The northern dimension: The problem of spatial development and the capabilities of online technology

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Abstract. Digital technologies have permeated all aspects of our lives, transforming research, organizational, and business processes as well as the ways suppliers and consumers of goods and services communicate. The level of territorial development in high latitudes, including the Arctic zone of the Russian Federation, is uneven. However, what is common for low-population and remote areas is the lack of units for generating knowledge and scientific and educational potential, which are theoretically necessary for building innovative systems. The presented study provides statistics that characterize the knowledge-generating potential of the Arctic territories of the Russian Federation. The technological capabilities of the 21st century make it possible to find a solution for innovative, efficient development of such territories. The authors propose a structure for multi-agent geographically distributed cooperation between the subdivisions of a single team. The localized part of the team (local agents) identifies the problem and finds agents (the remote part of the team) that can offer a globally competitive technology. The latter generally include competence centers and centers of excellence located in other territories. Then, both parts of the team glocalize the solution. The technical framework of multi-agent geographically distributed cooperation involves using online technology to organize synchronous, real-time messaging via digital information channels. This creates a fundamentally different approach to spatial development design. The online, real-time design process is organized through the interaction between the local agent and the remote agents. The result is the implementation of an efficient territorial development model: development as mastering – management – resources – hierarchy of authority – customization. Efficient operation of the localized part of a geographically distributed system requires an adequate infrastructure. Therefore, the authors aim to optimize the functional completeness of the infrastructure.

1. Introduction
The problems of socio-economic development of remote and low-population areas, aggravated by the climatic conditions in high latitudes in the case of the northern dimension, are civilizational in scale and still remain relevant.

In retrospect, talking about the process of development, there are two possible trajectories, which are fundamentally different. "Development as development implies a new ontology for the territory, radical changes in its internal and external infrastructure, which historically often turn out to be inhumane, environmentally harmful, and immoral. Development as mastering does not involve fundamental ontological transformations, but is rather an expansion of the existing resources and funds as well as the resources and funds of the developed territories..." [1]. Of the theoretically possible models for development as mastering, the economic model is preferable due to its fundamental
characteristic: the economy, as opposed to production, is value-oriented rather than target-oriented [2]. Economic development involves conservation and multiplication of resources during operation. "Economic development is "for good", it ensures that the developed resource and territory remain inexhaustible in their volume and beauty" [1].

As regards the Arctic zone of the Russian Federation (AZRF), it is desirable that economic development would gradually become the major form and content of innovative development programs for these territories. Researchers and experts agree that economic development of territories with extreme living conditions is only possible using innovative methods and special Arctic technologies, which prompts the creation of the Arctic technological platform, which is a set of technologies aimed at effective and safe development of the Arctic. Thus, below we shall focus solely on innovative technological development. However, where technologies intersect with territories and their improvement, it is necessary to structure the process of development as mastering of the existing picture.

The complex problem of the Arctic regions, including the Arctic zone of the Russian Federation (AZRF), is addressed in numerous professional periodicals and monographs. Works [3-9] serve as examples of such publications. The authors substantiate the concept of stability of spatial systems as their ability to maintain their purpose under the destabilizing impact of exogenous and endogenous factors. The proposed interpretation of spatial system stability becomes particularly relevant in the context of changes in the structure and force of such impact, including due to climate change. We must also mention another possible strategy for the development of northern territories, which does not involve intensive industrial development. This strategy, viewed as an alternative to the ones proposed above, can be applied primarily to territories with low population density (less than 1.0 – 0.5 inhabitants per square kilometer). It consists in circumspect reservation and preservation of these territories for future generations.

The spatial aspect of the systematic development of innovations is of fundamental importance. The innovative focus of economic development requires a set of measures that would consider not only the national interests of the country as a whole, but also the interests of its constituent entities. It cannot be limited to a system of cross-sectoral linkages at the macro-level, but instead should be tied to the economic, geographic, ethnic, cultural, and other aspects of the country's territory.

There is an apparent contradiction: on the one hand, the necessity of innovative territorial development in the form of regional (territorial, local) innovation systems is objectively established; on the other hand, it is also objectively confirmed that such remote and sparsely populated areas lack the required structural components, namely, units for generating knowledge, competencies, and training specialists. Table 1 shows the level of scientific and educational potential (STE) of the Arctic territories of the Russian Federation. The STE index is the sum of the indices in columns 3 and 5 recalculated using weight coefficients.\(^1\)

Table 1. The potential of the subsystem for generating knowledge in the Arctic territories (data provided by G.F. Detter, Cand. Sc. (Economics), lead researcher of the Arctic Research Center, Salekhard)

\(^1\) A 0.01 coefficient is applied to the number of university graduates, and a 0.1 coefficient is applied to the number of researchers. Based on the collected data, the authors compile a table and define the relative level of scientific and educational potential as high, good, average, low, or none. The level of the leading region is taken as 100 percent. High STE level is applied to the regions with the integrated index in the range from 75 to 100 percent, good – from 75 to 50 percent, average – from 50 to 25 percent, low – from 25 to 1 percent. Less than 1 percent – none.
It is found that the Arkhangelsk and Murmansk regions have the highest scientific and educational potential. The potential of the Nenets, Yamalo-Nenets, and Chukotka Autonomous Areas and Arctic territories of the Krasnoyarsk region is low. The Komi Republic and the Republic of Sakha (Yakutia), have no scientific and educational potential in their Arctic territories.

If we consider the subsystem for generating knowledge and competencies at the level of a territorial subsystem, it becomes obvious that almost the entire scientific and educational potential is concentrated in the cities of Apatity, Murmansk, Arkhangelsk, to a smaller extent – in Naryan-Mar, Salekhard, Novy Urengoy, Norilsk, and Anadyr, i.e. it has a pronounced focal nature, unevenly distributed across the territory of the AZRF. Hence, the list of AZRF features that affect its economic and innovative development should include targeted placement of knowledge-generating subsystem elements and high differentiation of intellectual potential within the territorial subsystem.

One of the reasons for the specific features of formation and implementation of national and regional innovative policies is the varying degree of the countries’ involvement in Arctic territories. For example, Canada and Russia have various less-developed northern territories along with established industrial, scientific, and educational centers, which stipulates the commodity specialization of Arctic territories and minimizes the functions aimed at the sustainable development of these territories. The socio-economic policy in these regions is limited to serving the interests of the indigenous communities and ensuring normal living conditions, while economic growth and innovative development are confined to old industrial areas with a stable population structure.

In some Arctic countries and territories, this contradiction is solved through cost-intensive establishment of units for generating knowledge, competencies, and training specialists in high
latitudes. Is there any other solution to this contradiction? Below we attempt to show that by using modern communication technologies offered by digital systems it is possible and necessary to create spatial collaborations that would provide the mobile and target sum of competencies required for the implementation of the functions of regional innovation systems.

The lack of scientific and educational potential in a particular locality is not a reason for abandoning the innovative way of development, i.e. the creation of a local innovation system. Innovative development includes not only the process of creating innovations, but also their implementation and achievement of significant commercial results. Therefore, regions with an underdeveloped scientific and educational potential can borrow innovations from other regions and develop a joint educational and research base with traditional competence centers in the region [3].

2. Main part

More recently, research and methodological developments have been embarked on the digital transformation of the whole range of processes – from economic, communication, and technological to business processes – which should eventually lead to the transition from the "analog" to the "digital" economy. It can be argued that overall practical implementation of such a transformation has become possible due to the exponential growth of the performance of computing devices and microminiaturization of their components over the past 20-30 years. Removal of the limitations of "slow", bulky microprocessors has made it possible to use the developments in the theory of digital control systems and the theory of construction of communication channels in a new way.

Within this broad area, we shall limit our research to the direction that was declared above, namely the construction and development of innovative systems for the territories that do not have their own knowledge-generating unit and scientific and educational potential. This provides the possibility in principle of changing the configuration of local innovation systems. The required functional completeness can be achieved by means of communication messages in the network information space for synchronized, real-time exchange of information with remote competence centers and centers of excellence, while 3G, 4G, and 5G information channels would provide an online interface for the digital economy. Based on the emerging "digital" opportunities, the general methodological approach to local innovation systems can be represented by the following sequence of steps: building an integrated digital platform with support for subject-to-subject interactions ---> identifying the localized problem ---> finding a global technology ---> glocalizing a solution. The invariant core of the integrated digital platform comprises the tools for the formation of a database and knowledge base of globally competitive technologies in a big data environment for the identified local problem.

This approach is implemented in the form of a multi-agent management system for geographically distributed teams (Figure 1).
Figure 1. Multi-agent geographically distributed system for the interaction between the agent that identifies the problem and glocalizes a solution in a local territory (AIPGS) with the agents that provide solutions (APS1…APSn)

In this context, a fundamentally different approach to spatial development design is formed:
- no need to wait for a peddler or traveling salesman of finished goods;
- the problem should be identified from within, by those located in the territory;
- it should be described (verbally, then formally), formulating technical requirements followed by a statement(-s) of work;
- finding and glocalizing a globally competitive solution on an integrated digital platform.

The entire online, real-time design process comes down to the interaction of the AIPGS agent, which identifies problems and glocalizes solutions in a local territory, with APSi agents (centers of excellence and competence centers). Thus, an efficient territorial development model is implemented: development as mastering – management – resources – hierarchy of authority – customization.

Efficient operation of the localized part of a geographically distributed system requires an adequate infrastructure.

The innovation infrastructure (II) is an open, complex, dynamic, organizational and technological system. The functional completeness of the II F is characterized by its capability to perform all necessary functions to ensure efficient operation of the local AIPGS agent:

$$F = \sum_{i=1}^{n} P_i * U_i$$

where \( i \) is the examined II subsystem, \( i = 1, 2, ..., n \), \( n \) is the number of subsystems of a functionally complete II; \( U_i \) is the level of preparedness of the \( i \) subsystem to perform its functions.
$f_i$, $U_i = [0,1]$; $P_i$ is the indicator of presence of the $i$ subsystem in the II, $P_i = 0$ when there is no $i$ subsystem, otherwise $P_i = 1$; $f_i$ is the functional completeness of the $i$ subsystem.

For each particular case of implementation, it is advisable to set the level of minimum acceptable functional completeness of the II and to normalize the minimum number of infrastructure subsystems $\min P_i$ and the minimum functional completeness level $\min f_i$ for each of them. As the II develops, the starting levels of minimum functional completeness will increase.

This problem is formalized as an optimization problem as follows. It is necessary to find the values of variables $B_{ik}$, which deliver the extremum to the selected criterion $F = (A_{ik}, A_{ik}) \rightarrow extr$ when the many analytically defined constraints and conditions are met, where: $B_{ik} \in \{0,1\}$; $B_{ik} = 1$, if the $k$ scenario is realized for the $i$ subsystem, otherwise $B_{ik} = 0$; $A_{ik}$ are the internal funds of the $i$ subsystem in the realization of the $k$ scenario; $A_{ik}$ are the additional funds of the $i$ subsystem in the realization of the $k$ scenario; $CF_{ik} = R_{ik} - C_{ik}$ is the cash flow balance of the $i$ subsystem in the realization of the $k$ scenario; $R_{ik}$ is the anticipated revenue; $C_{ik}$ is the estimated projection; $i = 1, 2, ..., n$ is the II subsystem index; $k = 1, 2, ..., K_i$ is the development scenario index of the $i$ subsystem; $K_i$ is the multitude of development scenarios of the $i$ subsystem.

Various integrated performance indicators, such as the indicator of economic efficiency of the analyzed development scenario calculated on the basis of net present value (NPV), can be used as a criterion.

In this case, the optimization problem takes the following form:

$$\sum_{i=1}^{n} \sum_{k=1}^{K_i} NPV_{ik} * B_{ik} \rightarrow \max$$

$$\sum_{i=1}^{n} \sum_{k=1}^{K_i} (A_{ik} + A_{ik}) * B_{ik} \leq A$$

$$\sum_{k=1}^{K_i} B_{ik} = 1, \quad i = 1, 2, ..., n$$

$$\sum_{i=1}^{n} \sum_{k=1}^{K_i} CF_{ik} * B_{ik} \geq 0$$

where $A$ is the maximum limit of investment in subsystem development.

3. Conclusion
The described development methodology can provide infrastructure support for the interaction between agents in the process of identifying the problem, finding a globally competitive solution, and glocalizing it in the territory.

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