Digital infrastructure as the factor of innovative development of Arctic regions in framework of Industry 4.0 concept

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Abstract. The purpose of the article is studying of the impact of the level of digital infrastructure development on formation of Industry 4.0 in Arctic regions of Russian Federation. The study objects are four arctic territories of Russian Federation, namely, Murmansk region, Yamalo-Nenets Autonomous District, Chukotka Autonomous District and Nenets Autonomous District. The methodological basis for the study is assessment of the level of regional digital infrastructure through analysis of separate indicators and calculation of the integrated indicator. The data of the Russian Federal statistic agency and its branches for period of 2014-2019 were used for assessment and analysis. The results highlight the not very positive dynamics of integrated digital infrastructure development indicator since the level of it has a tendency or stagnate or grow slowly. The formation of Industry 4.0 that requires to combine internal enterprise’s computerized design and automated machinery with ecommerce and Internet of Things in one integrated ebusiness system, is looking problematic in current situation for analyzed regions. The authors formulated the limitations for the study and defined the directions of the future research.

1. Introduction
Geopolitical value of the Arctic Zone for the Russia is evident, that’s why the significant attention is to be paid to the development of the Arctic territories by the Russian authorities. The whole set of measures was proposed in 2014 in the “Strategy of development of Russian Arctic Zone for the period until 2020” [1] and renewed in 2020 by the Presidential Decree No. 645 up to 2035 [2]. The Program and Decree distinguish the most significant of socio-economic development in Russian Arctic:

a) focus on science and technology development;
b) creation of modern information and telecommunication infrastructure;
c) the creation of new and modernization of existing industrial production.

Given priorities are evidently interconnected since socio-economic development is based on modern industrial technologies which is impossible without information and telecommunication infrastructure. The problem of industrial modernization in framework of Industry 4.0 concept is the most topical one especially for Northern territories of Russian Federation due to continuous depopulation and deindustrialization during the last thirty years.

Thus, the goal of the study is investigating of the impact of the level of digital infrastructure development on formation of Industry 4.0 in Arctic regions.

There are the following tasks to be realized to achieve the goal.
1. Distinguishing of Arctic regions comparable for purposes of the study.
2. Calculation of integrated indicator of the regional digital infrastructure development for selected Arctic regions.
3. Identification of available in official statistic data bases indicators characterizing the process of Industry 4.0 formation in Arctic regions.
4. Comparative analysis of impact of the level of digital infrastructure development on Industry 4.0 formation in selected Arctic regions.
5. Formulation of prospects for further digital development in context of Industry 4.0 formation in selected Arctic regions.

2. Literature review

The development of circumpolar regions is the subject of study by researches in many countries due to the natural and social characteristics of the Arctic [3, 4, 5]. An abundance of natural resources, the cultural diversity and value of the people in Russian Arctic, transport and infrastructure capabilities are the subject of analysis in these studies. In the studies of the Arctic, the special emphasis is paid to the processes of globalization. Special emphasis is drawn to the increased level of socio-economic risks for the Arctic [6, 7]. N.I. Didenko [8] suggests a dynamic econometric model of the globalization processes influence on the Arctic development which includes the indicators reflecting the social, economic, ecological and environmental development of the Arctic and the indicators characterizing globalization. This model is the most deeply developed quantitative approach to assessing the socio-economic processes of the Arctic countries.

The processes of digitalization and innovative development in the Arctic, which have recently been synergistically interlinked with the processes of globalization, have turned out to be much less studied. Scientists from Canada and Russia are leaders in their study [9, 10, 11].

Studies [12, 13] prove the need for innovative technological growth in the Arctic territories, but do not consider the development of digital infrastructure. The study [14, 15] presents 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.

There is a lot of research on digital infrastructure. The most comprehensive methodology for assessing the development of digitalization of different objects has been investigated in works on the development of digital ecosystems. The paper [15] proposed a detailed list of indicators for calculating the development index of the country's digital ecosystem, combined into four groups characterizing digitalization and social processes. Katz, R., Koutroumpis, P., Callorda, F.M. [16] propose to assess 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, these works investigate 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.

3. Methodology and Materials

Methodology of the study includes the general qualitative methods such as content, comparative and system analysis and quantitative ones based on analysis of official statistical data and calculation of integrated indicator of the regional digital infrastructure development distinguishing two groups of indicators. The method of statistical analysis defines the choice of the Arctic regions to be studied. Statistical data are comparable for those regions entire belonging to the Russian Arctic Zone. Thus, four Arctic territories were selected for the study: the Murmansk Region (MO) and the autonomous regions of Yamalo-Nenetsky, Nenetsky, and Chukotsky.

For the selected regions, an integral indicator was calculated that characterizes the level of development of the digital infrastructure of the regions. The calculation method is described in detail by the authors described by the authors in [17]. The proposed integrated indicator characterizes the digital infrastructure of the region including conditions that determine the opportunities and barriers associated with technical capabilities for digitalization, as well as the availability of information and
communication technologies for the regional organizations. The informative basis for the study is official statistical data of Russian statistic agency and its regional branches.

4. Results
An analysis of the official statistics data presented in the Rosstat database [18] shows that the share of budgetary funds in the total volume capital investments in the Arctic zone for the period from 2014 to 2019 increased from 5.5 to 7.6%. This is about 48% of the total budgetary investment in the Russia by 2019 (2014 – 32 %). Share of GRP of the Russian Arctic in GRP.

Regions of Russia grew from 5 p.p. (2014) to 6.2 p.p. (2018). [18] The labour productivity index for the Arctic zone was even higher in 2018 than the average level of this indicator for the Russian Federation (1.07 and 1.028, correspondingly).

But negative trends exist. The share of the added value of high-tech and knowledge-intensive sectors in the GRP of the Arctic zone decreased from 7.5 p.p. in 2016 to 6.1 p.p. in 2018. However, the share of high-tech and knowledge-intensive industries in the GRP of the Russian Arctic decreases from 19.7% in 2016 by 4 p.p. by 2018. [18] The share of science-intensive innovative products, work (services) of organizations is significantly reduced from 2014 to 2019 in shipped goods performed from 0.17 to 0.05%.

The dynamics of the integrated indicator for the analyzed regions is shown in Figure 1.

![Figure 1. The dynamics of the integrated indicator in the regions](chart-image)

Calculations based on Rosstat database [19]

Note the long-term upward trend in the indicator in MR, NAD, ChAD. Initially, a fairly high level of the integrated indicator for the YNAD does not show a clear upward trend, but does not change.

Despite the stated goals of the Strategies mentioned above [2], the share of organizations' expenses on ICT implementation in the GRP is less than 1% for NAD, about 1% for MR. The rather high costs in 2015 and 2016 for YNAD and ChAD are significantly reduced by 2018-2019 and amount to less than 1%. At the same time, we note that the share of expenses of organizations on the introduction of ICT in the gross regional product for St. Petersburg is about 2%, and for Moscow 3-5%. Note the high level of digitalization in these regions, and the high growth rate of the integral indicator in 2013–2017.

[20].

The total share of ICT expenses of Arctic regions in the total regional ICT expenses was 1.64% in 2017. For comparison, the same indicator for Moscow was near 50%.

Analyzing the structure of the use of special software for the period from 2014 to 2018, one can note an ambiguous tendency to reduce the share of the use of special software, % of the total number of surveyed organizations (Figure 2). The trend is especially strong in YNA District, where the use of special programs in 2014 was 96.4%.
Figure 2. Change in the share of using special software 2014 - 2019 to 2014
Calculations based on Rosstat database [18]

It is obvious that the structure of the software used in the Arctic regions corresponds to the structure in the Russian Federation (Figure 3) 2014 – 2019. Statistical data allows us to analyze the following types of special software:
1. for scientific research;
2. for design;
3. for the management of automated production and / or specific technical means and technological processes;
4. to address organizational, managerial and economic tasks;
5. for making financial settlements in electronic form;
6. to provide access to databases through global information networks, including the Internet;
7. editorial and publishing systems;
8. training programs;
9. CRM, ERP, SCM;
10. systems electronic reference systems;
11. other software.
Changes over the period 2014-2018 mainly aimed at reducing the percentage of organizations using special software, including for scientific research, for design, for managing technological processes, automated manufacturing and individual technical tools. It is a definitely negative trend in context of Industry 4.0.

The number of organizations in Arctic zone conducting their own R&D for the period 2014-2018 did not decrease. Although the number of R&D personnel in 2018 decreased for NAO to 40% compared to 2014, down to 85% for MR. In the YNAD, the number of personnel increased by 30%. The YNA District is among the leading regions of the Arctic zone regarding the digital infrastructure development in 2014, but there, too, the share of special programs is decreasing. The indicators of the use of special software YNA District and MR in 2014 were mainly higher than the average for the Russian Federation. By 2019, the YNA District and MR have reduced their advantages.
Summing up the results for the period 2014-2019 (Figure 4-7) one can note a decrease in the percentage of organizations using special software, including for scientific research, for design, for managing of technological processes, automated manufacturing and individual technical tools.

An increase in the use of training programs, and the same CRM, ERP, SCM – systems (Figure 4-7). Thus, we can note the formation in the Arctic zone of automation of planning, accounting, control and analysis of the main business processes of enterprises, supply chain management, customer relationship management.

Share of people using the Internet in the Russian Arctic is steadily increasing, from 83.4% in 2015 to 90% in 2019. The average level for Russia is 73.4 and 85.6 pp, respectively.
Although the share of developed technologies by region is not large, we note a slight increase in the used advanced production technologies in these regions of the Arctic zone (Table 1).

**Table 1.** Developed and used advanced production technologies. [18]

|          | 2014 | 2015 | 2016 | 2017 | 2018 |
|----------|------|------|------|------|------|
| Developed advanced production technologies |      |      |      |      |      |
| NAD      | -    | 2    | 3    | -    | -    |
| MR       |      |      |      |      |      |
| YNAD     | 16   | 13   | 22   | 12   | 12   |
| ChAD     | 2    | 2    | -    | -    | -    |
| Used advanced production technologies |      |      |      |      |      |
| NAD      | -    | 25   | 36   | 63   | 78   |
| MR       | 1135 | 1201 | 1236 | 1145 | 1380 |
| YNAD     | 3930 | 4052 | 3627 | 4354 | 4242 |
| ChAD     | 392  | 402  | 410  | 221  | 247  |

The science-intensive innovative goods, work (services) of organizations as the share in shipped products is decreasing in general across Arctic zone (Table 2). For the analyzed regions, the indicators are extremely uneven. We note a sharp drop in the Murmansk region.

**Table 2.** The science-intensive innovative goods, work (services) of organizations as the share in shipped products [18]

|          | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|----------|------|------|------|------|------|------|
| Arctic zone of Russia | 0,17 | 0,05 | 0,06 | 0,07 | 0,05 | 0,05 |
| MR       | 1,50 | 0,22 | 0,42 | 0,43 | 0,38 | 0,09 |
| YNAD     | 0,02 | 0,05 | 0,02 | 0,01 | 0,01 | 0,01 |
| ChAD     | 0,01 | 0,01 | 0,04 | 0,37 | 0,07 | 0,51 |

Thus, the analysis of official statistical data presented by Rosstat highlights some definite problems with formation of preconditions for Industry 4.0 concept introducing due to the fact that the integrated indicator is stagnating or just slightly growing for all analyzed regions. However, switching of enterprises to Industry 4.0 model needs in radical changes in internal and external digital infrastructure, usage of special software and broadband Internet access in particular. It correlates with declining of indicators of share of innovative and high-tech products in industrial output in analyzed regions with exception for Chukotka Autonomous District which can be explained by low basis for comparing.

5. Conclusions

The study conducted with purpose of investigating the impact of the level of digital infrastructure development on formation of Industry 4.0 in Arctic regions highlights definite problems in the process of regional digitalization. Some important indicators characterizing the level of digital infrastructure development such as the rate of the use of special programs, including for scientific research, for design, for managing of technological processes, automated manufacturing and individual technical tools in 2014-2019 were decreasing. The main focus in all analyzed regions was done on automation of planning, accounting, control and analysis of the main business processes of enterprises, supply chain management, customer relationship management. That results in the not very positive dynamics
of integrated digital infrastructure development indicator which has a tendency to stagnate (Yamalo-
Nenets Autonomous District) or to grow slowly (other three analyzed Arctic regions). Let us formulate
the general conclusions of the study. The formation of Industry 4.0 that requires to combine internal
enterprise’s computerized design and automated machinery with ecommerce and Internet of Things in
one integrated ebusiness system, is looking problematic in current situation.

The main limitation of the study is focus on restricted number of indicators available in official
statistical databases of Russian Statistic Agency. Moreover, these indicators characterize the level of
regional infrastructure development implicitly through real usage of local infrastructure by regional
organizations.

That defines the direction of the future research namely the increasing of list of separate indicators
used for analysis and evaluation of integrated indicator. The perspective way to broaden the scope of
analysis and refine the results is usage experts’ evaluation. It proposes the formulation of questionnaires,
formation of groups of experts competent in regional specifics, organizing interviews and analysis of results received.

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