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Point of View

Economic Assessment of Permafrost Degradation Effects on Healthcare Facilities in the Russian Arctic

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Abstract—The methodology and results of economic assessment and forecasting of the consequences of the most negative global climate change IPCC scenario (RCP 8.5) representative for the conditions of the Russian Arctic in the form of thawing and degradation of permafrost for healthcare facilities in eight Arctic regions of the Russian Federation are discussed. It is shown that the additional costs associated with these consequences for the maintenance and restoration of healthcare facilities in 2021–2050 may amount to about ₽60 bln, or about ₽2 bln per year (in 2021 prices) at the average rate of permafrost degradation and increase thawing depth, rising to ₽219 bln (₽7.5 bln annually) under the maximum expected damage.

Keywords: Russian Arctic, climate change, permafrost, thawing, degradation, healthcare facilities, risks.
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This article continues the series of the authors' publications focused on the economic assessment and forecast of the consequences of global climatic changes and impacts of permafrost thawing and degradation for the sustainable functioning of sectors and spheres of the Russian Arctic economy [1–3], which are critical for the life of this macroregion and, given its strategic importance, for the country's national security as a whole [4, 5]. Such assessments and forecasts have become an important step towards the adaptation of the population and the economy to climate change [6, 7], the equal importance of which with measures to reduce climate risks to socioeconomic development is emphasized in the Paris Agreement on climate, and Russia's special role in seeking an effective response to new climatic challenges, in the message of the country's president to the Federal Assembly of the Russian Federation in April 2021 [8].

Permafrost degradation will have a negative impact on the lives of 3.6 million people in Russia's Arctic macroregion by 2050 [9]. According to the results of recent studies by our colleagues [10, 11], the expected damage from permafrost degradation for municipalities in the Arctic zone of the Russian Federation by the middle of the century may amount to ₽5–₽7 trillion or more. These estimates, reflecting the scale of socioeconomic risks of the ongoing processes, calculations and assessments of the expected damage in key sectors and spheres of the economy of the macroregion under consideration are relevant, which is important for the development and justification of measures to reduce possible risks. In [2, 3], the authors calculated and estimated the transport infrastructure and the housing sector (at replacement cost) affected by the permafrost degradation. According to the data obtained, the total additional costs for mitigation of damage for the years 2020–2050 may be ₽1.4–₽4.4 trillion, or ₽48–₽145 billion in average annual terms. This is equivalent to 0.4–1.2% of the total gross regional product (GRP) of 2018 in eight subjects of the Russian Federation in which permafrost occupies a significant part of the economically developed space: the Republics of Komi and Sakha (Yakutia); Nenets, Yamalo-Nenets, Khanty–Mansi, and Chukotka Autonomous Okrugs (AOs); Krasnoyarsk Krai; and Magadan Oblast.

This article attempts to assess the expected damage to another critical sector of the Russian Arctic econ-

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omy, healthcare, more precisely, to its infrastructure facilities, the role of which in the sustainable development and national security of the country has increased due to the consequences of the 2020–2021 coronavirus pandemic, as well as due to negative demographic trends, including those in the Arctic macroregion [12–18]. At the same time, in the context of analyzing the risks caused by permafrost thawing and degradation, it is important to calculate not only direct damage to the stability of these facilities, but also—probably to an even greater extent—indirect damage associated with a decrease in the availability of medical services for the population of the Arctic, an increase in the waiting time for admission and transportation of patients to hospitals and medical centers (planned and emergency hospitalizations), and an increase in the load on medical institutions due to unscheduled repairs of buildings and infrastructure, as well as deformation and destruction due to permafrost thawing and degradation. The indirect damage may be many times greater than the direct damage and the cost of restoring facilities. Nevertheless, the focus of this work is assessment of the direct damage, which can be clearly defined and calculated in monetary terms.

ECONOMIC CHARACTERISTICS OF THE HEALTHCARE SYSTEM IN THE ARCTIC MACROREGION

The state healthcare system of the territories analyzed includes medical inpatient facilities (hospitals), an outpatient-polyclinic network (polyclinics and feldsher–obstetric stations), and emergency medical services (ambulance stations and medical aviation). In the course of the reforms of the past 10–15 years, aimed at the so-called optimization of the network of medical institutions and the number of medical personnel, the number of hospitals in eight Arctic regions of the Russian Federation in the period 2005–2018 decreased by 57%, and the outpatient clinic network, by 25%, which is significantly higher than the national indicators of 44 and 7%, respectively (Table 1).

In fairness, it should be noted that not all transformations led to the actual liquidation of institutions, since many reforms often involved legal reorganization (creation of branches, change of status, etc.). This, in particular, is evidenced by the data on the number of visits to medical institutions per shift, which has changed insignificantly over the period under review (see Table 1). The calculations presented below show that many hospitals, polyclinics, feldsher–obstetric stations, ambulance stations, and other medical institutions were included in larger centers, which was reflected in statistical records as a decrease in the number of facilities. In addition, almost every settlement of the regions studied has an institution that provides medical care: settlements from 300 to 800 residents have a feldsher–obstetric center, which, as a rule, is part of the central district hospitals of the municipality; and larger settlements (800–3000 inhabitants) have polyclinics or, in some cases, local hospitals. However, this does not exclude overcoming great difficulties in obtaining timely and high-quality medical care that occurs among residents of remote and hard-to-reach areas due to the liquidation of medical institutions there [20, 21].

Another important characteristic of the economic situation in the field of health care in the Arctic regions is the organization and amount of funding for medical institutions. Their financing system is two-channel. Today, about half of the funds are allocated by regional budgets, the remaining resources are transferred within the framework of compulsory medical insurance (CMI) through the territorial CMI funds, while in 2005 the bulk (about 90%) of expenditures was financed from regional budgets [19].

Analysis of the dynamics of financing of healthcare institutions indicates its decline in real terms: if in the period 2005–2013, the growth rate of the expenditure side was almost twice the rate of inflation growth, then in the years 2013–2018, this indicator dropped significantly (Table 2). This confirms the thesis that the reforms of the healthcare system, started in 2010–2013, were aimed, among other things, at reducing the growth rate of financing for the industry. Taking into account the fact that part of the costs in the structure of healthcare expenditures is directed to the salaries of medical personnel, which are regularly indexed to the inflation rate, in the long term, the continuation of this trend would mean a relative increase in the share of wages while reducing the share of investments in infrastructure, and, accordingly, limiting additional expenses for the maintenance and restoration of healthcare facilities affected by permafrost thawing and degradation.

METHODOLOGICAL APPROACHES TO ECONOMIC ASSESSMENT OF PERMAFROST DEGRADATION RISKS

The methodological approach to assessing direct damage to healthcare facilities from permafrost thawing and degradation is largely similar to the previously developed methodology for assessing risks for the residential sector [3]. For the economic and climate model of predicting the expected damage to healthcare facilities, the same geotechnical model for assessing the state and stability of permafrost for the long term, the quantitative indicators of facilities built on these soils, and the actual cost of construction of new healthcare facilities is used. At the same time, the adaptation of the mentioned methodology required significant modifications.

First, the calculations used the object-by-object approach due to the fact that the state statistics do not contain data on the total area of healthcare facilities.

Table 1. Functioning of medical institutions in Russia and regions of the Russian Arctic

Regions	Medical institutions and their indicators	2005	2010	2018
Russian Federation	Hospitals			
	Number of institutions (units)	9479	6308	5257
	Number of visits per shift, thous.	1575.4	1339.5	1172.8
	Outpatient network			
	Number of institutions (units)	21783	15732	20228
	Number of visits per shift, thous.	3637.9	3685.1	3997.8
Komi Republic	Hospitals			
	Number of institutions (units)	98	60	50
	Number of visits per shift, thous.	11.1	10.0	8.3
	Outpatient network			
	Number of institutions (units)	229	123	212
	Number of visits per shift, thous.	33.1	33.1	33.9
Nenets AO	Hospitals			
	Number of institutions (units)	9	9	2
	Number of visits per shift, thous.	0.5	0.5	0.4
	Outpatient network			
	Number of institutions (units)	17	22	9
	Number of visits per shift, thous.	0.9	1.1	1.2
Khanty–Mansi AO	Hospitals			
	Number of institutions (units)	92	90	56
	Number of visits per shift, thous.	14.7	12.9	12.5
	Outpatient network			
	Number of institutions (units)	223	181	186
	Number of visits per shift, thous.	39.3	39.0	40.1
Yamalo-Nenets AO	Hospitals			
	Number of institutions (units)	47	28	22
	Number of visits per shift, thous.	6.0	5.2	4.2
	Outpatient network			
	Number of institutions (units)	102	40	86
	Number of visits per shift, thous.	12.6	10.8	13.3

Table 1. (Contd.)

Regions	Medical institutions and their indicators	2005	2010	2018
Krasnoyarsk Krai	Hospitals			
	Number of institutions (units)	249	146	123
	Number of visits per shift, thous.	32.6	28.9	23.3
	Outpatient network			
	Number of institutions (units)	589	483	573
	Number of visits per shift, thous.	88.8	85.3	93.2
Republic of Sakha (Yakutia)	Hospitals			
	Number of institutions (units)	287	65	62
	Number of visits per shift, thous.	14.6	11.0	9.4
	Outpatient network			
	Number of institutions (units)	362	96	107
	Number of visits per shift, thous.	26.0	25.9	28.5
Magadan Oblast	Hospitals			
	Number of institutions (units)	29	21	19
	Number of visits per shift, thous.	3.0	2.3	1.7
	Outpatient network			
	Number of institutions (units)	60	43	45
	Number of visits per shift, thous.	6.6	6.1	6.2
Chukotka AO	Hospitals			
	Number of institutions (units)	32	1	3
	Number of visits per shift, thous.	1.3	0.9	0.7
	Outpatient network			
	Number of institutions (units)	40	34	27
	Number of visits per shift, thous.	3.0	2.5	2.3

Source: compiled by the authors according to Rosstat data [19].

Second, to assess the cost, the methodology of normative calculations for the construction of healthcare facilities was used, since the authors did not have information about their actual cost, and there was no possibility to use the all-Russia data on the fixed assets of the system, which was assessed in 2010. In [1–3], to assess the cost of the road infrastructure and the residential sector, we considered data on the cost of fixed assets in the regional context, but they were not available for healthcare facilities.

At the first stage, it was necessary to determine the total number of healthcare facilities (institutions) that were built on permafrost. For this, actual data on the number of medical institutions located in the permafrost zone were used, detailed down to the municipal level. Due to the lack of factual information about the number of facilities built directly on permafrost, the previously developed methodology of quantitative synthetic assessment, based on data from the International Permafrost Association (IPA), was

Table 2. Dynamics of financing of medical institutions in the regions of the Russian Arctic in 2005–2018, mln rubles

Regions	2005	2013	2018
Komi Republic	6701.3	24179.8	24528.9
Nenets AO	809.2	2694.1	3298.8
Khanty–Mansi AO	2644.5	76586.6	80819.9
Yamalo-Nenets AO	8353.4	29284.3	36630.1
Krasnoyarsk krai	17157.9	64037.0	68050.3
Republic of Sakha (Yakutia)	10425.3	35423.8	43646.0
Magadan oblast	2001.7	9719.8	10655.4
Chukotka AO	1964.1	4371.8	4769.5
Average across all regions	9482.863	31038.76	34302.1
Cumulative inflation in 2005–2013, 98.38%			
Cumulative inflation in 2013–2018, 42.36%			

Source: authors' estimates according to Rosstat data [19].

used.[1] It is assumed that in the zone of continuous permafrost, the share of healthcare facilities built on permafrost is 90%; the analogous indicator in the zones of discontinuous, massive-island, and sporadic (island) permafrost is 50, 10, and 0%, respectively. In general, the calculation formula for a specific municipal region is as follows:

$$N_i = 0.9N_{pi} + 0.5N_{pi} + 0.1N_{fi}, \quad (1)$$

where N_i is the total number of healthcare facilities built on permafrost in the ith region; N_{pi} is the number of healthcare facilities built in the continuous permafrost zone in the ith region; N_{pi} is the number of healthcare facilities built in the discontinuous permafrost zone in the ith region; and N_{fi} is the number of healthcare facilities built in the massive-island permafrost zone in the ith region.

For the cost assessment of healthcare facilities in the regions under study, data from the consolidated construction price standards approved by the order of the Russian Ministry of Construction in 2019 were used (Table 3).

The cost of specific healthcare facilities is calculated on the basis of the actual characteristics of their capacity with the involvement of regional and municipal statistics from Rosstat, information from the websites of medical institutions, and using correction factors that take into account climatic and physiographic parameters. The general calculation formula (2) is as follows:

$$V_j = V_{nj} * C_j * K_r * K_c * K_s * K_s, \quad (2)$$

where V_j is the cost of the jth healthcare facility; V_{nj} is the standard cost of the jth healthcare facility taking into account its functional features (see Table 3); C_j is the actual capacity of the jth healthcare facility; K_r is the regional coefficient of change in construction costs; K_c is the coefficient of change in the cost of construction taking into account the climatic factor; K_s is the coefficient of change in the cost of construction in seismically hazardous areas; and K_s is the coefficient of the increase in the cost of construction of facilities under the conditions of dense (compacted) urban development.

When the actual capacity of the jth healthcare facility C_j differs from standard values, shown in Table 3, the indicator V_{nj} in formula (2) is replaced by the indicator V_{fj}, which is calculated by interpolation.

At the final stage, the expected damage to healthcare facilities from permafrost thawing and degradation for the period up to 2050 is calculated using the most unfavorable scenario of climate change (RCP 8.5), which seems to be the most relevant for the Arctic conditions, where the rate and intensity of climate change and permafrost degradation are most pronounced.[2]

[1] According to the methodology of the International Permafrost Association, the following permafrost types are distinguished by areal extent: continuous (90–100% of territory coverage), discontinuous (50–90%), massive-island (10–50%), and sporadic or island (less than 10%); and by the ice content in permafrost: high, medium, and low. Murmansk oblast, the Middle Urals (Perm' krai and Sverdlovsk oblast), Southern Siberia (Irkutsk oblast, Altai krai, the Republic of Tyva, and Kemerovo oblast), and the Far East (Amur oblast and Sakhalin) excluded from analysis as permafrost, as a rule, is located either in hard-to-reach mountain regions or in spots with no substantial risk for economic activity.

[2] Justified by the Intergovernmental Panel on Climate Change (IPCC). This scenario, in particular, was applied in the preparation of the V Assessment Report on Climate Change (CMIP-5) for the period up to the middle of the 21st century, based on six global climate change models: CanESM2, CSIRO-Mk3-6-0, GFDL-CM3, HadGEM2-ES, IPSLCM5A-LR, and NorESM1-M.

Table 3. The expanded standards of prices for construction of healthcare facilities

Healthcare facility, capacity	Price, thou. rubles
Hospital for 36 beds	6562.72
Hospital for 100 beds	4024.36
Hospital for 200 beds	3679.18
Hospital for 250 beds	3455.5
Children's hospitals for 100 beds	5733.22
Children's hospitals for 200 beds	3010.21
Children's hospitals for 250 beds	2511.27
Polyclinics for 50 visits per shift	2068.09
Polyclinics for 200 visits per shift	1510.21
Polyclinics for 600 visits per shift	1191.52
Children's polyclinics for 150 visits per shift	896.39
Children's polyclinics for 200 visits per shift	735.52
Perinatal centers for 130 beds	16080.60
Perinatal centers for 150 beds	14 401.58
Feldsher–obstetric stations for 15 visits per shift	2199.40
Feldsher–obstetric stations for 24 visits per shift	1244.91

Source: compiled by the authors according to the order of the Ministry of Construction of Russia dated March 11, 2021, No. 131/pr [22].

The bearing capacity of soils, the depth of thawing, and ground subsidence were assessed on the basis of previously developed geotechnical models [1, 23–25] and included three scenarios with a corresponding decrease in the bearing capacity of soils: minimum, average, and maximum.

A number of assumptions were made in the calculations. First, in this work, the authors abandoned the scenario economic assessment of damage, having no data on long-term government programs and plans for the construction (reconstruction) of healthcare facilities in the regions under study. Second, the expected damage to specific healthcare facilities (for example, ambulance stations and diagnostic laboratories) was not calculated due to the authors' lack of data on the number of trips and visits to these institutions by patients necessary for calculating the price parameters. Third, the proposed assessment model is static and does not take into account the parameters of inflation and growth of the gross regional product (GRP) due to the authors' lack of reliable sources on the long-term forecast for these parameters at the regional level. Fourth, due to the significant uncertainty of climatic processes, it is difficult to assess the real rate and extent of permafrost degradation in each particular year. Therefore, an assumption was made about a gradual and uniform increase in the surface air temperature and degradation of these soils for the period 2021–2050 and, accordingly, a uniform distribution over time of the magnitude of the expected economic damage.

ASSESSMENT OF EXPECTED DAMAGE TO HEALTHCARE FACILITIES

In accordance with the proposed methodology, the number of healthcare facilities built on permafrost in the regions studied and their cost were calculated. As of 2020, the total network of healthcare facilities included 173 hospitals, 1200 polyclinics, and 636 feldsher–obstetric stations (Table 4).

The data presented in Table 4 differ from the official statistical information.[3] This difference is due, first, to the fact that more than two-thirds of the structure of the hospital fund of the regions fall on the branch network, which is reflected in statistical records as a whole, and, second, in the statistics, the outpatient polyclinic network takes into account only independent medical institutions, without polyclinics that are part of larger medical centers. The noted discrepancy does not introduce any contradictions, since

[3] For the Komi Republic, Krasnoyarsk krai, and the Khanty–Mansi AO, the data were calculated only for municipalities located in the permafrost zone.

Table 4. Healthcare facilities built on permafrost

Regions	Inpatient facilities		Outpatient clinic facilities	
	Number of facilities	Cost of facilities, mln rubles	Number of facilities	Cost of facilities, mln rubles
Komi Republic*	9	1733	144	4465
Nenets AO	6	2027	44	2527
Khanty–Mansi AO**	27	1825	161	2731
Yamalo-Nenets AO	20	8856	233	17553
Krasnoyarsk krai***	36	7136	478	16662
Republic of Sakha (Yakutia)	68	51860	616	83046
Magadan oblast	22	8125	90	18445
Chukotka AO	14	6757	72	10056
Total	173	88320	1838	155486

Sources: the authors' calculations using Rosstat data, the database "Municipalities," websites of regional health departments, territorial health insurance funds, and healthcare institutions.

* Data calculated for seven municipalities.

** Data calculated for 12 municipalities.

*** Data calculated for 16 municipalities.

for this study, it is the actual data on the facilities of the healthcare system that are needed.

The total cost of healthcare facilities in the eight regions of the Russian Arctic, built on permafrost soils, in terms of replacement cost was ₽243.806 bln. At the same time, geographically, the cost of each facility varies depending on its capacity and the cost of construction work in each region. Construction is more expensive in the Republic of Sakha (Yakutia) and Magadan oblast, where the average cost of building one hospital is ₽1.037 bln and ₽738.65 mln, respectively; one outpatient and polyclinic institution, ₽134.8 mln and ₽204.9 mln, respectively.

Next, we will evaluate the impact of permafrost thawing and degradation on the stability of the healthcare facilities built on it and present forecast calculations of the costs of eliminating (mitigating) the expected damage until 2050. The calculation results are presented in Table 5.

According to the estimate obtained, under the baseline scenario—the average depth of thawing, subsidence, and decrease in the bearing capacity of permafrost soils—the expected economic damage to the healthcare facilities built on them and the costs of restoration and maintenance of their stability necessary to minimize this damage may amount to about ₽64.5 bln for 2020–2050 or ₽2.2 bln, on average, per year. In a negative scenario—accelerated degradation and the maximum depth of thawing, subsidence, a decrease in the bearing capacity of permafrost soils—the total amount of damage may increase to ₽234 bln or ₽8 bln annually.

In the regional context, under the baseline scenario, the risks of the greatest damage are typical for the Yamalo-Nenets AO, ₽26.36 bln for 2021–2050 or ₽0.9 bln in average annual terms; Krasnoyarsk krai, ₽17.71 bln and ₽0.61 bln; and the Republic of Sakha (Yakutia), ₽8.77 bln and ₽0.38 bln, respectively. Under a maximum scenario, we calculated for the Republic of Sakha (Yakutia) (₽131.8 bln and ₽4.54 bln) and the Yamalo-Nenets AO (₽26.36 bln and ₽0.9 bln, respectively) (Table 5).

Considering that these values are at the same time the essence of the costs of reducing these risks, including a set of measures to restore and maintain the sustainability of healthcare facilities, it is essential to compare them with the amount of funding for the healthcare system in the regions under consideration. In previously published works of the authors on similar issues [1–3], such a comparison was made in relation to the volume of the GRP. However, it is more interesting to compare costs with the amount of financing of the relevant sector or industry, in this case, the healthcare system, from where the funds for its functioning are actually drawn, including the costs of maintaining the stability (repair, restoration, etc.) of fixed assets (see Table 5).

The amount of funding for the healthcare system is determined by the revenues of regional budgets and the territorial health insurance funds, which, as noted, have significantly decreased in recent years. This narrows the base and increases the burden of additional costs to reduce the risks of damage from thawing and degradation of the permafrost. Thus, in case of a neg-

Table 5. Assessment of economic damage and costs of restoration and maintenance of the sustainability of healthcare facilities built on permafrost soils and at risk of thawing and degradation

Regions	Buildings at risk of permafrost degradation, %*	Health financing		Economic damage		Restoration and sustainability costs of facilities at risk, % of annual healthcare costs
		bln rubles (2018)	% of GRP (2018)	Bln rubles over 2021–2050 (2021 prices)	Bln rubles on average per year (2021 prices)	
Komi Republic	100 (100/100)	24.53	3.52	6.2 (6.2/6.2)	0.2137 (0.2137/0.2137)	0.87 (0.87/0.87)
Nenets AO	99 (0.3/99.1)	3.30	1.03	4.51 (0.01/4.51)	0.1554 (0.0005/0.1556)	4.71 (0.01/4.72)
Khanty–Mansi AO	4.1 (0.0/60.9)	80.82	1.79	0.19 (0.00/2.77)	0.0064 (0.0/0.0957)	0.01 (0.00/0.12)
Yamalo-Nenets AO	99.8 (79.1/99.8)	36.63	1.20	26.36 (20.89/26.36)	0.9088 (0.7203/0.9088)	2.48 (1.97/2.48)
Krasnoyarsk krai	74.0 (0.1/99.4)	68.05	2.87	17.71 (0.02/23.66)	0.6105 (0.0008/0.8157)	0.90 (0.00/1.20)
Republic of Sakha (Yakutia)	6.5 (0.0/97.7)	43.65	3.87	8.77 (0.00/131.80)	0.3024 (0.0/4.5450)	0.69 (0.00/10.41)
Magadan oblast	2.6 (0.0/97.2)	10.66	6.04	0..69 (0.00/25.83)	0.0238 (0.0/0.8906)	0.22 (0.00/8.36)
Chukotka AO	0.6 (0.6/81.1)	4.77	5.72	0.10 (0.10/13.62)	0.0035 (0.0035/0.,4696)	0.07 (0.07/9.85)
Total	53.8 (29.9/95.2)	272.40	3.25	64.52 (27.23/234.75)	2.2247 (0.9388/8.0947)	0.82 (0.34/2.97)

* *Source calculations used*: D.A. Streletskiy, L. Suter, N.I. Shiklomanov, B.N. Porfiriev, and D.O. Eliseev, "Assessment of climate change impacts on buildings, structures, and infrastructure in the Russian regions on permafrost," Environ. Res. Lett. **14** (025003), 1–15 (2019).

The values of the indicators without brackets correspond to the values at the average depth of thawing, subsidence, and decrease in the bearing capacity of permafrost; the values of the indicators in parentheses are their values at the minimum (numerator) and maximum (denominator) depths of thawing, subsidence, and decrease in the bearing capacity of permafrost based on six CMIP5 models.

ative scenario of hazardous natural processes and a decrease in the bearing capacity of permafrost in the next 30 years, certain regions, to minimize risks, may need to increase healthcare costs or reallocate operating costs by 5–10% of the total funding.

The most problematic is the assessment of the expected indirect damage to the facilities of the healthcare system from the consequences of permafrost degradation. Such damage can be attributed to the costs associated with the temporary relocation of healthcare institutions from emergency buildings, the temporary closure of individual medical centers, and an increase in the load on existing capacities and the timing of medical care to the population for these reasons. Due to the considerable distances, low population density, and the sparse network of medical institutions characteristic of the Russian Arctic, transport accessibility of medical facilities is becoming critical. Thus, the connectivity of the settlements of the Dolgano-Nenets and Evenk municipalities of Krasnoyarsk krai is mainly provided by aviation. Therefore, the temporary closure of any healthcare facility in these territories will require additional resources for air ambulance services.

In the work of N.V. Shartova, M.Yu. Grishchenko, and B.A. Revich, using the example of several municipalities of Arkhangel'sk oblast, a model assessment of the transport accessibility of medical institutions for the population was carried out, which showed that even relatively prosperous and populated areas of this region of the Arctic zone are characterized by significant differences in transport accessibility and, accordingly, the timeliness of obtaining qualified medical care. According to the results of the assessment, about 25% of the population is in the risk zone in terms of the time of transportation to the hospital or polyclinic—from an hour to an hour and a half; if adverse weather conditions occur, for example, in winter, half of the total population is in the risk zone [26].

If this assessment is projected onto the eight Arctic subjects of the Russian Federation under consideration, it turns out that, if it is necessary to move and close health facilities temporarily, the overwhelming majority of the population of Krasnoyarsk krai; the Republic of Sakha (Yakutia); and the Nenets, Yamalo-Nenets, and Chukotka AOs will fall into the risk zone, as will Magadan oblast. The reason is that in the structure of the network of healthcare institutions of municipalities, the district/municipal hospital is located only in the administrative center of the municipality; in the regions, there are mainly feldsher–obstetric centers and small polyclinics, the distance between which often exceeds several hundred kilometers.

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The consequences of climate change for natural ecosystems, the population, and the economy of the Russian Arctic have long been a reality and are turning into more serious challenges and risks to the sustainable development of this macroregion. Accelerated thawing, degradation, and the resulting decrease in the bearing capacity of permafrost soils, on which hundreds of enterprises and organizations are built and operate, including critical facilities, is one of the largest threats to regional and national security, especially in the long term.

This fully applies to the facilities of the healthcare system. Although the scale of the *direct* economic damage expected for them from thawing and the decrease in the stability of permafrost soils due to climate change, as well as the need to attract additional funds to mitigate this damage, are comparatively small relative to losses in other sectors of the Russian Arctic economy, nevertheless, the *indirect* socioeconomic damage and costs for its reduction can be very significant, many times higher than direct costs. At the same time, the matter is not so much in the amount of monetary costs as in the scale of socioeconomic costs, bearing in mind the specifics of this sector, the condition and efficiency of which to a great extent determine life expectancy and health of the population. The enduring importance of this sphere and its vital necessity has been reaffirmed by the experience of 2020–2021 to overcome the consequences of the coronavirus pandemic, which directly or indirectly caused the premature death of more than 200000 people [27]. Moreover, in a number of northern regions of the country (Arkhangel'sk oblast, the Komi Republic, and Krasnoyarsk krai), there was a noticeably higher mortality rate per 1 mln inhabitants than the average for Russia, which confirms the special urgency of timely, high-quality, and affordable medical care for the population of remote areas.

The rapid pace of climatic and other related natural conditions of life in general and the functioning of healthcare facilities in particular can become an additional and significant risk factor for the population and the economy and can complicate the implementation of the strategy for the development of the Arctic zone of the Russian Federation and the provision of national security for the period up to 2035 [28] and more distant horizons. Taking into account and assessing this factor, including the risks of expected economic and social damage from the degradation of permafrost, as well as developing an effective response to these challenges, is one of the key tasks of domestic science, which must be addressed in close cooperation with the relevant stakeholders at all levels.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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