Determination of environmental indicators critical values depending on their impact on various types of infrastructure in harsh climate

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Abstract. The article is devoted to the methods and algorithm for ranking of environmental indicators depending on their impact on infrastructure for long-term planning of infrastructure development in the Arctic zone of the Russian Federation in the context of global climate change. The article presents the environmental indicators critical values database focused on supporting decision-making as well.

1. Introduction

The strategic planning documents for the development of the Arctic zone of the Russian Federation (AZRF) such as the Fundamentals of the state policy of the Russian Federation in the Arctic region [1], and the Strategy of development of the Arctic zone of the Russian Federation [2] emphasize the specifics of the Arctic climatic conditions. In accordance with these documents, the specifics of the AZRF include:

- extreme natural and climatic conditions, including permanent ice cover or drifting ice in the Arctic seas;
- focal character of industrial and economic development of territories;
- low population density;
- remoteness from the main industrial centers;
- high resource intensity and dependence of economic activity and social life on the supply of fuel, food and essential goods from other regions of Russia;
- low stability of ecological systems, which determine the biological balance and climate of the Earth, and their dependence on even minor anthropogenic impacts.

The Arctic zone of the Russian Federation is characterized by extreme natural conditions. Among them are low temperatures throughout the year, a long polar night and a long polar day, frequent magnetic storms, strong winds and blizzards, dense fogs, monotonous Arctic deserts and tundras, permafrost, climate change. From a social point of view, it is significant that in the Arctic region there are factors of natural discomfort as well. Among them is a shortage of solar radiation. The cycle "polar day and polar night" not only affects the health and performance of a person, but also causes additional costs for any kind of economic activity.

By taking into account the specifics of long-term infrastructure development in the Arctic region, it should be noted that the natural extremity of the macroregion is enhanced by the negative impact of social and economic factors. Among them are transport inaccessibility, high production costs and cost of living, small size of the economy. At the same time, it is necessary to take into account a number of other characteristic features that strikingly distinguish the AZRF from other regions of the Russian
Federation. Among them are the low population density and high dispersion of the settlement system, remoteness from the main industrial centers and focal development of the territory. Thus, the spatial development of the AZRF clearly distinguishes a group of old industrial regions such as Murmansk and Arkhangelsk regions, municipal districts of the Republic of Karelia and Krasnoyarsk region (more precisely Norilsk industrial and Taimyr municipal areas), and the regions of new large-scale industrial development: Nenets, Yamal-Nenets, Chukotka autonomous districts, Arctic districts of the Republic of Sakha (Yakutia).

The main factors of the Northern rise in price [3] include:
- increased labor cost related to appreciation of life, scarcity of trained personnel, and payments for discomfort of climatic conditions;
- the increased cost of fixed assets in the so-called Northern execution and their accelerated wear;
- infrastructure costs, including increased transport costs, as well as the costs of various types of communication transactions;
- increased environmental costs;
- increased costs associated with social obligations, underdevelopment of municipal infrastructure [4-7].

There are other factors that significantly complicate economic activity, which are determined by the rise in price, for example:
- increased risks of emergencies and costs of their prevention or elimination [8-9];
- a significant number of single-industry and single-resource cities and towns established in the industrial period of economic development of the AZRF [10].

The need to overcome the high costs and specific factors of the Northern rise in price causes the legislative consolidation of specialized, targeted measures of economic regulation and stimulation. These measures should take into account a lot of peculiarities of economic conditions, priorities of social and economic development [11], as well as restrictions imposed on climatic, social, cultural, environmental, technological and other reasons [12].

At the same time, the main obstacle to sustainable social and economic growth of the AZRF is the underdevelopment of infrastructure, its marine and continental components. This problem prevents the development of the natural resource base, not only in the Arctic region, but also in the Urals, Siberia, Perm Krai and other territories, which are specialized in the extraction of mineral and energy resources. The infrastructure of the AZRF is unbalanced and insufficient for the realization of global competitive advantages of the macroregion. These advantages are connected with the geographical position of the AZRF. Despite all technical difficulties of sailing in the High North geographically the North Sea Route (NSR) is the shortest route connecting Europe with the Far East, Asia and the Western part of North America. The use of the NSR can reduce the length of the reference route between Hamburg and Yokohama 2.3 times when sailing around Africa and 1.4 times in comparison with the passage through the Suez Canal [13]. Thus, infrastructure development is a key factor to the social and economic growth of the AZRF [14]. It demands special decisions in informational and communicational spheres. The most effective instruments of the solution of the problems are connected the elaboration and realization of the long-term forecast of infrastructure development and its implementation in the system of public administration and strategic planning.

Another problem of infrastructure development in the AZRF is connected with the unpreparedness of all types of infrastructure to the global climate change. The negative effects of climate change deal with impacts on ecosystems, environment, public health and traditional lifestyle of the local population. The positive effects include the decrease of the heating expenditures, increased opportunities for agriculture and forestry, the extension of the navigation along the NSR, as well as increased access to the marine living and mineral resources.

The warming of the AZRF will increase the duration of ice-free navigation, opening the possibility of using vessels with lower ice reinforcement or without it. This trend is projected on coastal shipping as well. River–sea shipping also will be increased. It is possible to forecast an increase in the duration of navigation time as well as in the vehicle’s velocity.
2. Methods and algorithm for ranking of environmental indicators depending on their impact on infrastructure

The proposed algorithm for ranking of environmental indicators depending on their impact on various types of industrial and social infrastructure can be visualized according to the figure 1. It used the following triad as criteria for ranking:

- criterion of extremity, which takes into account the specifics of Arctic harsh climate;
- criterion of localization, which takes into account the specifics of the long-term development of infrastructure in the AZRF;
- criterion of consequences, which takes into account an assessment of the extent and degree of possible damage to the integral development of infrastructure from a particular climatic phenomenon.

![Diagram of the algorithm for ranking of environmental indicators](attachment:image.png)
Figure 1. Model algorithm for ranking of environmental indicators depending on their impact on infrastructure.

3. Structure of the environmental indicators critical values database
The database of environmental indicators critical values depending on the rate of their impact on various types of infrastructure in the territories of the AZRF was calculated by the authors. It was systematized in an original way for use in monitoring and forecasting the impact of natural environment on infrastructure.

The database was structured according to the following main groups of information presentation.

3.1. Information is presented in the context of spatial development of the AZRF in accordance with the Decree of the President of the Russian Federation dated 02.05.2014 № 296 (as amended by the Decree of the President of the Russian Federation dated 27.06.2017 № 287), including:
- name(s) and initials;
- territory of the Murmansk region;
- territory of the Nenets Autonomous district;
- territory of the Chukotka Autonomous district;
- territory of Yamalo-Nenets Autonomous district;
- territory of municipalities “Belomorsky municipal district”, “Loukhsky municipal district” and “Kemsky municipal district” of the Republic of Karelia;
- territory of the municipality of the city district “Vorkuta” of the Republic of Komi;
- territory of Allaikhovsky ulus (district), Anabar national (Dolgan-Evenki) ulus (district), Bulun ulus (district), Nizhnekolymsky district, Ust-Yan ulus (district) of the Republic of Sakha (Yakutia);
- urban district of Norilsk, Taimyr Dolgan-Nenets municipal district, Turukhansk district of the Krasnoyarsk territory;
- territory of municipalities “the City of Arkhangelsk”, “Mezensky municipal district”, “Novaya Zemlya”, “the City of Novodvinsk”, “Onezhsky municipal district”, “Primorsky municipal district”, “Severodvinsk” of the Arkhangelsk region.

3.2. Environmental indicators critical values are presented in the following categories.
The main parameters of the environment, including:
- Hydrometeorology, including air temperature, land surface temperature, wind, humidity, precipitation, snow cover, aerial phenomena, glaze-ice and rime formations, atmospheric pressure, integrated meteorological indicators.
- b) Hydrology, including water level, duty of water, flowing storage, unit runoff rate, runoff depth, ice phenomena (drift ice, freeze-up).
- Geocryology, including depth of ground / soil freezing, the maximum freezing level, depth of permafrost (cryogenic) processes, the average annual temperature of permafrost soils, the number of days with the transition of air temperature through 0 centigrade, soil temperature at a depth of 5 cm, 10 cm, 15 cm, 20 cm, dangerous phenomena associated with permafrost.
- Ecology, including chlorophyll-a concentration in the Arctic seas, normalized difference vegetation index (NDVI), criteria for environmental assessment of territories to identify areas of environmental emergency and environmental disaster zones, approved by the Ministry of Natural Resources and Ecology of the Russian Federation on November 30, 1992 (demographic and health criteria of the health status of the population, maximum one-time concentrations of air pollution).

The unification of indicators for 3 main groups was made by the nature of the manifestation for each of the parameters, including:
- extremes/averages and deviations from them;
amplitude;
• duration / frequency, including continuous duration.

According to the rank depending on their impact on infrastructure they are divided into 5 groups (zones).
For each zone minimum and maximum thresholds requirement was calculated and presented in the database:
• within normal range (green area);
• slight deviation from normal range (yellow zone);
• deviations from the normal range (orange zone);
• adverse phenomenon (red zone);
• dangerous phenomenon (black zone).

According to the scope of further application, the parameters are presented in 3 main groups:
• monitoring;
• short-and medium-term forecast;
• long - term forecast of climate change.

3.3. A separate database array, designed in accordance with the above in the PP.1-2 structural elements, represents weighing coefficient of environmental indicators critical values for the following types of infrastructure:
• transport infrastructure, including: railway transport; road transport; air transport; maritime transport; inland water transport;
• energy infrastructure, including linear as well as stationary objects;
• social infrastructure, including educational, health, cultural, physical culture and sports infrastructure.

4. Conclusion
The database contains the parameters connected with minimum and maximum critical threshold values of environmental indicators. These indicators were structured according to the degree of impact on the infrastructure in 5 groups (within the norm, minor deviations from the norm, deviations from the norm, adverse events, dangerous phenomena). The database represents more than 300 indicators. They are characterizing the main parameters of the environment in the field of hydrometeorology, hydrology, permafrost studies and ecology (for example, air temperature, wind speed, atmospheric phenomena, etc.). The database contains the weight coefficients for the critical values of environmental indicators by types and subspecies of industrial and social infrastructure. The data were structured in the context of the territories of the AZRF.

The field of application of the methods is connected with assessment of the impact of environmental parameters by their critical values on different types of infrastructure in monitoring, short-term and medium-term forecasting, as well as long-term forecasting the context of global climate change.

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