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RESEARCH PAPER

THE VALUE OF BUILDINGS AND STRUCTURES FOR PERMAFROST DAMAGE PREDICTION: THE CASE OF EASTERN RUSSIAN ARCTIC

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ABSTRACT. The relevance of the study lay in the need to obtain reliable information on the possible economic consequences of changing geocryological conditions in the Russian Arctic, to find methods for preventing (reducing) potential damage, increasing the safety of the population and economy in the areas of the highest geocryological risks, and ensuring balanced socio-economic development in the Russian Arctic permafrost zone for the long term. The study aimed to assess the cost of fixed assets, including their most vulnerable part – buildings and structures (case study: municipalities of the Russian Arctic Asian sector). Economic sectoral structure was evaluated in accordance with the Russian Standard Industrial Classification of Economic Activities using primary statistical data – closed data from companies accounting reports. The work used statistical, cartographic, and visual-graphic methods, as well as methods for analyzing spatial information and microeconomic data. According to calculations, the Russian Arctic Asian sector concentrates the fixed assets of commercial companies with a total value of about 14.8 trillion rubles, including buildings and structures worth 10.7 trillion rubles. The obtained calculated data can be used in modeling the directions of state policy in the field of climate change adaptation and territory protection from natural hazards.

KEYWORDS: Arctic zone of the Russian Federation, economic damage, natural risk, fixed assets, permafrost

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INTRODUCTION

According to modern studies, the expected global climate changes will be most intensely manifested exactly in the circumpolar latitudes (Anisimov et al. 2016; The second assessment…, 2014; Arctic…, 2017; Volodin et al. 2017), i.e. primarily in the territories belonging to the Arctic zone of the Russian Federation (AZRF), most of which is located in the permafrost zone. The predicted climate warming may bring both positive economic effects (first of all, a decrease in costs of construction, passengers and cargo transportation, geological exploration and geological production, an increase in the navigation period duration in the Arctic seas basins, a reduction in energy consumption for life support in the Arctic regions, etc.), and negative economic effects, associated primarily with a damage increase from the natural hazards activation (Kislov et al. 2011; Porfiriev et al. 2017, Orttung et al. 2021). According to some forecasts (Porfiriev et al. 2017), the cumulative effect of the positive consequences of climate change for the AZRF and the country economy as a whole until 2030 will be characterized by a noticeable excess of costs over benefits.

In this case, permafrost degradation, where more than two-thirds of the total Russian Arctic urban population lives (and 100% of the population in the Russian Arctic Asian sector), seems to be a key problem associated with colossal direct and indirect damage. In the Arctic the temperature of upper permafrost horizons rises much faster than the air temperature (Streletsky et al. 2012), and over the past 30 years it has increased by about 0.5-2.0°C in general in the Russia permafrost zone (Romanovsky et al. 1997; Romanovsky et al. 2010). At the same time, the warming trend continues (Kukkoneni et al. 2020; Vasiliev et al. 2020a; Vasiliev et al. 2020b). According to various estimates as a warming result by the end of the XXI century, thawing may occur from 30% to 85% of the upper permafrost horizons (Scholes et al. 2018). Exceeding the values of the soil temperatures optimal range laid down in the design of buildings and structures with pile type of foundations leads to their deformation and destruction (Grebenets et al. 2012). A one-time and massive decommissioning of a significant share of residential buildings, buildings and structures of the economy, regional and local road infrastructure

elements will inevitably lead to a rapid deterioration of the socio-economic situation in the Arctic regions, impose disproportionately high loads on grassroots budgets, since the fixed assets restoration is a long and capital-intensive process, (Badina 2020). The significance of the permafrost degradation problem, need to renew its monitoring system is highlighted in such key modern strategic planning documents as the «Strategy for the AZRF development and national security until 2035» and the «Strategy for the spatial development of the Russian Federation until 2025», as well as in the «National action plan for the first stage of adaptation to climate change for the period up to 2022».

However, the formation of timely adaptation strategies to changing geocryological conditions and preventive measures require a scientifically grounded understanding of intraregional differences in the vulnerability level of the Arctic territories, potential damage amount, and geocryological risk integral level. The permafrost degradation consequences forecasting is a pioneering area of scientific researches, since for the first time in world history, society may face such catastrophic socio-economic damage within the permafrost zone. Thus, the need for reliable and scientifically based forecasts is an important challenge for modern science. Economic studies of engineering and geocryological risk in the context of climate change are currently at the initial stage, both in conceptual and methodological aspects. There are serious methodological difficulties associated primarily with a high degree of uncertainty (an extremely wide range of values for forecast scenarios of climatic and geocryological changes), difficulties in comparing natural and socio-economic parameters in order to predict damage both in space (natural boundaries with synthetic administrative-territorial division boundaries) and in time (economic processes, and, accordingly, forecasts, in general, are shorter than climatic and geocryological ones), but the most important limitation is the imperfection of Russian statistics necessary to probable damage assessment. Exactly the statistical limitations predetermined the fact that in all previous researches, the assessment of fixed assets value (its elements) was given very approximately, using many assumptions (Table 1).

Table 1. Analysis of key researches in the field of material damage assessing from permafrost degradation

Damage indicators	Key weaknesses of economic assessments	Key strengths of economic assessments	Amount of damage
Hjort et al. 2018. The study area is the permafrost zone of the Northern Hemisphere in «unprecedented high (~ 1 km) spatial resolution»			
Infrastructure (buildings and structures): residential (settlements and buildings), transport (roads, railways and airports), industrial facilities (pipelines and industrial areas)	The authors show the share of infrastructure (in %) that will be affected by permafrost thawing (its cost estimates are not given). There is a very significant range of probable damage, for example, from 24 to 70% for pipelines. Polygonal objects were converted to point objects in order to estimate their number in hazardous areas, which is a very significant simplification	Geospatial data analysis. Reliance on satellite images, clear geo-referencing of economic objects to specific permafrost degradation areas	33% of the total number of consider infrastructure objects (without a cost estimate)
Suter et al, 2019. Study area – permafrost regions of Russia			
Objects of linear (roads and pipelines) and point (housing, airports and ports) infrastructure	Buildings and structures for the main economy sectors (industry, services, etc.) are not taken into account. The regional level does not allow recognizing intraregional differences in terms of infrastructure maintaining costs, while they are quite significant. The current (at the study time) cost of infrastructure is considered, however the change for the forecast period is not estimated (for the second half of the XXI century, taking into account the new infrastructure projects implementation)	The average annual costs of infrastructure maintaining during its operational period and direct damage are shown in relation to the GRP of the corresponding regions, which makes it possible to assess the scale of the expected consequences	The cost of Arctic infrastructure maintaining in case of permafrost degradation will increase by 27.5% (in Russia) and will be $ 6.63 billion by 2050–2059. The cost of influenced infrastructure will be $ 40339.14 million (32% of the total Russian infrastructure in the permafrost zone)
Streletskiy et al, 2019. Study area – regions (for some indicators – municipalities) of the Russian permafrost zone			
Residential buildings, non-residential commercial and social facilities, linear infrastructure, heavy machinery and industrial equipment, vehicles and intangible assets	The calculation is based on the assumption that the spatial structure of fixed assets in the region corresponds to the spatial structure of the population (proportional dependence). But this dependence is far from always linear, especially for the Arctic, where industry plays a key role in the economy, the subsectors of which differ greatly in terms of labor intensity and fixed assets intensity	Integrative spatial analysis made it possible to best compare socio-economic and environmental (climate, permafrost) data	The total population of the Russia permafrost zone is 5.4 million people; the cost of fixed assets is $1.29 trillion. The cost of structures in the permafrost degradation zone is $ 39.3 billion, the cost of infrastructure – is $ 209.2 billion, and the cost of residential real estate – is $ 52.6 billion. The total cost of infrastructure maintenance costs associated with permafrost changes will rise to $ 105.07 billion by the middle of the 21st century

Melnikov et al. 2021. Study area – municipalities of AZRF			
Buildings and structures by economy sectors; housing stock	Re-estimates of damage parameters for municipalities are based on many assumptions. Authors examples of obtained results verification show in a number of cases a discrepancy with the actual data	The damage assessment method was developed for the municipal level with a high degree of information detailing; intraregional differences in the expected damage amount are well sown. The authors used a most comprehensive set of parameters characterizing damages (however, railways and roads were not considered separately)	5.7 – 7.7 trillion rubles (in 2020 prices)

Source: compiled by the authors

Scientists (Streletsky et al. 2019) were among the first who proposed an approach to assessing the value of fixed assets in the municipalities of the Russian permafrost zone. However, their estimates are based on very bold assumptions, which does not allow their conclusions to be considered correct. For example, in order to move from the regional to the municipal level, they guessed that the spatial structure of fixed assets in the region was proportional to the spatial structure of the population (simple proportional dependence): «it was assumed that the spatial pattern of the fixed assets within a given region corresponds to that of population: higher and denser population indicates higher fixed assets». Earlier, in 2015, researchers (Baburin and Badina 2015) proposed an identical solution for fixed assets value calculating for municipalities: «The value of regional fixed assets should be distributed in proportion to the size of the population (rural, urban or total, depending on the economic activity type) or in proportion to the value of the product produced for the relevant type of economic activity. The latter option is more rational, since the relationship between fixed assets and the population is not always linear, especially in the Arctic and the Far East, where it is impossible to ignore the specific features of industries with different fixed-asset needs. Indeed, a distinctive feature of Russian Arctic regions is pronounced industrial specialization. Industry represents an average of 52% of the gross regional product (GRP) of Arctic regions, compared to an average of 33% for all Russian regions. This is reflected in the structure of fixed assets. Industrial assets also represent 44% of the total value of fixed assets in the Arctic regions, exceeding the average of 31% for all Russian regions (Badina 2021). As a result, it would be better to use correlation dependence of fixed asset value and the value of production in the relevant type of economic activity (but not population size).

Therefore, a common problem for all of the above works is the limited primary statistical information characterizing fixed assets value, which predetermines the need to develop various kinds of re-estimates for more detailed large-scale calculations or to present the results in a very generalized and approximate form at the regional level. In this regard, the expected damage amount varies quite strongly among themselves, even in the works of one researchers group, depending on the selected assessment methods of fixed assets value. Unlike damages to housing stock and infrastructure, damages to the commercial companies fixed assets are practically not paid attention to in modern scientific research. Although exactly they form regional economy, GRP, population employment and local and regional budgets revenues, in other words, with this type of fixed assets associated the greatest share of not only direct (Melnikov et al. 2021), but also indirect damages to regional and local economies. It is important to note that indirect damage from buildings and structures deformation and destruction in the Arctic can negatively affect the economies of other regions, since some of the enterprises directly operating in the AZRF are legally registered in other regions, often far beyond the permafrost zone.

Researches in modern Russian and foreign science devoted to the issue of fixed assets value assessing can be divided into several key directions (Table 2).

Table 2. Analysis of key researches in the field of fixed assets value assessing

Russian researches	Foreign researches
Methodological approaches to assessing the fixed assets value of individual enterprises	
(Didkovsky 1997): approaches to assessing the replacement value of fixed assets; (Gribovsky 1998): accounting for depreciation models in case of assessing the fixed assets market value of enterprises; (Shichkov 2003): assessment of the intrinsic value of the company's fixed assets; (Petruk 2016): approaches to assessing the fixed assets value of an enterprise; (Zhurkina et al. 2018): improving of methods for company's fixed assets analyzing	(Fernandes 2007): methods for assessing the value of a company's fixed assets
Assessment of the fixed assets value of large territorial units: countries and regions	
(Ableeva 2011): comparative assessment of fixed assets of the Bashkortostan Republic; (Adamadziev et al. 2011): statistical relationships between economic parameters and fixed assets values in Russian regions	(Gourfinkel 2007): regional study on the management, control and accounting of fixed assets: Latin America and the Caribbean
Assessment of the fixed assets value in the context of industries and economic activity types	

(Khanin 2010): assessment of the fixed assets replacement value of the Russian industry; (Fomin et al. 2012): assessment of the fixed assets value of railway transport in Russia	(Daniels 1933): assessment of industrial fixed assets
Alternative approaches to assessing the fixed assets value	
(Sapritsky et al. 1996): computer methods for assessing the fixed assets value; (Eidelman et al. 2010): approaches to replacement value assessing in the framework of fixed assets revaluation	(Carpenter et al. 2005): fixed asset accounting software evaluation: a structured methodology for the mid-market firm

Source: compiled by the authors

At the same time, the development of methodological approaches, as well as a direct assessment of the fixed assets value of economic sectors, and even more so the value of buildings and structures, on municipal level in case of the Russian Arctic, have not yet been undertaken due to the limited and imperfect statistical data, the need for significant temporary and labor costs for this task implementation. Another problem is the discrepancy between the data of regional statistics and the obtained calculated data on municipal level.

In this research, key attention is paid to the study of the real territorial organization of companies fixed assets in the case of the Russian Arctic Asian sector. Thus, for the first time in the Russian and world (in relation to the Russian territory) practice of permafrost thawing damage forecasting, the cost of fixed assets (in particular, buildings and structures) was estimated at the microeconomic level – in the context of enterprises, that is, the most detailed and reliable statistical observation level. The basis is the data of the companies financial statements provided by the info-analytical system «SPARK-Interfax»[1].

Thus, based on the obtained data analysis, it becomes possible for the first time to make the most realistic forecast of probable damage from the permafrost degradation, provided they are compared with the geocryological changes forecasts. In the context of the fixed assets vulnerability of companies, it is important to note one significant aspect. Many directly operating in the AZRF enterprises are registered on the territory of other regions. There are prerequisites for a change in this situation with the introduction of a preferential regime in the Russian Arctic[2], however, preferences are designed primarily for the creation of new companies not related to the minerals extraction, therefore, cardinal changes, most likely, will not happen soon (Kuznetsova et al. 2021; Pilyasov 2020).

The discrepancy between the registration of legal entities and the real localization of production determines the key problem for the Russian Arctic, when companies, in case of completion of their activities in the Arctic territories, or in case of emergencies, including due to climate change, «leave» the region, not wanting to eliminate the negative consequences of their activities. This problem was raised at the highest level by the Russian President V. Putin in the course of his message to the Federal Assembly in April 2021: «Our approaches to environmental protection are absolutely principle and cannot be revised ... I ask you to speed up the law adoption, which will establish the financial responsibility of the enterprises owners for the elimination of accumulated damage, for the reclamation of industrial sites ... if you got it at the expense of nature – clean up after yourself»[3]. At the same time, this issue is seen more deeply by the authors, as businesses need to eliminate not only the consequences of their activities, but also prevent and eliminate the consequences of likely climate change that could lead to environmental and man-made disasters, such as diesel leaks in Norilsk on May 29, 2020.

Accordingly, part of the regional and local taxes goes outside the AZRF, thereby, on the one hand, the potential of the Arctic regions' resistance to permafrost degradation decreases. On the other hand, the damage caused to the fixed assets of commercial companies localized in the Russian Arctic will cause indirect damage from permafrost thawing in regions located often far beyond the permafrost zone, which will undoubtedly entail negative multiplier effects spreading throughout the country. In the context of such negative scenario, the possibility of implementing the state course for the priority Arctic socio-economic development as a special geostrategic territory (Pankratov et al. 2020, 2021), investment activity stimulating and population consolidating (Badina et al. 2020) is excluded.

MATERIALS AND METHODS

The methodological approach adopted in this study is based on the «risk» concept, which is a function of the natural hazard likelihood (in this case, an engineering-geocryological hazard) and the value of potential consequences for the population and the economy (damage value) (Akimov et al. 2013; Korolev et al. 2007; Myagkov et al. 2004; Osipov et al. 2017; Porfiriev 2011). Thus, it is planned to estimate the total value of buildings and structures of commercial companies on permafrost in the AZRF Asian sector: Yamalo-Nenets Autonomous Okrug, Chukotka Autonomous Okrug, arctic municipalities of Krasnoyarsk krai and Sakha Republic (Yakutia), taking into account the specifics of the engineering-geocryological hazard. In this study, primary attention is paid to the Asian sector of the Russian Arctic, because exactly there the most catastrophic changes in engineering-geocryological conditions are expected (Anisimov et al. 2015; SWIPA 2017).

To assess the market value of fixed assets, including buildings and structures for the AZRF Asian sector municipalities, the authors have created a technique based on statistical and cartographic methods, visual-graphic methods, as well as methods for spatial information and microeconomic data analysis. The informational basis of the study is data on the Russian companies of the «SPARK-Interfax» system, collected from all enterprises operating in the studied territory. In addition, in some cases, in order to exclude emissions, annual reports of companies (mostly large companies) were used. In the framework of the analysis, a database was formed. This database contains information on the fixed assets market value, the company's belonging to the corresponding economic activity type (according to Russian Standard Industrial Classification of

[1]SPARK-Interfax – a system for professional analysis of markets and companies. http://www.spark-interfax.ru/Front/Index.aspx (accessed May 1, 2021)

[2]Federal Law of July 13, 2020 N 193-FZ "On state support of entrepreneurial activity in the Arctic zone of the Russian Federation". http://www.consultant.ru/document/cons_doc_LAW_357078/ (accessed May 1, 2021)

[3]Message from the President of Russia to the Federal Assembly, April 21, 2021, http://www.kremlin.ru/events/president/transcripts/messages/65418, (accessed July 18, 2021)

Economic Activities-2), addresses of operating and legal registration, the tax revenues volume, revenue volume and other significant technical-economic indicators. In total, about 13.5 thousand commercial companies were analyzed.

The calculation of the economy fixed assets value for the AZRF Asian sector municipalities was carried out for all companies, regardless of its legal registration place. At the same time, in the manual setting mode, the data on the biggest Russian interregional companies were adjusted in terms of the fixed assets accounting directly in the AZRF in order to increase the reliability, quality and representativeness of statistical information (using data from annual reports or information from the official websites of the relevant companies). In order to additional verification, the obtained data were compared with the available Rosstat data on the fixed assets value and the tax revenues volume in the case of the regions or the largest cities. The calculation of the commercial organizations buildings and structures values was carried out based on its average share values[1] in the total fixed assets values (by multiplying the total fixed assets values by the calculated decreasing coefficients for corresponding economic activity type (Table 3). These coefficients were developed and tested in previous studies of the authors (Badina 2021).

Thus, within the framework of this study, for the first time in Russian scientific and managerial practice, the buildings and structures value of companies as the most vulnerable to permafrost degradation part of the economy fixed assets was calculated.

As an alternative method for measuring the value of fixed assets on municipal level, it is possible to use the data on property tax of organizations. The Federal Taxation Service of the Russian Federation provides this data in the public domain. It should be noted that this approach has been repeatedly used by Russian researchers in the framework of the implementation of tasks in terms of assessing the gross municipal product in the Russian Federation (Zemlyansky et al. 2021; Dmitriev et al. 2020).

In particular, taking into account the fact that the tax rates on the property of organizations are established by the laws of the Russian regions and cannot exceed 2.2%[2], as well as on the basis of available open data on tax reporting, it seems possible to estimate the total value of the taxable base, which theoretically will correspond to the fixed assets value. At the same time, without making these calculations, it is also possible to directly use the available data on the residual value of real estate recognized as an object of taxation.

Table 3. Average contribution of the buildings and structures costs to the total fixed assets value by the economy sectors, %, 2019 (case study – commercial organizations)

Economic sector	Average contribution, %
Average	62.53
Agriculture, forestry, hunting, fishing and fish farming	44.16
Mining industry	74.43
Manufacturing industries	41.24
Electricity, gas and steam supply; air conditioning	57.16
Water supply; sewerage, organization of waste collection and disposal, pollution elimination	83.13
Building	33.40
Wholesale and retail trade; repair of motor vehicles and motorcycles	80.40
Transportation and logistics	67.07
Hotels and catering	74.93
Information and communication	25.65
Finance and insurance	28.94
Real estate transactions	85.19
Professional, scientific and technical activities	63.19
Administrative activities and related additional services	31.05
Public administration and military security; social security	32.76
Education	54.94
Health and social services	53.50
Culture, sports, leisure and entertainment	71.38
Other types of services	50.42

Source: calculated by the authors based on Rosstat data (https://fedstat.ru/indicator/58656, (accessed July 18, 2021))

[1]meaning the average for the Russian economy

[2]Article 380 "Tax rate" of the Tax Code of the Russian Federation, URL: https://base.garant.ru/10900200/ece92382efb38f5899252c9982390b2d/ (accessed October 18, 2021)

At the same time, these method contains a number of limitations, which ultimately largely distort the real picture in terms of assessing the fixed assets value, and, thus, cannot be considered as a representative approach in the framework of the proposed study.

Firstly, in relation to real estate objects, the taxable base is determined as their cadastral value, which, as a rule, is several times less than their market value. Thus, the measurement of the fixed assets value by the revaluation method based on data on property tax of organizations is several times lower than the real fixed assets market value. Secondly, it is inappropriate to make quantitative estimates by the method of correlation of cadastral and market values for different regions and municipalities, without taking into account the existing interregional differences in approaches to assessing the cadastral value of buildings and structures. These differences may be even more significant for the territories of the AZRF.

Thirdly, it is important to take into account that cadastral values are calculated once every several years. In addition, this important limitation determines the presence of significant discrepancies between the cadastral values of fixed assets of different organizations in the context of the possibility of linking them to the current price level.

Nevertheless, within the framework of these study, in order to determine interregional differences between the fixed assets market value, calculated using closed data from the accounting reports of companies (SPARK-Interfax) and their cadastral value in accordance with the data of the Federal Tax Service of the Russian Federation, it is advisable to supplement the calculated data with data on the residual value of real estate recognized as an object of taxation in the studied municipalities of the AZRF Asian Sector.

RESULTS AND DISCUSSION

According to Rosstat, the total fixed assets carrying value of the Russian Federation in 2019 amounted to 349.7 trillion rubles (at full accounting value for a full range of organizations); the studied Arctic regions (Yamalo-Nenets Autonomous Okrug, Krasnoyarsk krai, Sakha Republic (Yakutia), Chukotka Autonomous Okrug) – 22.6 trillion rubles, or 6.5% of the total fixed assets value in Russia. Fixed assets value of AZRF Asian sector municipalities, according to the SPARK-Interfax database, amounted to 14.8 trillion rubles, or 65.7% of the total fixed assets value of considered Arctic regions. It is important to note that the obtained results will make it possible to clarify the results of the fixed assets assessment proposed by the previous authors' works (for example, Baburin et al. 2020; Badina, 2020; Melnikov et al. 2021) by further detailed analysis of each municipality (Table 4):

Based on the calculations results, it can be argued that the territorial organization of fixed assets in study municipalities varies significantly. Therefore, the territory of the AZRF Asian sector can be divided into two parts according to the accumulated social-economic potential volume:

- Western sector: municipalities of Yamalo-Nenets Autonomous Okrug and Krasnoyarsk krai, for the overwhelming majority of which the accumulated fixed assets volume exceeds 100 billion rubles;
- Eastern sector: municipalities of Sakha Republic (Yakutia) and Chukotka Autonomous Okrug, for which the accumulated fixed assets volume is less than 100 billion rubles.

The largest fixed assets volume is concentrated in Novy Urengoy – 3 890 billion rubles, Salekhard – 2 998 billion rubles, Yamal district – 2 899 billion rubles, Purovsky district – 1,201 billion rubles, Noyabrsk – 954 billion rubles, Shuryshkarsky district – 438 billion rubles, Taimyr Dolgan-Nenets district – 359 billion rubles, Turukhansky district – 339 billion rubles, Nadym – 310 billion rubles, Gubkinsky – 267 billion rubles, Tazovsky district – 229 billion rubles and Norilsk – 186 billion rubles (Fig. 1).

Taking into account the average coefficients that characterized the share of buildings and structures in fixed assets value by economy sectors, the value of buildings and structures in AZRF Asian sector municipalities was estimated. According to these calculations, the total value of buildings and structures is 10.7 trillion rubles (72% of the total fixed assets value in 2019). In addition, based on the open data of tax reporting of the Russian Federal Tax Service (FTS) (information about the property tax of organizations), the cadastral values of buildings and structures of the studied municipalities in 2019 were calculated. (Table 5):

The highest value of buildings and structures, both in absolute and relative terms, is typical for the municipalities of the Yamalo-Nenets Autonomous Okrug and Krasnoyarsk krai. More than 75% of buildings and structures in the fixed assets are on the territory of Shuryshkarsky, Tazovsky, Priuralsky districts, Nadym. The high value of buildings and structures in Yamalo-Nenets AO is a consequence of its highest territorial development, the highest population density relative to the rest of the studied regions, the most developed urban network, as well as the increased importance of housing and communal services and the presence of a highly developed oil and gas production complex. The Arctic territories of the Krasnoyarsk krai have a high accumulated industrial potential related, first of all, to the fixed assets of «Norilsk Nickel».

The smallest buildings and structures share corresponds to the Iultinsky and Providensky districts of the Chukotka Autonomous Okrug (less than 55%), as well as the Arctic

Table 4. The cost of fixed assets in the regions and municipalities of the AZRF Asian sector in 2019, billion rubles

Region	Regions of the AZRF Asian sector (Rosstat)	Municipalities of the AZRF Asian sector (SPARK-Interfax)	Municipalities of the AZRF Asian sector (according to previously approved author's methods)
Yamalo-Nenets Autonomous Okrug	13 937	13 515	13 937
Krasnoyarsk krai	4 856	884	2 070
Sakha Republic (Yakutia)	3 589	221	151
Chukotka Autonomous Okrug	212	216	212
Sum	22 594	14 836	16 370

Source: calculated by the authors based on Rosstat and «SPARK-Interfax» data

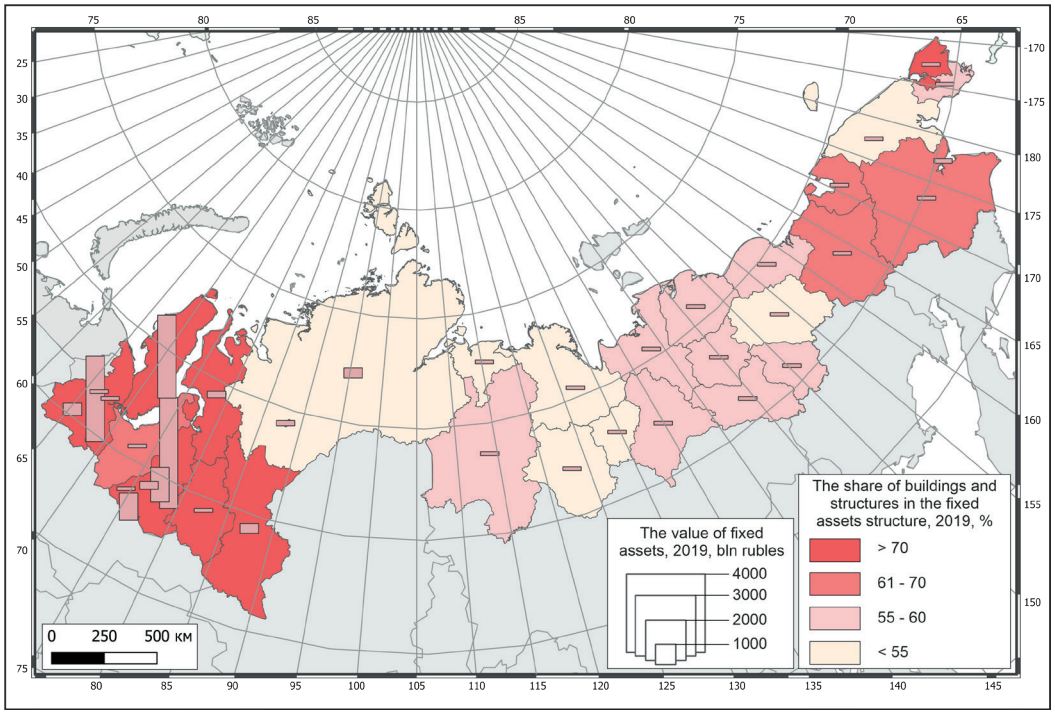

Fig. 1. Fixed assets value in municipalities of the AZRF Asian sector, 2019

Table 5. The value of buildings and structures in municipalities of the AZRF Asian sector, 2019

Region	Value of buildings and structures, billion rubles, 2019		The difference between the market and cadastral values, times	Share of the total fixed assets value (according to calculated data),%
	FTS data (cadastral value)	Calculated data (market value)		
Yamalo-Nenets AO	5 185	9 955	1,9	74
Krasnoyarsk krai	370	517	1,4	58
Sakha Republic (Yakutia)	65	122	1,9	55
Chukotka AO	55	139	2,5	64
Sum	5 675	10 733	1,9	72

Source: calculated by the authors based on «SPARK-Interfax» and Russian Federal Tax Service data

municipalities of the Sakha Republic (Yakutia), which are characterized by low territorial development, insignificant socio-economic potential.

The data of the Russian Federal Tax Service on the cadastral value of buildings and structures in considered municipalities, presented in Table 5, as a whole, make it possible to verify the calculated market fixed assets value. A number of Russian studies provide analytical and empirical average ratios of cadastral and market values for real estate objects. In particular, a number of Russian researchers indicate that in most cases the cadastral value is one third or even half less than the market value (Kotlyarov et al. 2012; Myasnikov et al. 2019; Berdnikova 2019). This pattern is generally reproduced within the specified range with the ratio of the cadastral and market values in studied municipalities of the AZRF Asian sector.

On average, for Arctic territories, the market value of buildings and structures exceeds their cadastral value by 1.9 times (by 47%), while the smallest difference is typical for the Arctic districts of the Krasnoyarsk krai – 1.4 times (by 28%), the largest – for the Chukotka Autonomous Okrug – 2.5 times (60%). These interregional differences may indicate, on the one hand, the existing differences in assessing the cadastral value in different regions of Russia and for different types of economic activities, on the other hand, about the limitations of the SPARK-Interfax database – lack of statistical data on a number of companies. Taking into account these circumstances, it can be assumed that the real market value of buildings and structures in Asian Arctic municipalities is slightly higher than the calculated values.

CONCLUSIONS

An analysis of the fixed assets (including buildings and structures) territorial organization in the AZRF Asian sector municipalities shows a significant heterogeneity of the study area in terms of their density distribution. It determines the need to develop a differentiated approach to the state system modeling aimed at natural risks preventing, in particular, those associated with engineering-geocryological conditions changes. Based on this, it is advisable to plan the financial support of this system, taking into account the real fixed assets carrying value concentrated in areas of maximum permafrost throwing danger, as well as the regional and local budgets financial capabilities.

The largest probable damage, as well as the financial burden associated with adaptation measures implementation, will be in the regions and municipalities that concentrate the largest fixed assets volume, ceteris paribus. In total, according to our estimates, fixed assets of commercial companies with a total value of about 14.8 trillion rubles (including buildings and structures – 10.7 trillion rubles) are concentrated in the AZRF Asian sector permafrost zone.

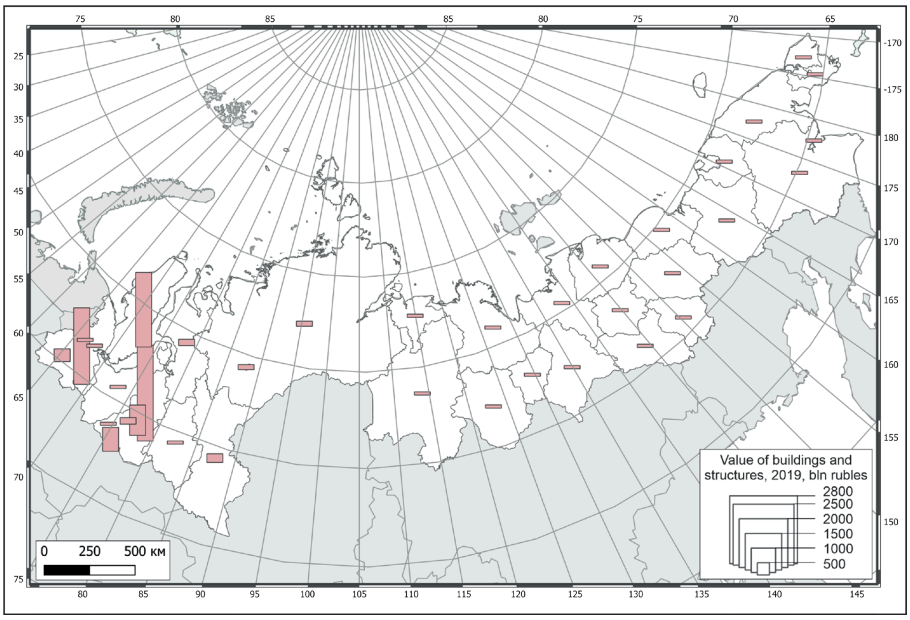

Fig. 2. The value of buildings and structures in the municipalities of the AZRF Asian sector, 2019

This research is pioneering; therefore, the results presented in the article are only the first necessary generalization, taking into account promising clarifying and improvements in methods. First, at the next iteration, it is planned to create a GIS, where specific enterprises with already known fixed assets (buildings and structures) values will be georeferenced to specific permafrost degradation areas in order to damage prediction. It requires scientific cooperation and work with specialized cryolithologists.

This study results can be used in developing and correcting strategic planning documents (both sectoral and territorial planning), adaptation programs at various territorial levels, including the subsequent stages of the National Action Plan for Adaptation to Climate Changes developing. Based on the obtained results, the development and early application of measures set aimed at geocryological risk level reduction can be carried out.

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