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Digital infrastructure as the factor of economic and industrial development: case of Arctic regions of Russian North-West

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Abstract. The article is aimed on analysis of digital infrastructure as the factor of economic and industrial development of the three Arctic regions of Russian North-West: Murmanskaya oblast', Arkhangelskaya oblast' and Komi Republic. These regions faced serious social and economic problems last years. The only way to solve these problems is reindustrialization and technological modernization. Modern industrial technologies are based on the digital transformation of all business processes of enterprise. That's why the regional digital infrastructure, information and communication technologies availability is an important factor of economic and industrial development of the regions. The article uses the method of calculation of integrated indicator characterizing the level of development of the digital infrastructure of the regions and proposed a formula for computing the numerical value of the integrated indicator. The formula allows receiving numerical results of calculation, based on data of the state official statistics regarding separate indicators aggregated into two groups. The indicators of the first group characterize the material factor of the digital infrastructure of the region. The second group reflects the real ability of regional business use of information and communication technologies and software. The calculations of the integrated indicator dynamics for the period when statistic data are available for three regions allowed to figure out main factors making impact on the level of digital infrastructure development and formulate recommendations for the future.

1. Introduction

The North-West federal district is an important part of Russian economy providing of almost 11% of GDP of Russian Federation. [1]. This federal district consists of 11 federal regions (subjects) including three ones fully or partly belonging to the Arctic zone of Russian Federation: Murmanskaya oblast', Arkhangelskaya oblast', Komi Republic. These federal subjects take a special position in the region due to geopolitical reasons, natural resources abundance and cultural diversity [2]. It's necessary to mention Nenets autonomous district which is an one more federal district officially belonging to the Arctic zone, however this district is firstly a part of Arkhangelskaya oblast' geographically, secondly it is essentially less populated in comparison with other North-West regions, thirdly it has a very specific social and economic structure. That's why the subject of our study is limited by three above listed Arctic regions of the North-West federal district.

These Arctic regions of Russian North-West faced some serious economic, social and demographic problems during last years. The population of Murmanskaya oblast', Arkhangelskaya oblast', and



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Komi Republic dropped down in period of 2001-2018 to 19%, 17%, 20%, accordingly. [3]. Overage GDP growth rate during period of five years (2012-2016) is low and it had been fluctuating from 1,5% in Arkhangelskaya oblast and 0,8% in Murmanskaya oblast up to -2,4% in Komi Republic.

According to the statistical data the mineral resources and manufacturing industries are the main contributors to the Great Regional Product for all three regions [4]. It means that the most perspective way to solve current economic and social problems and provide economic growth and sustainable development is fostering of modernization processes in industries presented in the Arctic regions of Russian North-West.

The modern industrialization (reindustrialization) is based on digital transformation of all business processes inside of the enterprises [5]. The other important condition for successful digitalization of industries is development of regional infrastructure providing facilities necessary for on-line communications and access to data bases and integrated managerial systems. That's why the high level of digital infrastructure development is the crucial term for industrial development in modern business reality.

Thus the goal of the research is to assess the level of the digital infrastructure development of the three Arctic regions of Russian North-West listed above, conduct comparative analysis and develop recommendations for further development of the digital infrastructure.

To achieve the goal the following tasks are to be done.

- To justify the method of quantitative assessment of the digital infrastructure development in a region.
- To assess the level of the digital infrastructure development in the Arctic regions of Russian North-West using the chosen method.
- To analyze the factors defining the level of the digital infrastructure development in the Arctic regions of Russian North-West.
- To identify the main success factors of the of the digital infrastructure development based on experience of the Arctic regions of Russian North-West.
- To formulate the recommendations for further development of the digital infrastructure in the Arctic regions of Russian North-West based on identifies success factors.

Researchers from all circumpolar countries note similar factors and vectors of development of the Arctic regions [6-9]. These regions are sparsely populated and have special economic structure, including natural and market elements. This gives rise to various socio-economic risks and requires the implementation of the concept of sustainable development [6, 10-12]. In this regard, the most promising direction of development is the digitalization of social and economic processes [13-15], which contributes to the dynamic development of the region on a resource-saving basis.

The specifics of the development of the Arctic regions determine the specificity of methodological approaches. The most interesting in this aspect are the works [8, 16, 17], but they, convincingly proving the need for innovative technological growth in the Arctic territories, do not consider the development of digital infrastructure. The study [18] represents a model of the influence of innovative activities on the economic indicators of the Arctic regions and shoes a direct impact of innovative activities on the economic growth but it does not contain indicators of digital infrastructure.

On the other hand, there is enough research on digital infrastructure. The most profound methodology for assessing the development of digitalization of different objects has been developed in works on the development of digital ecosystems. The paper [19] proposed a detailed list of indicators for calculating the development index of the country's digital ecosystem, aggregated into four groups: ICT adoption, connectivity, absorption capacity, influenced by social capital.

A slightly different list was compiled by Katz, R., Koutroumpis, P., Callorda, F.M. [20], who proposed assessing the level of digitalization of the country using a composite index, which includes six indicators: accessibility, investment in infrastructure, network access, capacity, use and human capital. However, we note that these works considered the digital ecosystem of the country but not the country's region. Therefore, in our opinion, it is necessary to clarify the proposed list of indicators in relation to the regional level.

The methodological approach was justified by us in our work [21] and in our opinion, the proposed approach is quite applicable for the analysis of the development of digital infrastructure in the Arctic regions of Russia.

2. Methodology

Methodology of the research is based on the general qualitative methods such as content and comparative analysis and quantitative ones based on assessment of integrated indicator of the regional digital infrastructure development distinguishing two groups of indicators.

The indicators of the first group characterize the infrastructure and technical prerequisites for the formation of the digital economy in a region, for instance, costs of information and communication technologies in the total volume of GRP, use of personal computers by regional organizations, use of servers and global networks by organizations in a region.

The second group of indicators reflect the real ability of regional business use of information and communication technologies and software, for example, relative value of organization expenses on ICT, share of organizations that had a website, share of organizations using electronic document management systems, share of organizations that used specialized software, etc.

The study uses the method of calculation of integral indicator characterizing the level of development of the digital infrastructure of the regions, proposed by authors in [6] according to formula

$$I_{di} = k_m \frac{\sum_{j=1}^{N_m} p_{mj}^{norm}}{N_m} + k_i \frac{\sum_{j=1}^{Q_i} p_{ij}^{norm}}{Q_i}$$

Where I_{di} - is a calculated value, an integral index of the level of development of the digital infrastructure of the region;

p_{mj}^{norm} - the j-th - normalized indicator of the group of material indicators characterizing the level of development of the digital infrastructure of the region;

N_m - the number of indicators of the first group characterizing the level of development of the digital infrastructure of the region;

k_m - coefficient of significance of the indicators of the first group, the group of material indicators characterizing the level of development of the digital infrastructure of the region;

p_{ij}^{norm} - the j-th normalized indicator of the second group of indicators characterizing the level of development of the digital infrastructure of the region;

Q_i - the number of indicators of the first group characterizing the level of development of the digital infrastructure of the region;

k_i - the coefficient of significance of the indicators of the second group of indicators characterizing the level of development of the digital infrastructure of the region.

Thus, the steps to achieve the goal of the study will be as follows.

1. Defining of the list of indicators characterizing the level of development of the digital infrastructure of selected regions for the two groups distinguished above.

2. The determination of numerical values of indicators for the period when the data is available.

3. Calculation of an integral indicator of the level of development of digital infrastructure of selected urban agglomerations for the time period.

4. Analysis of the results and formulation of conclusions and recommendations.

Data for assessing the first group of indicators for the selected objects of study are presented in the table. 1.

Table. 1. Indicators for assessing the subsystem characterizing the material conditions and technical prerequisites for the formation of a digital economy in the regions 2013-2017

Regions (subjects)	Komi Republic					Murmanskaya oblast'					Arkhangelskaya oblast'				
Periods	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Costs of information and communication technologies in the total gross regional product (GRP), %	11,7	14,3	13,1	13,4	15,2	10,9	8,6	9,7	9,2	10,6	27,8	8,8	12,1	13,3	7,3
Use of personal computers, % firms	96,5	93	94,4	94,7	92,9	96,2	96	94,9	95,7	94	96,5	95,6	91,4	92,6	93,0
Use of servers, % of firms	5,7	4,2	36,7	44,7	46,4	13,1	23,5	52,8	56,2	55,9	20,6	33,4	46,8	49	48,2
Use of global information networks, % of firms	92,8	90	91,5	92,8	90,9	93,1	93,2	91,6	89,3	90,1	92,1	92,7	89,2	90,6	91,1
Use of Internet, % of firms	91,3	88,1	89,6	90,9	88,1	92,5	92,7	91,3	89,1	89,1	91,2	91,6	87,5	89,2	89,7
The broadband access of them, % of firms	81,8	84,2	90,9	88,1	81,8	89	89,2	88,6	86,9	86,7	78,3	82,1	77,5	81,5	83,2
Subsystem characterizing the material conditions and technical prerequisites for the formation of a digital economy	63,3	62,3	69,4	70,8	69,2	65,8	67,2	71,5	71,1	71,1	67,8	67,4	67,4	69,4	68,8

Data for assessing the first group of indicators for assessing the Information and communication subsystem are gathered in the table. 2.

Table. 2. Indicators for assessing the Information and communication subsystem in the regions 2013-2017

Regions (subjects)	Komi Republic					Murmanskaya oblast'					Arkhangelskaya oblast'				
Periods	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Organizations that had a website, % of the total organizations surveyed	34,8	36,6	38,8	42,4	43,8	49,9	45,8	48,4	49,3	50	38,9	35,4	37	39,6	43,5
Organizations using automatic exchange data between their external information systems, %	26,1	52,2	56,7	60,7	57,2	29	51,6	80,2	80,3	62,6	27,5	52	59,3	58,8	58,2
The relative value of organizations spending on ICT, %	40,6	49,7	49,8	52,6	62,9	23,9	20,4	28,0	28,6	33,9	100	34,3	54,7	65,2	39,2
Organizations using electronic document management systems, %	30,8	67,9	72,4	76,1	76,2	70,2	57,3	66,5	66,5	66,6	69,1	57	65,4	69,4	67,6
Use of special software, % of the total number of organizations surveyed	88,4	85,1	85,6	87	84,3	92,6	91,4	90,2	86,6	85,7	87,9	87,7	83,5	84,7	83,5
Information and communication subsystem	44,1	58,3	60,7	63,8	64,9	91,2	90,5	89,6	86,7	86,1	84,1	85,5	81,1	83,4	83,4

To calculate the indicators, we used the data presented on the websites of state and regional statistics. Unfortunately, we could not make calculations for 2018, because on official sites there is no data on the GRP of the regions. The calculation of the integrated indicator in the table. 3.

Table. 3. Integrated indicator in 2013-2017

Regions (subjects)	Periods	Subsystem characterizing the material conditions and technical prerequisites for	Information and communication subsystem	Integral megalopolis digital infrastructure
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		the formation of a digital economy		development index
Komi Republic	2013	63,3	44,1	51,8
	2014	62,3	58,3	59,9
	2015	69,4	60,7	64,2
	2016	70,8	63,8	66,6
	2017	69,2	64,9	66,6
Murmanskaya oblast'	2013	65,8	91,2	81,0
	2014	67,2	90,5	81,2
	2015	71,5	89,6	82,4
	2016	71,1	86,7	80,5
	2017	71,1	86,1	80,1
Arkhangelskaya oblast'	2013	67,8	84,1	77,6
	2014	67,4	85,5	78,3
	2015	67,4	81,1	75,6
	2016	69,4	83,4	77,8
	2017	68,8	83,4	77,6

3.Results

The dynamics of the integral indicator is presented in Fig. 1. The steady growth of the integral index of the level of development of the digital infrastructure of the region is observed only in the Komi Republic.

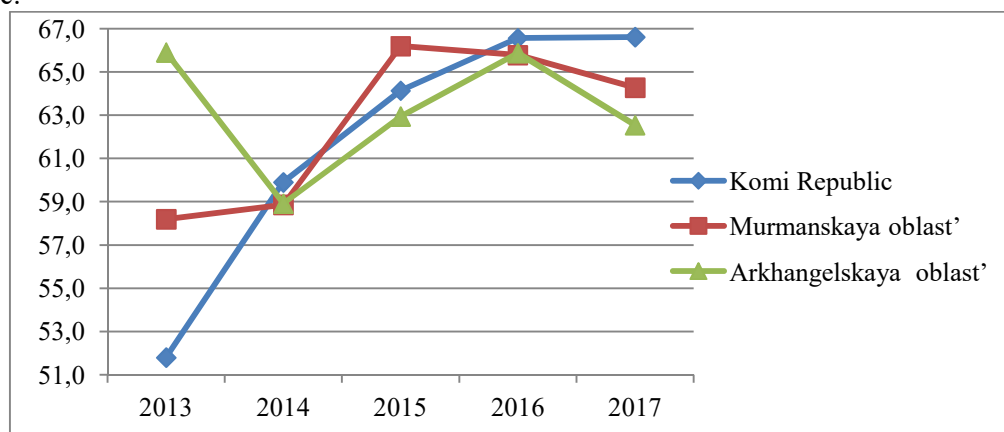


Fig. 1. The dynamics of the integral indicator in the regions 2013-2017

Digitalization processes in all regions are taking places against the background of a decrease in the population and an outstripping decrease in the number of employed. The negative dynamics of the population, together with the growth of gross regional product, determines the high growth rate of GRP per capita in all regions, incl. in the Arkhangelsk region more than 1.5 times compared with 2013 (table 4).

Table. 4. Dynamics of regional indicators, 2013-2017

Regions /(subjects)	Komi Republic					Murmanskaya oblast'					Arkhangelskaya oblast'				
Periods	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Population dynamics	1,00	0,99	0,98	0,98	0,96	1,00	0,99	0,99	0,98	0,98	1,00	0,99	0,99	0,98	0,97

Employment growth rate	1,00	0,97	0,98	0,95	0,92	1,00	0,98	0,91	0,91	0,88	1,00	0,99	0,93	0,91	0,91
GRP growth rate	1,00	1,00	1,10	1,14	1,19	1,00	1,07	1,31	1,41	1,45	1,00	1,09	1,26	1,36	1,49
GRP per capita growth rate	1,00	1,01	1,12	1,17	1,23	1,00	1,08	1,33	1,44	1,49	1,00	1,09	1,27	1,39	1,53
The growth rate of the number of enterprises	1,00	0,98	0,99	0,97	0,90	1,00	1,01	1,05	0,88	0,85	1,00	0,96	0,98	0,91	0,87
Share of small enterprises in the region	0,60	0,61	0,57	0,52	0,57	0,28	0,27	0,47	0,62	0,64	0,65	0,57	0,54	0,60	0,63
ICT costs per organization, rubles / org	0,26	0,33	0,32	0,35	0,45	0,15	0,13	0,17	0,21	0,26	0,52	0,19	0,29	0,37	0,24

The analysis of indicators of subsystem characterizing the material conditions and technical prerequisites for the formation of a digital economy shows that for 5 years there have been no significant changes. We note only a slight increase in the share of organizations using servers.

In all the regions examined, there is a decrease in the number of enterprises and organizations (10-15%). At the same time, the share of small enterprises and organizations in the Komi Republic and the Arkhangelsk region fluctuates around 60%, while in the Murmansk region the share of small enterprises is gradually increasing from 27% to 64%. The share of ICT expenditures per organization is gradually increasing in the Komi Republic (from 26% to 45%), insignificantly in the Murmansk region (from 15% to 26%), and is gradually decreasing in the Arkhangelsk region (from 52% to 24%). The structure of expenses on ICT takes into account the actual expenses of organizations related to the purchase of computer equipment and software, payment for communication services, training employees in the development and application of ICT, payment for services of third-party organizations and specialists. Other ICT costs take into account the costs of organizations developing software on their own. Analysis of the structure of ICT spending for the period from 2013-2017 revealed the following general trends:

- the share of expenditure for payment of telecommunication services, including Internet access is reduced;
- the share of expenditure on payment of third-party organizations has increased;
- the costs of training personnel associated with the development and use of ICT are negligible and amount to 0.1% for the Komi Republic and the Arkhangelsk region, 1.1% for the Murmansk region.

At the same time, we note that the proportion of organizations using special software not only does not increase, but decreases in all the regions examined, by about 5%. Analysis of the structure of the software used showed that organizations primarily use special software to carry out financial calculations and solve organizational and managerial problems. For the period from 2013-2017 the structure of the software used has not changed. The absence of expenses related to staff training, together with the increase in payments to external organizations, means that companies prefer to outsource part of the services than to invest in the development of digital competencies of their own staff and more fully use modern capabilities of computer technology.

Note that it is precisely the dynamics of ICT spending that largely determines the dynamics of the integral indicator in the regions (Fig. 2).

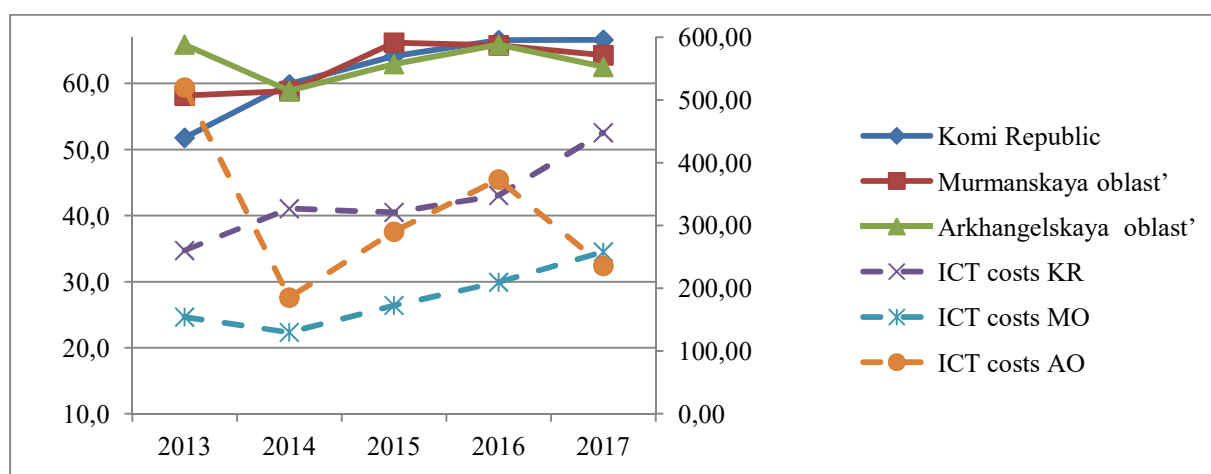


Fig. 2 Dynamics of the integrated indicator and ICT expenditures per 1 organization, rubles by region

The analysis of the results presented in figures 1 and 2 and tables 1-3 allow formulating the following recommendations for digital infrastructure development of the three Arctic regions of Russian North-West.

For enterprises

- to invest intensively in the development of digital competencies of their employees and more fully use modern capabilities of computer technologies;

for local authorities:

- to consider a change in the structure of the GRP in order to determine whether the reduction in the share of firms using special software and the change in the structure of production in the regions, as well as the share of small enterprises, are related;
- to increase spending into information and communication technologies.

4. Conclusions and discussion

Thus, the article presents the results of analysis of digital infrastructure development of the three Arctic regions of Russian North-West: Murmanskaya oblast', Arkhangelskaya oblast' and Komi Republic. The analysis is based on the method of calculating of the integrated indicator characterizing the level of development of the region's digital infrastructure. It is proposed to take into account the indicators presented in the database of Russian official statistics and combined by the authors in the two groups: firstly, indicators characterizing the general material conditions and technical prerequisites for the formation of the digital economy, and secondly, indicators which are reflecting the level of development and usage of information and communication technologies and software.

Using the formula proposed by the authors, we calculated the values of an integral indicator that characterizes the level of digital infrastructure development for three important regions, subjects of the Russian Federation: Arctic regions of Russian North-West: Murmanskaya oblast', Arkhangelskaya oblast' and Komi Republic. The analysis of the integrated indicator dynamics and diagrams drawn allows formulating the recommendations for the future development of the regional digital infrastructure.

The application of the results of the study has some definite limitations. First of all, the study makes a focus on the three regions of Russian Arctic only. Evidently the future study needs to cover a greater number of regions, ideally all the subjects of the Russian Arctic. It gives an opportunity to compare different regions, figure out more, recognize tendencies more clearly and formulate more justified recommendations. The other direction of the future research is construction of diagram for longer period of time to follow tendencies in the indicators' future dynamics.

The distinguishing of the two groups of indicators with different weights of significance looks justified. However the same coefficient for all separate indicators seems as too simplified approach.

That means the numerical values of the weight coefficients should be determined using more reasonable procedures in the future.

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