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 socio-economic 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 socio-economic 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-
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   |
|--------------------------|------------------------------------------|--------|--------|--------|
|                          | **Hospitals**                            |        |        |        |
| Russian Federation       | 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   |
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

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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].
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:

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

where \( N_i \) is the total number of healthcare facilities built on permafrost in the \( i \)th region; \( N_{pi} \) is the number of healthcare facilities built in the continuous permafrost zone in the \( i \)th region; \( N_{pi} \) is the number of healthcare facilities built in the discontinuous permafrost zone in the \( i \)th region; and \( N_{fi} \) is the number of healthcare facilities built in the massive-island permafrost zone in the \( i \)th 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:

$$V_j = V_{nj} * C_j * K_r * K_c * K_s * K_u,$$  \hspace{1cm} (2)$$

where \( V_j \) is the cost of the \( j \)th healthcare facility; \( V_{nj} \) is the standard cost of the \( j \)th healthcare facility taking into account its functional features (see Table 3); \( C_j \) is the actual capacity of the \( j \)th 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 \( K_u \) 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 \( j \)th 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.\(^2\)

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\(^1\) 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.
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. 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

| 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 | 14401.58         |
| 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].*
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-

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**Table 4. Healthcare facilities built on permafrost**

| Regions                  | Inpatient facilities | Outpatient clinic facilities |
|--------------------------|----------------------|----------------------------|
|                          | Number of facilities | Cost of facilities, mln     |
| Komi Republic*           | 9                    | 1733                       |
| Nenets AO                | 6                    | 2027                       |
| Khanty—Mansi AO**        | 27                   | 1825                       |
| Yamalo-Nenets AO         | 20                   | 8856                       |
| Krasnoyarsk krai***      | 36                   | 7136                       |
| Republic of Sakha (Yakutia) | 68                  | 51860                      |
| Magadan oblast           | 22                   | 8125                       |
| Chukotka AO              | 14                   | 6757                       |
| Total                    | 173                  | 88320                      |

|                          | Number of facilities | Cost of facilities, mln     |
|--------------------------|----------------------|-----------------------------|
| Komi Republic*           | 144                  | 4465                        |
| Nenets AO                | 44                   | 2527                        |
| Khanty—Mansi AO**        | 161                  | 2731                        |
| Yamalo-Nenets AO         | 233                  | 17553                       |
| Krasnoyarsk krai***      | 478                  | 16662                       |
| Republic of Sakha (Yakutia) | 616                  | 83046                       |
| Magadan oblast           | 90                   | 18445                       |
| Chukotka AO              | 72                   | 10056                       |
| Total                    | 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.
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 |
|--------------------------|-----------------------------------------------|------------------|-----------------|--------------------------------------------------------------------------------------|
|                          |                                               | Health financing | Economic damage |                                                                                       |
|                          |                                               | 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.
In the work of N.V. Shartova, M.Yu. Grishchenko, and B.A. Revich, using the example of several municipalities of Arkhangelsk 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 (Arkhangelsk oblast, the Komi Republic, and Krasnoyarsk krai), there was a noticeably higher mortality rate per 1 mn 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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