % of the total population aged 15–72
	1.2 Landline	1.2.1 Digitalization of the local landline telephone network, %
	1.3 Digital transmission systems	1.3.1 Length of long-distance, intra-zone and international landline telephone channels formed by digital transmission systems per area of the region, channel-kilometer/ha
2. Digital competences of the population	2.1 Internet skills	2.1.1 People who use the Internet every day or almost every day, % of the total population aged 15–72
	2.2 Computer skills	2.2.1 People who use personal computers, % of the total population aged 15–72
3. Digital education	3.1 Education level	3.1.1 Share of employed population with higher education in the total number of employed population, %
	3.2 Digitalization of education	3.2.1 Number of personal computers used for educational purposes in state and municipal organizations engaged in educational activities under educational programs of higher education, units per 1,000 people
4. Spatial and territorial structure	4.1 Urbanization of the territory	4.1.1 Proportion of urban population in total population, %
	4.2 Development of the territory	4.2.1 Population density, persons/km2
5. Development of science and innovation	5.1 Scientific research	5.1.1 Inventive activity coefficient, %
		5.1.2 Number of personnel engaged in research and development, people/10 thousand people
	5.2 Innovation activity	5.2.1 Share of innovative goods, works, services in the total volume of goods shipped, works performed, services provided by industrial production and the sphere of services, %
6. Endowment with resources	6.1 Energy resources	6.1.1 Power generation per capita, kWh/person
	6.2 Financial resources	6.2.1 Proportion of ICT expenditure in GRP, %
Sources: own compilation based on: 1. *Regions of Russia. Socio-Economic Indicators. 2016: Statistics Collection*. Rosstat. Moscow, 2016; 2. Laikam K.E., Abdrakhmanova G.I., Gokhberg L.M., Dudorova O.Yu. et al. *Information Society in the Russian Federation: Statistics Collection*. Rosstat, Nats. issled. un-t "Vysshaya shkola ekonomiki". Moscow: NIU VShE, 2017. 328 p.		

When assessing digital ecosystems of constituent entities of the Russian Federation we use matrix analysis with the method of k-max, which is a procedure for reducing a specific number of observations to several groups with similar characteristics. Since the selected indicators for the assessment of digital ecosystems are stimulator indicators (the higher their value, the better), then k is the maximum value of the variable x (indicator). The main advantage of the method consists in the use of mathematical apparatus in the calculations; this eliminates the subjectivity of the assessment.

Matrix analysis of the state of digital ecosystems was carried out according to the following algorithm.

Stage 1 – calculating the index of activity of digitalization subjects of the region *(Q_{mij})*.

To assess the level of activity of digitalization subjects of Russia's regions, we selected statistical data on the indicators of the region's digitalization index *(m_1, m_2, m_3,..., m_i)* for 2015 and 2016 presented in Table 2. The formula (1) was used to calculate the index of activity of digitalization subjects of each region):

$$Q_{m_{ij}} = \frac{x_j}{k_{max}}, \quad (1)$$

where x_j is the value of the index of digitalization of the *j*-th subject of the Russian Federation;

k_{max} is the maximum value of the digitalization index in the aggregate of all the subjects of the Russian Federation under consideration.

Stage 2 – calculating the index of activity of digitalization subjects of the region (I_{d_j}) by the formula (2):

$$I_{d_j} = \frac{(Q_{mij_1} + Q_{mij_2} + \cdots + Q_{mij_{17}})}{17}. \quad (2)$$

Stage 3 – calculating the index of digitalization conditions of the region *($P_{n_{ij}}$)*.

To assess the conditions of digitalization of the Russian regions, we selected statistical data on the indicators of the region's digitalization conditions index *(n_1, n_2, n_3,..., n_i)* for 2015 and 2016 presented in Table 2. The formula (3) was used to calculate the index of digitalization conditions for each region):

$$P_{n_{ij}} = \frac{y_j}{k_{max}}, \quad (3)$$

where y_j is the value of the terms of digitalization of the *j*-th subject of the Russian Federation;

k_{max} is the maximum value of the indicator of digitalization conditions in the aggregate of all the subjects of the Russian Federation under consideration.

Stage 4 – calculating the index of digitalization conditions in the region *(I_{dc_j})* according to the formula (4):

$$I_{dc_j} = t_1 * \frac{P_{nij_1} + \cdots + P_{nij_3}}{3} + t_2 * \frac{P_{nij_4} + P_{nij_5}}{2} + t_3 * \frac{P_{nij_6} + P_{nij_7}}{2} + t_4 * \frac{P_{nij_8} + P_{nij_9}}{2} + t_5 * \frac{P_{nij_{10}} + \cdots + P_{nij_{12}}}{3} + t_6 * \frac{P_{nij_{13}} + P_{nij_{14}}}{2}, \quad (4)$$

where $t_1 - t_6$ are the weighting factors of the digitalization conditions.

The weighting factors for calculating the index of digitalization conditions in the region were obtained through a survey of experts using the analytic hierarchy process – the Saaty method *(Tab. 3)*.

The experts were representatives of public authorities, business community, scientific and educational organizations. In total, we interviewed 24 experts from eight regions of Russia: Arkhangelsk Oblast, Krasnoyarsk Krai, Vologda Oblast, Sverdlovsk Oblast, Republic of Karelia, Republic of Tatarstan, Republic of Komi, Republic of Sakha (Yakutia).

Table 3. Weighting factors for the groups of digitalization conditions

Group of digitalization conditions	Value
Digital infrastructure (t_1)	0.25
Digital competence of the population (t_2)	0.10
Digital education (t_3)	0.15
Spatial and territorial structure (t_4)	0.20
Development of science and innovation (t_5)	0.10
Resource availability (t_6)	0.20
Source: own elaboration according to a survey we conducted	

In our opinion, the introduction of weighting factors for the calculation of the index of activity of digitalization subjects of the region (Id) is not possible due to the equivalence of digitalization directions; and the high level of development of one direction does not guarantee the development of the others and the achievement of an effectively functioning digital ecosystem.

In order to present the results of the study more clearly, we propose to use the matrix method. To identify different types of ecosystems, the number of possible options must be specified in advance. The criterion of the optimal number of types is the possibility of their clear interpretation. We identify six types of regions (problem, passive, actively engaged, balanced, advanced and leading) that form the matrix of the digital ecosystem *(Fig. 1)*. The matrix allows us to group constituent entities of the Russian Federation according to the level and conditions of digitalization; this further simplifies the elaboration of recommendations to public authorities for the development of regional digital ecosystems.

In order to determine the boundaries of the types of digital ecosystems, we propose to use the formulas and the coordinate system presented in *Figure 2*.

Thus, the method we propose helps conduct a comprehensive assessment of both the level of activity of the subjects of digitalization of the region and the conditions for the development of digitalization formed in this territory. At the same time, on the basis of the estimates we have obtained it is possible to determine the main types of regional digital ecosystems and to identify their specific features in both positive and negative aspects.

Research results

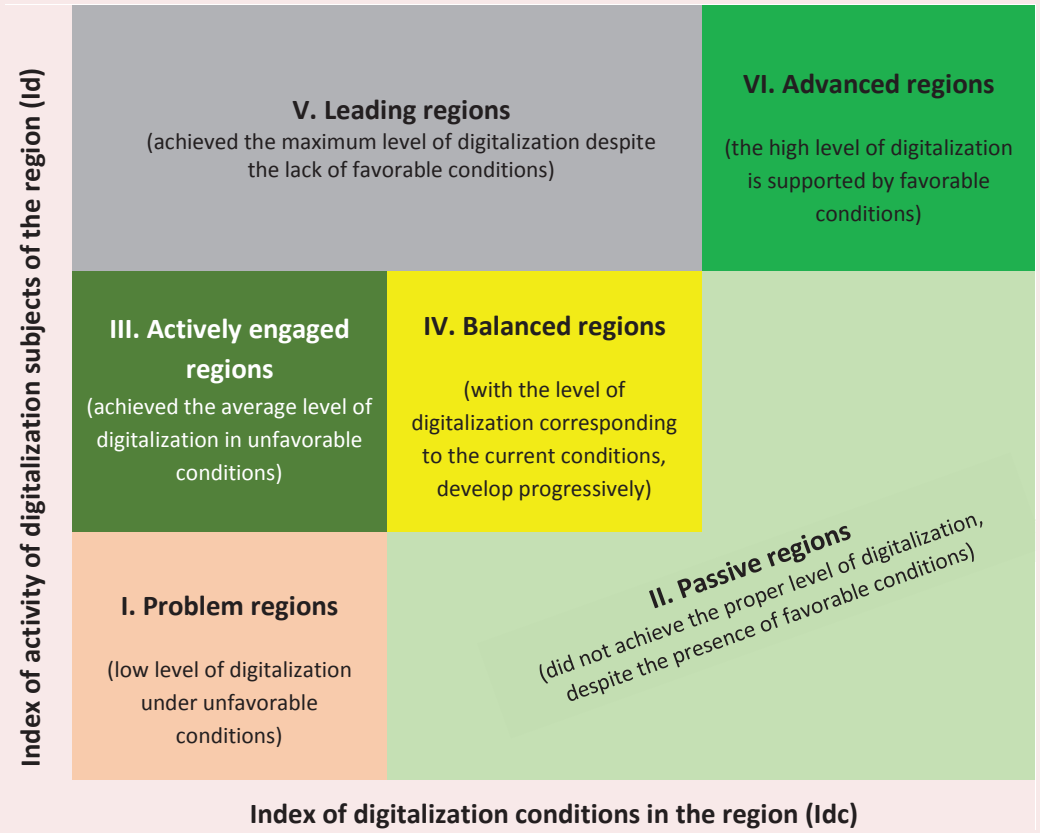
The objects of the study were 82 regions of Russia. Moscow, Saint Petersburg and Sevastopol were excluded from the total, as the values for most indicators of these cities differ significantly from the regional average. This is due to their special political and socio-economic situation, which may lead to misrepresentation of the evaluation results and to incorrect comparisons.

Having tested our method, we estimate digital ecosystems in regions of the Russian Federation in 2015–2016.

According to the results of the assessment in 2016 no region was included in the group of advanced regions. However, we should note that in 2015 this group was represented by Khanty-Mansi Autonomous Okrug, a region which implemented the existing potential for digitalization of the region to the fullest extent.

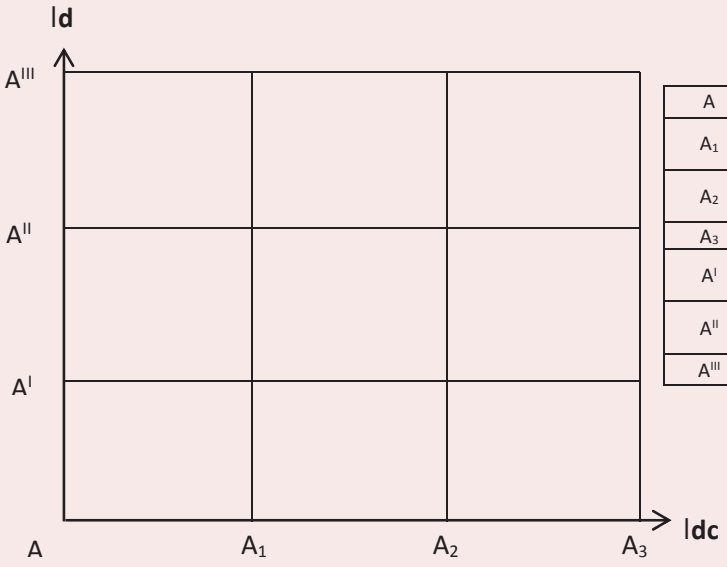
The group of advanced regions in 2016 included ten regions. Khanty-Mansi Autonomous Okrug was included in this group primarily due to the high index within the direction of "Digital activity of the population", the Yaroslavl Oblast – "Digital activity of organizations", and the Rostov Oblast – "Digitalization of the state".

Figure 1. Matrix of the types of digital ecosystems



Source: own compilation.

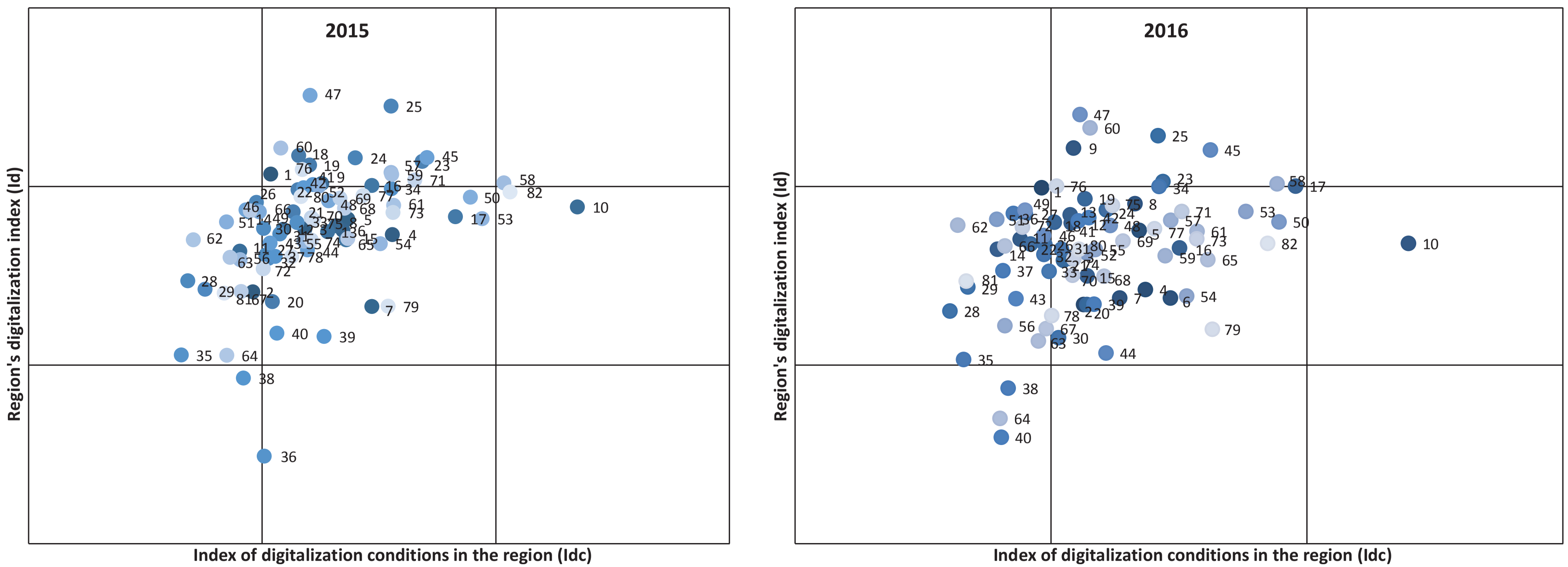
Figure 2. The form, according to which the boundaries of types of digital ecosystems are determined



A	minId – 0.1; minIdc – 0.1
A_1	$(\text{minIdc} - 0.1) + \frac{(\text{maxIdc} + 0.1) - (\text{minIdc} - 0.1)}{3}$
A_2	$(\text{minIdc} - 0.1) + 2 * \frac{(\text{maxIdc} + 0.1) - (\text{minIdc} - 0.1)}{3}$
A_3	maxIdc +0.1
A^I	$(\text{minId} - 0.1) + \frac{(\text{maxId} + 0.1) - (\text{minId} - 0.1)}{3}$
A^{II}	$(\text{minId} - 0.1) + 2 * \frac{(\text{maxId} + 0.1) - (\text{minId} - 0.1)}{3}$
A^{III}	maxId +0.1

Source: own compilation.

Figure 3. Matrices for assessing digital ecosystems of Russia for 2015–2016

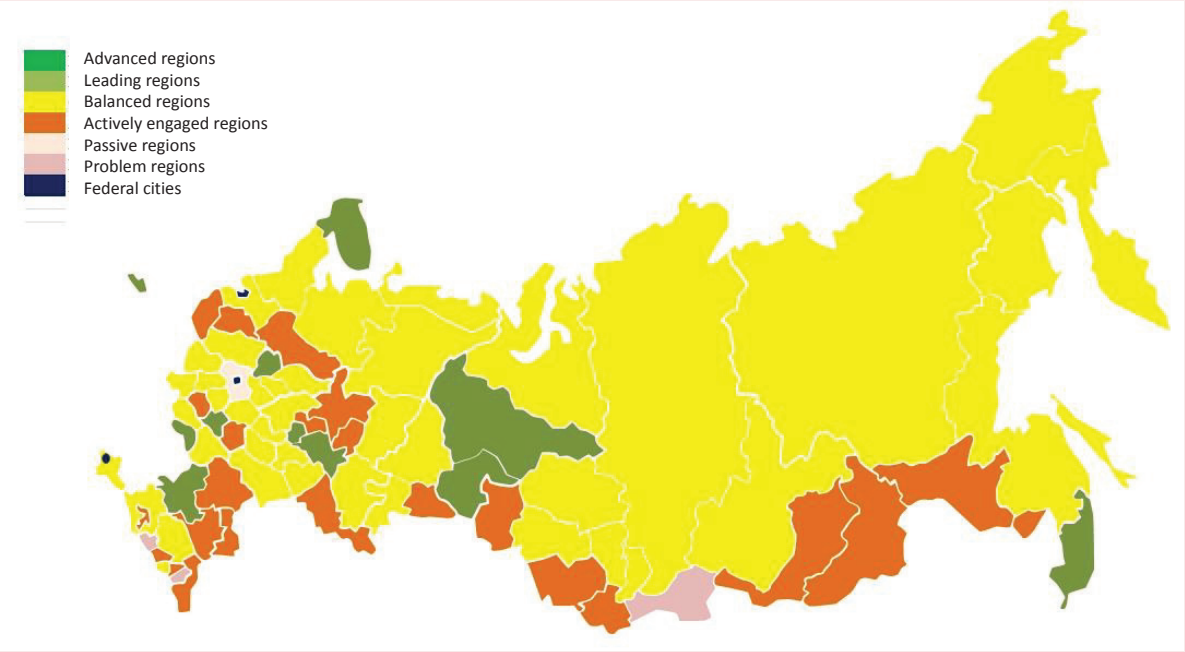


1.Belgorod Obl.
2.Bryansk Obl.
3.Vladimir Obl.
4.Voronezh Obl.
5.Ivanovo Obl.
6.Kaluga Obl.
7.Kostroma Obl.
8.Kursk Obl.
9.Lipetsk Obl.
10.Moscow Obl.
11.Oryol Obl.
12.Ryazan Obl.
13.Smolensk Obl.
14.Tambov Obl.
15.Tver Obl.
16.Tula Obl.
17.Yaroslavl Obl.
18.Rep.of Karelia
19.Rep.of Komi
20.Nenets AO
21.Arkhangelsk Obl.
22.Vologda Obl.
23.Kaliningrad Obl.
24.Leningrad Obl.
25.Murmansk Obl.
26.Novgorod Obl.
27.Pskov Obl.
28.Rep.of Adygea
29.Rep.of Kalmykia
30.Rep.of Crimea
31.Krasnodar Obl.
32.Astrakhan Obl.
33.Volgograd Obl.
34.Rostov Obl.
35.Rep.of Dagestan
36. Rep.of Ingushetia
37. Kabardino-Balkar Rep.
38.Karachay-Cherkess Rep.
39.Rep.of North Ossetia – Alania
40. Chechen Rep.
41.Stavropol Krai
42.Rep.of Bashkortostan
43.Mari El Rep.
44.Rep.of Mordovia
45.Rep.of Tatarstan
46.Udmurt Rep.
47.Chuvash Rep.
48.Perm Krai
49.Kirov Obl.
50.Nizhny Novgorod Obl.
51.Orenburg Obl
52.Penza Obl.
53.Samara Obl.
54.Saratov Obl.
55.Ulyanovsk Obl.
56.Kurgan Obl.
57.Sverdlovsk Obl.
58.Khanty-Mansi AO
59.Yamalo-Nenets AO
60.Tyumen Obl.
61.Chelyabinsk Obl.
62.Altai Rep.
63.Rep.of Buryatia
64.Rep.of Tuva
65.Rep.of Khakassia
66.Altai Krai
67.Zabaykalsky Krai
68.Krasnoyarsk Krai
69.Irkutsk Obl.
70.Kemerovo Obl.
71.Novosibirsk Obl.
72.Omsk Obl.
73.Tomsk Obl.
74.Rep.of Sakha (Yakutia)
75.Kamchatka Krai
76.Primorsky Krai
77.Khabarovsk Krai
78.Amur Obl.
79.Magadan Obl.
80.Sakhalin Obl.
81.Jewish AO
82.Chukotka AO

Note. Federal cities are excluded from the total number of regions.

Source: own compilation on the basis of own calculations.

Figure 4. Map of digital ecosystems of Russia, 2016



Source: based on the data from Fig. 3, 2016.

The remaining regions of the leading group (Kaliningrad Oblast, Murmansk Oblast, Republic of Tatarstan, Lipetsk Oblast, Tyumen Oblast, Chuvash Republic and Primorsky Krai) demonstrated high indices in at least two areas of digitalization. This confirms the need for comprehensive development of digitalization in all areas. These regions, even if they do not enjoy the most favorable conditions, have reached a high level of digitalization, which deserves high scores.

The reverse situation is typical for the Moscow Oblast, which, despite the presence of the best conditions and favorable economic and geographical location, is the only one in the group of passive regions, primarily due to the low digital activity of the population.

The group of regions that are being actively involved in the process of digitalization included 24 regions. At the same time, 16 of them (Belgorod Oblast, Tambov Oblast, Pskov Oblast, Kabardino-Balkar Republic, Volgograd Oblast, Novgorod Oblast, Altai Krai, Astrakhan Oblast, Altai Republic, Orel Oblast, Udmurt Republic, Republic of Ingushetia, Kirov Oblast, Orenburg Oblast, Vologda Oblast and Omsk Oblast), under similar conditions with other regions of this group (Republic of Dagestan, Jewish Autonomous Oblast, Republic of Buryatia, Zabaikalsky Krai, Kurgan Oblast, Republic of Mari El, Republic of Kalmykia), have a high index of digitalization. In general, the regions of this group also deserve positive assessments, because, without favorable conditions, they were able to achieve an average level of digitalization. However, such regions as the Orel Oblast, Volgograd Oblast, Republic of Dagestan, Kabardino-Balkar Republic and the Kurgan Oblast, entered this group only due to relatively high values according to the direction of "Digitalization of the state". These results are ambiguous, as they can be interpreted both

as an effective regional policy in this area, and as the use of administrative resources by regional authorities.

The most numerous is the group of balanced regions, which includes the vast majority of the regions of the Central Federal District, the Volga region, Siberia and the Far East. We find it especially necessary to point out that the balanced group includes quite a few subjects of the Russian Federation located in the Arctic Zone. This is largely due to the geographical proximity of these regions, which forms ecosystems at the supra-regional level and allows them to obtain additional effects.

Problem regions from the point of view of the state of digital ecosystems are represented by three subjects of the Russian Federation: Karachay-Cherkess Republic, Chechen Republic and the Republic of Tuva. These regions have a low level of digitalization in all areas (digital activity of the population, digitalization of organizations, digitalization of the state) under unfavorable conditions for its development.

The results of the study are shown in *Figure 3*.

Visualization of the obtained results can be represented on the digital map of ecosystems in the regions of Russia *(Fig. 4)*.

Our paper describes the primary approbation of the proposed method for two years. In the future, it will be improved both in the territorial context (in-depth assessment of the territories of different macroregions), and in the context of new statistics characterizing digitalization of the country.

Conclusion

Thus, in order to make an assessment of the level of development of digital ecosystems in the regions reliable and accurate enough, the algorithm should take into account not the individual characteristics of these systems, but their full content, including the subjects of digitalization of the economy and society, environmental conditions, territorial features, information technology, the development of science and innovation, and infrastructure. Therefore, our assessment methodology includes two integrated indices, which in turn aggregate 31 statistical indicators.

The technique we propose is more resistant to technological and technical changes in the digital economy and the ecosystem as a whole with respect to other methods considered. This means that, with the advent of new technologies and services, the outdated indicator is easily replaced, but the direction of digitalization and the conditions that ensure it remain unchanged.

Having tested the proposed method we were able to carry out a pilot analysis of the state of digital ecosystems in the regions of Russia and to determine their specific and typical features. In most regions, the level of development of digital ecosystems corresponds to the conditions of the information environment and the availability of the necessary infrastructure; such regions are balanced regions. Unfortunately, there is a number of regions which should be called problem regions, as in them the level of development of the digital economy, and the conditions for its formation are insufficient, much lower than the average values (Karachay-Cherkess Republic, Chechen Republic and the Republic of Tuva). As a positive example, we should note the regions that, with insufficient development of conditions for digitalization and without the most favorable conditions, have achieved the maximum level of digitalization (for example, Chuvash Republic, Tyumen Oblast, Murmansk Oblast).

Our method for assessing digital ecosystems allows us to reliably assess not only the level of their development, but also certain specific

features (advantages or problems), and its results can be used by the executive authorities in order to make management decisions and adjust their activities toward the development of regional digital ecosystems. As a pilot project, the results of the study were used during strategic sessions in the development of draft texts of the strategy for socio-economic development of the Arkhangelsk Oblast for the period up to 2035.

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Information about the Authors

Vera V. Stepanova – Doctor of Sciences (Economics), Associate Professor, professor at department, Northern (Arctic) Federal University (17, Northern Dvina Embankment, Arkhangelsk, 163002, Russian Federation; e-mail: nirvvs@mail.ru)

Anna V. Ukhanova – Researcher, N. Laverov Federal Center for Integrated Arctic Research, RAS (23, Northern Dvina Embankment, Arkhangelsk, 163000, Russian Federation; e-mail: karmy-anny @yandex.ru)

Aleksei V. Grigorishchin – Expert at department, Northern (Arctic) Federal University (17, Northern Dvina Embankment, Arkhangelsk, 163002, Russian Federation; e-mail: grigorishchin@mail.ru)

Dilmurad B. Yakhyaev – Assistant Professor, Northern (Arctic) Federal University (17, Northern Dvina Embankment, Arkhangelsk, 163002, Russian Federation; e-mail: dilmurad-92@mail.ru)

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