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Towards the development of the information system for the long-term planning of infrastructure in the Artic zone of the Russian Federation in the context of climate change

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Abstract. The article presents the rationale for the creation of an information system for long-term planning of infrastructure development in the Arctic in the context of global climate change. The system will be focused on supporting decision-making in the interests of the effective infrastructure development of the Arctic zone of the Russian Federation - the country's key macro-region, which plays a significant role in the socio-economic development of Russia.

1. Introduction

The strategic planning documents for the development of the Arctic zone of the Russian Federation (hereinafter - the Russian Arctic) consistently hold the thesis that economic development and livelihoods in the macroregion are closely related to the oceans, maritime transport, and reliable operation of the Northern Sea Route. Most of the settlements in the Russian Arctic are located on the coast of the Arctic seas or in its immediate vicinity, as well as in the lower parts of the rivers flowing into the Arctic Ocean [1]. Disruption of the work of maritime transport, late delivery of fuel, food and other goods to the Arctic due to the short periods of Arctic navigation leads to significant social and economic consequences, up to a threat to the lives of the population living and working here. Climate change, a shift in economic activity in the shelf zone of the Arctic seas leads to an increasing role of the marine factor in the economic and social development of the Russian Arctic [2]. The coastal location of the macroregion differentiate it from the "continental" parts of the North of Russia and determines the uniqueness of the regional economic complexes formed here [3].

At the same time, the fragility and vulnerability of the Arctic environment require the development of the resource efficient technologies that do not cause irreversible environmental damage during the exploitation of the rich resources of the macroregion. Modern environmentally compatible technologies and highly qualified personnel with competence in the field of environmental safety and sustainable development will be required.

The Arctic region is undergoing pronounced climatic changes, which affect all components of the environment, including aquatic ecosystems, the water balance of river basins, cryogenic processes, etc. [4]. The state and development of various types of infrastructure in the Arctic are subject to natural risks associated with adverse hydrological processes: floods, congestion, and blockages, ice formation, etc. One of the main factors affecting the processes of flow formation is permafrost [5]. During the recession of permafrost, water exchange increases between surface and groundwater, groundwater flow, including the movement of water in soils, supra-permafrost, and sub-permafrost. Direct and indirect evidence of such changes is observed in various cold regions of the world [6, 7]. Different

types of models are applied to the modeling of the influence of hydrometeorological, hydrological, cryolithological, ecological and other parameters on certain types of infrastructure in the Arctic [8-12].
Today, geo-information systems (GIS) provide significant assistance for decision-making. "Dewberry" has developed the TerraGo GeoPDF GIS application, which allows the user to get data from the Hurricane Evacuation Studies GIS to everyone involved in emergency response, including users with mobile devices. The new geo-information tool uses data from the monitoring and analysis of hazardous phenomena. The TerraGo GeoPDF performs an important function: it transfers data processed by the geographic information system directly to field workers, to other individuals and organizations who may not have access to GIS capabilities. In practice, the capabilities of TerraGo GeoPDF allow users to receive geographic data using mobile devices, as well as exchange maps and snapshots. GeoPDF allows compiling several layers in one PDF format, inserting coordinates, hyperlinks and viewing various types of visual information.
The US Department of the Interior has launched a GIS called Interior Geospatial Emergency Management System (IGEMS), which is designed to assist federal, regional, and local governments in making decisions in the state of emergency. Data are available to the public. GIS allows continuous monitoring and analysis of the development of natural hazards. Reference data and base maps are associated with real time information. The IGEMS web service for monitoring events can run on smartphones and has three basic maps: administrative, street map and satellite. Various information layers allow seeing on the map information about earthquakes, floods, hurricanes, the boundaries of forest fires, volcanic eruption zones, etc. The strength of the hazards is displayed both in relative numbers and in color. In addition to increasing the effectiveness of emergency response, such systems help prevent public panic. XtremeGIS uses the AccuWeather meteorological web service information, which allows monitoring the movement of storms and assesses precipitation in specific regions. XtremeGIS software also uses ArcGIS Online geoservice and Esri analytic tool. As a result, XtremeGIS can indicate which office buildings, production sites, retail logistics centers, and transportation hubs could be threatened by a storm. This allows taking timely measures to evacuate staff and protect property.
The international insurance company Guy Carpenter & Company launched the GC CAT-VIEWSM service, which uses geospatial analytical tools to assess the damage caused by natural disasters, such as floods. CAT-VIEWSM service is designed for specialized analysis of data obtained using satellites, manned and unmanned aircraft platforms, social networks, reports of field workers and other sources. The system is able to analyze images, compare data for different periods and determine the damage caused by the elements.
The Ministry of the Interior of Japan uses big data analytics to provide timely information on evacuation during disasters. Such a system more effectively notifies residents of evacuation plans during environmental disasters, such as floods and landslides. The system collects statistics on various PALs, as well as user data from social networks. This data allows for providing more accurate and personalized information based on the location of users and the level of danger. During major disasters such as tsunamis and earthquakes, rescuers use geolocation information from smartphones and other mobile devices during the evacuation. The information is disseminated both through traditional notification channels (radio and television), and through the Internet, mobile networks. Extreme natural conditions are typical for the Arctic zone of the Russian Federation: low temperatures throughout the year, long polar night and a long polar day, frequent magnetic storms, strong winds and blizzards, dense fogs, rapid climate changes in recent decades. Natural extremality is aggravated by the negative impact of socio-economic factors — transport inaccessibility, high production costs, and cost of living, the small size of the economy and tendencies to its monopolization, isolation, and dispersion of settlement [13].
From a social point of view, it is essential that in the Arctic there are also factors of natural discomfort - a deficit of solar radiation and a disturbance of the daily rhythms that are usual for non-Arctic residents - the alternation of day and night. The cycle “polar day - polar night” not only affects the state of health and human performance but also causes additional costs to cover any economic activity [14].

The strategic planning documents for the socio-economic development of the Russian Arctic and national security approved by the President of the Russian Federation and the Government of the Russian Federation are aimed at increasing Russia's presence in the Arctic region and intensifying economic activity. The tasks of full-scale infrastructure development are set, not only updating and upgrading existing facilities but also creating new ones [15]. At the same time, the life cycle of infrastructure facilities is decades, and in some cases hundreds of years (ports, railways, airports, etc.), which places special demands on the forecast and planning horizons [16]. In turn, the development of infrastructure, due to "feedback", affects the environment, which requires consideration when making management decisions.

In order to reduce economic costs, increase the sustainability of the infrastructure framework of the macroregion in front of possible negative climate processes, it is now necessary to take appropriate response measures and adapt to the observed and predicted climate changes. To solve both of these tasks it is necessary to integrate programs of socio-economic development of the regions and sectors of the economy of the Russian Arctic. Climate change is not only a scientific or ecological problem but to a much greater degree economic. Adaptation measures have a direct impact on the development of energy, agriculture, forestry and other sectors of the economy, affecting international trade in energy resources and technologies. Therefore, solving this problem directly affects the socio-economic and political interests of the Arctic countries.

In this regard, tasks related to linking environmental indicators with indicators of infrastructure development at the macroregional (Arctic zone of the Russian Federation) scale become extremely important [17]. Hypothetically, there are 2 options for their possible solutions:

1) inertial - in the framework of existing national and global information systems and networks;

2) active (target) - the creation of an automated system to support the infrastructure development in the extreme environmental conditions of the Arctic.

The system analysis of the current state of information support for the development of the Arctic allows us to conclude the following:

- information systems and networks in this area are in most cases fragmented, and information resources of these systems and networks are not properly systematized and not unified in terms of their recording formats;
- decision makers involved in the planning of the development of infrastructure in the Russian Arctic often do not have access to integrated, complete and accurate information about environmental parameters and long-term forecasts of climate change in the Arctic;
- standards (protocols) of informational interdepartmental interaction of existing and newly created information systems and networks are not fully developed;
- competent distributed user access to departmental paper and electronic information resources in this area is significantly limited in access time (calculated in days);
- many relevant information resources are provided exclusively on a fee basis;
- the completeness and relevance of information resources in the studied area do not fully meet the requirements of the modern public administration system.

These circumstances impose significant restrictions on the implementation of the first option. Thus, today it is extremely important to create an automated system to support the activities of the industrial and social infrastructure in the difficult climatic conditions of the Arctic.

2. Methodology for creating an information system for planning of the development of infrastructure along the Northern Sea Route in the context of global climate change

During long-term forecasting of the socio-economic development of the Arctic zone of the Russian Federation, it is advisable to rank the indicators of the state of the environment according to the degree of their impact on various types of industrial and social infrastructure [18]. The indicators obtained after aggregation may become input parameters for modeling and creating an automated system to support the production and social infrastructure in the difficult climatic conditions of the Arctic. Methodologically, the creation and implementation of an information system model imply 8 steps or iterations in accordance with Figures 1 and 2.

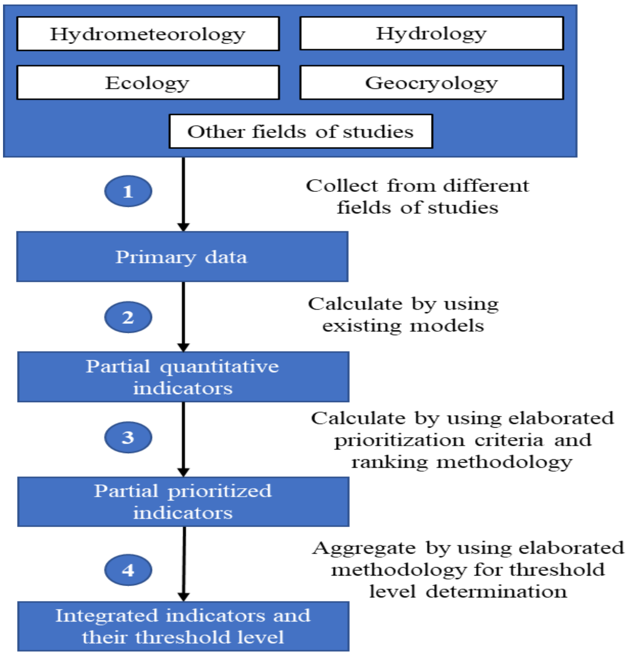

Figure 1.. Methodology and algorithm for model input parameters calculation

The various parameters of the environment affect different types of infrastructure to a different degree. The same parameter will be critical for one type of the infrastructure, but neutral for another.
Meanwhile, all natural and climatic parameters should have common, universal properties that allow assessing their complex impact on infrastructure development as a whole. These properties include the need to take into account the specifics of the macro-region, on the one hand, and the degree of damage that a particular climatic phenomenon can cause to the infrastructure, on the other. In turn, the specific conditions of the Arctic place special requirements on specialized construction materials used in the construction of infrastructure in the so-called northern design adapted to the harsh Arctic climate, architectural solutions, etc.

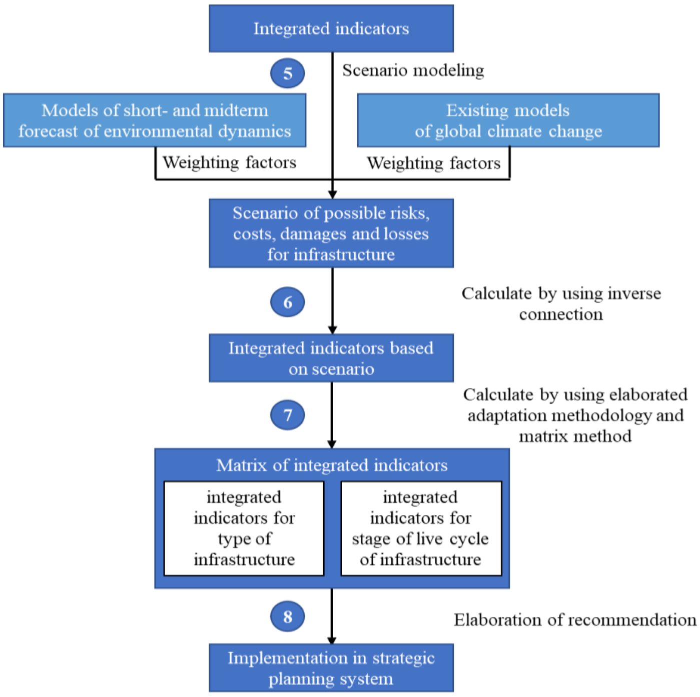

Figure 2. Schematic diagram of the model and its implementation algorithm

Thus, the following triad can serve as criteria for ranking indicators of the state of the natural environment according to the degree of their influence on various types of industrial and social infrastructure:

1) a criterion that takes into account the specifics of the Arctic climatic conditions (briefly: extremity);

2) a criterion that takes into account the specifics of the long-term development of infrastructure in the Arctic (briefly: localization);

3) a criterion that takes into account an assessment of the extent and degree of possible damage to the complex development of infrastructure from a particular climatic phenomenon (briefly: consequences).

Visually, such a triad can be represented in accordance with Figure 3.

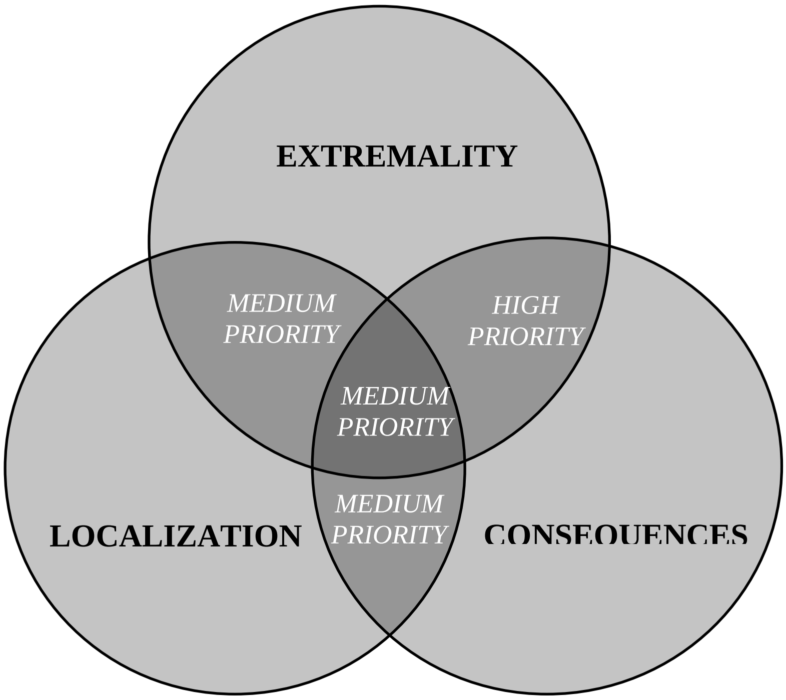

Figure 3. Visualization of criteria for ranking indicators

As a result of this project, a qualitatively new level of information support for the implementation of Russian state policy in the Arctic can be provided. In turn, the technical and technological solutions adopted as part of the creation of the system have a high degree of commercialization, since they automate operations that can significantly reduce costs in the construction and operation of infrastructure facilities, as well as reduce potential damage caused by the occurrence of dangerous natural phenomena and emergency situations. In general, the results of the project implementation are characterized by a significant multiplicative effect, which is largely determined by the complexity and universality of the proposed approaches. The implementation of the proposed recommendations will ensure the achievement of the strategic goals and priorities of the state policy of the Russian Federation in the Arctic, related to the building up of technological potential and the introduction of advanced technologies into the economy and social sphere of the macroregion.

3. Conclusion

Recently, there has been an exponential growth of decision support systems in various industries and spheres of life. Such systems are becoming more efficient, reliable and popular, including in public administration processes, including strategic planning [19]. There are dozens of information systems and networks in individual areas of knowledge (primarily hydrometeorology, hydrology, permafrost, ecology, etc.). They are developed at the departmental, national, or global (created under the auspices of international organizations) levels. Information resources circulating in these systems are fragmented (in frequency, coverage, detail, comparability, etc.), in most cases not aggregated, not adapted to be taken into account when forecasting long-term infrastructure development. The information systems and networks themselves are weakly interconnected. There is no uniform data format. On the other hand, industry information systems and networks are functioning and developing. The tasks of linking environmental indicators with indicators of infrastructure development at the macroregional (Arctic zone of the Russian Federation) scale in the interests of long-term forecasting were set and resolved non-systemically and irregularly. It should be noted that the object of research itself - the Arctic zone of the Russian Federation - was outlined only in 2014 with the approval of the Decree of the President of the Russian Federation dated May 2, 2014 No. 296 "On land territories of the Arctic zone of the Russian Federation" (as amended on June 27, 2017 year number 287) [20]. Thus, the implementation of the proposed model will enhance the level of information support for the implementation of Russian state policy in the Arctic, solving scientific, technical, economic, strategic and other tasks in the field of research, development of resources of the Russian Arctic.

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