Risk Management of Infrastructure Projects as a Way to Ensure Sustainability of the Arctic Territories

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Abstract: Climate change opens up great opportunities for the development of the Russian Arctic. Significant reserves of minerals, easy access to the sea for the transportation of crude oil, liquefied natural gas and other resources make this region promising and energetically important. This investment area is a priority for Russia and can bring positive effects. At the same time, development of the northern territories is associated with inevitable problems caused by the vulnerability of their ecosystems. Air pollution poses serious health, environmental and economic problems for urban areas and contributes to global climate change. Among the atmospheric pollutants, black carbon has an extremely negative impact on the environment, especially in the Arctic territories. Although the Northern Sea Route is a direct route, some sections of it are too shallow for large container ships. There are a number of other equally important operational restrictions, for example, environmental issues: emissions from ships, oil spills on ice, etc. Article presents main directions for the implementation of the Arctic region development concept in the framework of the large infrastructure projects realization. Factors that negatively affect ecological state of the Arctic territories are highlighted, methods to reduce black carbon emissions for the Murmansk region are described taking into account various types of activities in the region. As a result, authors show that there is a significant potential for reducing emissions of pollutants, including black carbon. In order to increase the sustainability of the region, authors classify possible types of risks and suggest a conceptual model of the risk management system. As an example, the reasons and consequences of improper planning of supply chains are considered. While drawing up development strategies, risks that can disrupt the balance of ecosystems should be taken into account. This in general will contribute to the sustainable development of the Arctic territories.

1 INTRODUCTION

The issues of sustainable territorial development acquire special relevance in the 21st century, since the depletion of natural resources forces, along with the implementation of comprehensive strategies for their careful use, to search for their new sources. The new territories development is associated with a number of problems, which are caused by their inevitable urbanization, ecosystems disruption due to various types of activities, which will especially negatively affect the Arctic zone. Currently, a number of complex projects are being implemented in the Russian Arctic. Within their framework it is planned to develop industrial and touristic sectors of economy, which is possible only by creating transport corridors to ensure the raw materials' export and goods delivery, as well as solving the population mobility problems. All of these activities are accompanied by different risks that can lead to serious consequences. In order to reduce possible damage, it is necessary to understand the reasons causing risky situations, as well as possible ways to prevent their occurrence and to minimize the likely consequences. The relevance of the Arctic marine environment's integrated management based on the ecosystem approach is obvious. This is evidenced not only by the activities of the Arctic Council and its

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working groups, but also by broader international activities to implement the goals of sustainable development. Therefore, strategic planning and forecasting is important when creating development programs and infrastructure projects, taking into account risks and consequences for the short and long term (Makarova et al., 2013; Makarova et al., 2017a; Pernebekov et al., 2014).

Strategic vision for the Arctic zone development is determined both by its resource potential, which includes about 25% of the world's undiscovered mineral reserves, and by new opportunities in creating transport and logistics corridors (TLC) due to global climate change. A special role in the implementation of the Arctic development projects plays the Northern Sea Route (NSR), which has a great potential in the formation of international transport corridors (ITC) between Europe and Asia. However, despite the obvious advantages of water transport over its other types (low cost; large carrying capacity of sea vessels and their versatility), there are significant limitations: low speed of goods delivery; high production cost of ships and specially equipped seaports; significant operation costs for ships and infrastructure (seaports, terminals, etc.); environmental problems associated with ships' diesel emissions, especially in coastal areas and port cities. All this requires a detailed study of development prospects, taking into account economic and environmental factors and risks.

2 METHODS OF RISK RESEARCH IN THE ARCTIC REGION

2.1 Ecosystems' State, Risks and Methods to Maintain Their Sustainability

Climate change could irreversibly modify the Arctic ecosystems. To preserve vulnerable Arctic tundra landscapes in the various anthropogenic activities context, a system of specially protected natural areas of the Russian Arctic has been created and is developing (Aleinikova et al., 2020). Voronina (2021) formulates principles of ensuring the environmental safety of the Arctic region, which can be used in strategic planning for the Arctic development and for implementation of environmental protection measures. In the climate change context, the Arctic landscapes transformation monitoring is relevant, because it contributes to the environmental problems' solution, as well as to preservation of not only the natural, but also the Russian historical and cultural heritage. Chekmareva et al. (2019) explore the anthropogenic impact on the species community's composition in the high-latitude Arctic and their ecological state. It is shown that modeling makes it possible to establish the system degradation degree, as well as the level of additional permissible load, at which the system will not lose the ability to self-recover. And for the active cruise tourism development in the Barents Sea region, it is needed to reconstruct the maritime transport and navigation infrastructure along the entire planned shipping corridor of the NSR, as well as to reopen the seaports (Sevastyanov et al., 2021).

Issues of the Russian Arctic region's ecological and economic system's managing are relevant due to a number of aspects, including the increased costs of production and life support, the economic situation's uncertainty and the need to minimize the technogenic impact on the vulnerable Arctic environment. For this reason, it is necessary to improve the methodology for an objective assessment of the environment state; to develop actions to increase efficiency of the regional ecological and economic system's management; to improve the regulatory framework; and to ensure the monitoring of financial costs for environmental protection and the environmental policy results (Tsukerman et al., 2020). Stepanko and Tkachenko (2020) outline the main priority areas of activity for the balanced ecological and economic development of the Russian Far East Arctic territories, taking into account traditional employment sectors.

2.2 Methods to Implement Infrastructure Projects and Their Impact on the Territories' Sustainability

The Arctic territories development involves the infrastructure projects implementation, which include industrial enterprises construction and creation of a transport and logistics framework for the raw materials and goods delivery. In connection with the activities of transport and industrial complex, the risk of accidents and man-made disasters increases. Katansky et al. (2020) have developed models to reduce the risk of major accidents with petrochemical pollution of environmental objects, to increase industrial safety of water and coastal areas of the Barents Sea Kola Bay in case of oil spillings. Alekseeva et al. (2020) show that to monitor the state of oil-producing areas, to detect timely and to assess oil pollution risks in hard-to-reach and fragile tundra and marine ecosystems, it is important to use space images. The proposed methodology using remote and ground data will make it possible to identify areas of environmental oil pollution risk and develop plans for preventive and remediation measures. Yakovlev et al. (2019) have developed a technology to manage the Arctic regions' technogenic and environmental safety, as well as an information and analytical system to support planning of emergency protection at the level of potentially hazardous production facilities and complexes.

Varotsos and Krapivin (2018) use the Geoecological Information Modeling System (GIMS) as one of the Big Data tools to assess the impact on the Arctic Basin's ecological system and the pollution of its waters. In simulation, heavy metals, petroleum hydrocarbons, and radionuclides are considered as primary pollutants, and to predict the Arctic ecosystem's state indicators of bio-complexity and survivability are used. Shulga et al. (2020) using mathematical model of multifunctional energy complex have shown that transition to Liquefied Natural Gas (LNG) should significantly improve environmental conditions.

Port infrastructure's development can significantly worsen environmental conditions. As the China experience has shown, with the ports' development, emissions from cargo ships and container ships have become one of the most significant sources of air pollution in port cities and surrounding areas. Such studies are described by Zhao et al. (2020), Xu et al. (2018) and Wan et al. (2019), who have found that emissions depend on the type and size of ships and the highest percentages of pollutant emissions are ships with a large gross tonnage and with a high rated power of the main engines, such as cruise ships, container ships and tankers for liquefied gas transportation. For example, López-Aparicio et al. (2017) emphasize the importance of a detailed emission inventory as a basis for the development of efficient measures to reduce emissions from shipping in port areas. Authors have used a bottom-up approach to develop a comprehensive emission inventory for the Oslo Port. The main sources of ocean-going ships' emissions, according to the research, are international ferries, cruise ships and container ships. Sorte et al. (2019) have used numerical simulations based on the web-based study screening tool C-PORT to study ship emissions in Porto harbors (Portugal) to estimate the relative contribution of different source sectors to emissions, including ports (terminals, ships and roads), road traffic and industrial (oil refining) sources that potentially affect the port vicinity, including residential areas.

2.3 Methods to Study Negative Impact of Transport on the Arctic Zone's Ecosystems

Negative impact of transport on the Arctic ecosystems is associated, first of all, with development of shipping along the NSR, as well as with the logistics of raw materials and goods for the industry and life development in this region. Since the traffic on the NSR is still insignificant, prospects and risks of the NSR development can be assessed quite easily. However, the negative impact of road and rail transport will depend on support zones development strategy and many factors that are stochastic. For the purposes of analysis and forecasting, it will be necessary to apply multivariate analysis and modeling, including data mining, machine learning, neural networks, genetic algorithms, dynamic programming, etc. (Żabiński and Zielosko, 2021).

Numerous researches are devoted to the shipping impact along the NSR on the ecosystems' state in the Arctic, which is seen as a promising area for economic activity and a potential connecting corridor between Asia and Europe / America. Growth of number of ships passing the NSR means an increased accidents risk and related oil spills. Since the window for successful cleaning will be short, according to Kelly et al (2018), it is necessary to take into account the duration of the recovery period from pollutants. Dalaklis et al. (2018) show that, as activity is expected to increase in this region, it is imperative to assess the current level of support for ships that will traverse the region; and capabilities related to search and rescue operations and oil spill response.

Arctic exploration and transportation pose significant risks due to the region unique features, such as ice, harsh operating conditions, unpredictable climatic changes and remoteness. Khan et al. (2018) propose a model of an object-oriented Bayesian network for dynamically predicting the probability of a ship colliding with ice and assessing the risk, including the likely consequences, taking into account the state of the navigation and operating system, weather and ice conditions, as well as human errors. Lin and Chang (2018) propose a new risk model using a Bayesian network applicable to the NSR to study the possibility of marine accidents such as collision, flooding and grounding. The proposed model takes into account various operational and environmental factors. When researching and controlling the negative environmental impacts of shipping in the Arctic, travel time, fuel consumption and related exhaust emissions from ships must be taken into account (Schröder et al., 2017).

Chou et al. (2017) determine the navigation efficiency along the NSR between different ports by fuel consumption, arguing that fuel consumption and carbon dioxide emissions can be reduced by transit from different ports along the European Sea Route, and that navigation efficiency is determined by distance. Analysis of NSR's sea traffic flows differs from other transport modes, since navigation follows the recommended routes, depending on ice and hydrometeorological conditions. The GIS for the NSR, developed by Ol'khovik (2018), allows calculating models of potential hazards depending on the distance between ships, course crossings, ice conditions and navigation area hydrographic studies. Afonin et al. (2018) propose the GIS including data on the speed and routes of various sizes vessels, as well as data from remote sensing of ice conditions.

3 RESULTS AND DISCUSSIONS. RISK MANAGEMENT TO IMPROVE SUSTAINABILITY: CASE STUDY OF MURMANSK REGION

3.1 Murmansk Region as a Support Zone for the Arctic Development

Arctic development is planned through a system of so-called "support zones". There are nine such zones defined in the State program "Socio-economic development of the Russian Federation Arctic zone" (2014). Their task is to connect all projects and resources located on their territory for the development of socio-economic activities, communication and resource potential in the Arctic zone and to obtain the maximum synergistic effect. The basis of the support zones' spatial structure is the transport-industrial framework, which includes transport, industrial and multifunctional objects (Dmitrieva and Bury, 2019). The main consequence of such projects' implementation will be urbanization of the territories, that have been deserted before. This will inevitably affect ecosystems' state.

The Kola support zone provides for the implementation more than 30 large-scale investment projects. According to the sectoral principle, they are combined into seven clusters: transport and logistics; marine service; petrochemical; mining, chemical and metallurgical; fishery; tourist and recreational; scientific and educational. Development of the first two of them is directly connected to the Arctic projects, activities of the rest will contribute to the Arctic's evolution indirectly, however they will directly affect its regional socio-economic progress.

3.2 Actions to Reduce Negative Impact of Industrial Facilities on the Region's Environment

Fast industrial development is an important change factor for the Arctic Ocean and coastline: the Arctic was once perceived as a region with no prospects, but now, due to rich natural resources and new opportunities for shipping, interest is growing. Expansion of activities such as coastal and offshore fisheries, coastal and offshore hydrocarbon exploration, its mining and shipping can drive development in the region, but also threaten ecosystems (Avila-Diaz et al., 2021).

Murmansk region's industry is historically built around mining industries and ports. The peninsula territory is rich in ore with a high-solid of valuable metals and minerals: sulfide copper-nickel fields, iron ore, apatite, nepheline and baddeleyite concentrate. About a quarter of all minerals known on Earth have been discovered on the region's territory. The region provides 10% of the total Russian production of iron ore concentrate, as well as 7% of refined copper. In 2019, mining took just over a quarter in the structure of shipped industrial products (137.5 billion rubles); 60% were provided by manufacturing (319 billion rubles), and 11% – by the electricity provision, gas and other energy sources.

Due to the fact that nickel and copper production impacts negatively on the environment, obsolete production facilities are being closed. Thus, together, shutdown of smelters in Nikel and Monchegorsk will reduce sulfur dioxide emissions on the Kola Peninsula in 2021 by 85 percent compared to 2015.

The mining and metallurgical industry of the Arctic is also faced with the problem of local ore fields depletion, many of which have been developed since the 30s of the last century. An urgent scientific and technical problem that is being solved by the Kola Scientific Center of Russian Academy of Sciences scientists is the development of technologies that allow additional extraction of useful components from substandard ores and mining and processing waste. In the last decade, pilot work has begun on heap leaching of poor copper-nickel sulphide ores, in which useful components are extracted from the ore using special solutions. About 20 percent of copper is produced in the world today using this technology.

Black carbon (BC) poses a huge threat to the Arctic, polluting snow, darkening its surface. This enhances the absorption of solar radiation, heating the snow and causing it to melt. Due to their low weight, BC particles are spread by air currents over huge areas, which makes the Arctic a particularly vulnerable part of the planet (Chen et al., 2021). Thus, the largest source of BC emissions in the Murmansk region is the mining industry, which accounts for 71% of total emissions. There are at least 250 diesel-powered mining trucks operating in the industry, which are a significant source of BC emissions. Because mining truck engines have a relatively short lifespan, there are many options to choose from to reduce emissions, such as investing in replacing engines with cleaner engines that run on LNG. In this case, fuel efficiency can increase by 5-15% and BC emissions can sharply decrease with a relatively small increase in engine cost (Kholod et al., 2015).

Murmansk region has made the top ten Russian regions in the rating of socio-economic sustainability and has made the top twenty in the rating assessing efficiency of regions' activity. In addition to benefits for residents of the priority development area "Arctic capital" and the Arctic zone of Russian Federation, a federal law "On protection and encouragement of investments" has been launched. It provides tax rates fixing during the realization period of such projects as "Olkon", which will develop the new Pechegubskoye iron ore deposit, where production will begin in 2022. The second project is the expansion of "Oleniy Ruchey" mine, where 600 new jobs will be created. At present, the third Investment Protection and Promotion Agreement (IPPA) is being prepared for the project for the development of "Fedorova Tundra" platinoid deposit.

Another area that is actively developing is fishing and fish processing. 15% of all Russian fish is caught near Murmansk. According to Russian Federal Fisheries Agency, in 2019, almost 659 thousand tons of fish were caught in the region (mainly horse mackerel, scomber, sardines and cod), 90% of which was processed in Murmansk and shipped to retail chains. Three seaports in the region have been loaded, including the leader in the goods transportation in the north-western part of Russia, JSC "Murmansk Commercial Sea Port".

Much attention is paid to energy and its eco-efficiency. The Kola Nuclear Power Plant (NPP) is a unique energy enterprise: it is the first nuclear power plant built in the harsh Arctic climatic conditions located beyond the Arctic Circle (commissioned in 1973); and it is the northernmost in Europe. In 2006, an unparalleled liquid radioactive waste processing complex was created at the Kola NPP, which uses a unique ion-selective sorption technology that allows cleaning liquid radioactive waste and converting it into a safe salt melt. This technology makes it possible to reduce amount of radioactive waste to be buried by 100 times. In 2019, the plant successfully completed a large-scale modernization of the first stage power units, which made it possible to significantly increase their safety level and extend the service life until 2033 and 2034.

3.3 Negative Impact of Transport and Daily Living Activities on Urbanized Areas and Ecosystems

Transport framework of Murmansk region is being formed within the development of Kola support zone. Road transport, including diesel vehicles with BC emissions, is a significant contributor to air pollution in the region. As in the whole Russia, the problem is exacerbated by the growing diesel vehicles' fleet (Analytical agency "AUTOSTAT", 2021). For example, in Murmansk, the percentage of passenger cars running on diesel fuel is 12% (Evans et al., 2015) and almost the entire trucks' fleet and buses also run on diesel fuel. The use of gas diesel (Kapustin et al., 2020) or natural gas as a vehicle fuel contributes to the reduction of vehicles' emissions, which will significantly reduce BC emissions. Switching to natural gas will increase the environmental class of vehicles, increase engine life and reduce fuel costs by 40-60%. Russia is uniquely positioned to use natural gas because it is the largest natural gas producer and also has technologies to produce Compressed Natural Gas (CNG) vehicles and buses. Considering that an LNG transshipment terminal will be commissioned in Murmansk in 2022, the possibility of switching from diesel to gas is becoming a reality (Tikhonov, 2020).

Another emissions source, including BC, is maritime transport. Murmansk, with its ice-free Kola Bay, is the western gateway to the Arctic, and Murmansk region has several ports. A great prospect for the NSR development was showed by the congestion that recently formed in the Suez Canal, which indicated the high risks of traditional sea routes and demonstrated their limited capabilities. Since the NSR is now becoming an increasingly viable alternative to the traditional southern sea routes, it is obvious that emissions from shipping will continue growing.

Since the main cargo flows today are tankers carrying hydrocarbons, the future NSR economic efficiency will be determined by the large-capacity fleet presence, for passage of which hydrographic studies and new high-latitude deep-water routes are required. At the same time, it will be necessary to carry out work on the ports' reconstruction. In parallel, implementation of dredging works should be carried out taking into account recommendations of ecologists, so as not to harm the ecosystem. Russian nuclear icebreaker fleet's role is growing, and today there are nuclear icebreakers of this class only in Russia. Such vessels can operate autonomously without entering the port for reloading for several months, which determines their main advantage. According to the projects for the icebreaker fleet's modernization by 2035, the Arctic fleet should consist of 5 nuclear-powered icebreakers of the UAL type with a capacity of 60 MW, three icebreakers "Leader" with a capacity of 120 MW, four icebreakers powered by gas fuel engine with a capacity of 40 MW and an atomic icebreaker "50 Let Pobedy" (Kashka et al., 2021).

In the Arctic, in addition to icebreakers, they use ice-class vessels – tankers, etc. The main tasks of the new nuclear-powered ships should be to ensure year-round navigation along the NSR and expeditions to the Arctic. To create conditions for safe navigation and maintenance of year-round transit along the NSR and in accordance with the Transport strategy of the Russian Federation for the period up to 2030 (2008), it is planned to build ships to support the fleet. These are nuclear icebreakers for escorting transport ships; diesel-electric icebreakers for servicing fields on the Arctic shelf; multifunctional rescue vessels; new generation tugs; technical rescue equipment from offshore oil and gas facilities in ice conditions. The NSR has a network of control and corrective stations that ensure the operability of coastal navigation aids, as well as GLONASS / GPS monitoring and correction stations. This creates conditions for increasing the reliability and accuracy of observations, provides the calculation of the position of the vessel, and contributes to the safety of navigation, in general (Strategy for the development of inland waterway transport of the Russian Federation for the period up to 2030, 2016). The use of fuel which is cleaner from the point of view of emissions will make navigation along the NSR more environmentally friendly, as well as will reduce the negative impact on the environment in the port area.

Waste is a problem in urbanized areas. In Russia, gas-fueled municipal vehicles on the KAMAZ chassis are already in operation (Makarova et al., 2020); their use in the Arctic zone is a good way to reduce the burden on the environment. In addition, since January 1, 2019, the Murmansk region switched to a new waste management system: regional operator for the management of municipal solid waste (MSW) put into operation a waste sorting complex and a solid waste landfill, as well as two waste transfer stations in closed administrative-territorial entities.

An energy efficiency project is being implemented in a number of pilot municipalities in the Murmansk region. In Kirovsk city, a set of measures is envisaged that should save up to 70% of the consumed heat resource by 2025. The funds saved within the program framework are fully directed to the social sphere development. The environmental aspect associated with the enterprises transition to new energy sources is important for the region.

3.4 Risk Management as a Way to Reduce Negative Impact on the Environment: Case of Transport and Logistics Processes

To minimize the vulnerability of the population and economy sectors (agriculture, industry, housing and communal services) to climate change, a national climate risk management system is being created in Russia. Russian Ministry of Natural Resources has developed new requirements for environmental impact assessment (EIA) materials, which will take effect from September 1, 2021. In order to assess correctly prospects for the implementation of long-term strategies, it is necessary to assess risks (Makarova et al., 2017b). For the Arctic, these are, first of all, environmental risks. If to analyse the life cycle of any technical system, you can see that among the various risks types, environmental risk is present at all stages (Figure 1).

Analyzing the main risks identified in numerous studies, they can be grouped according to different criteria: by the influenced object (ecosystem, atmospheric air, water area of seas and rivers, etc.), by activity type (production, transportation, tourism, etc.), by the impact's duration (seasonal, permanent). In addition, it is necessary to understand what is the likelihood of a risk situation, whether its occurrence is inevitable and whether its consequences can be reduced. Figure 2 shows the main risks' types that must be taken into account when developing a strategy for the Arctic development.

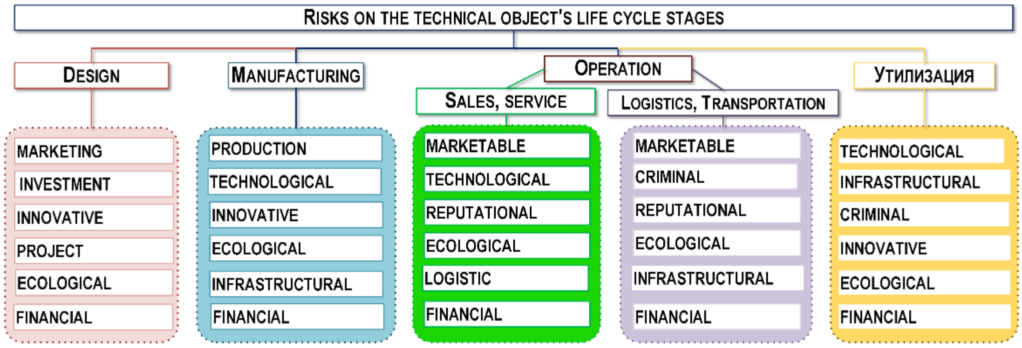

Figure 1: Classification of risks by life cycle stages of technical systems.

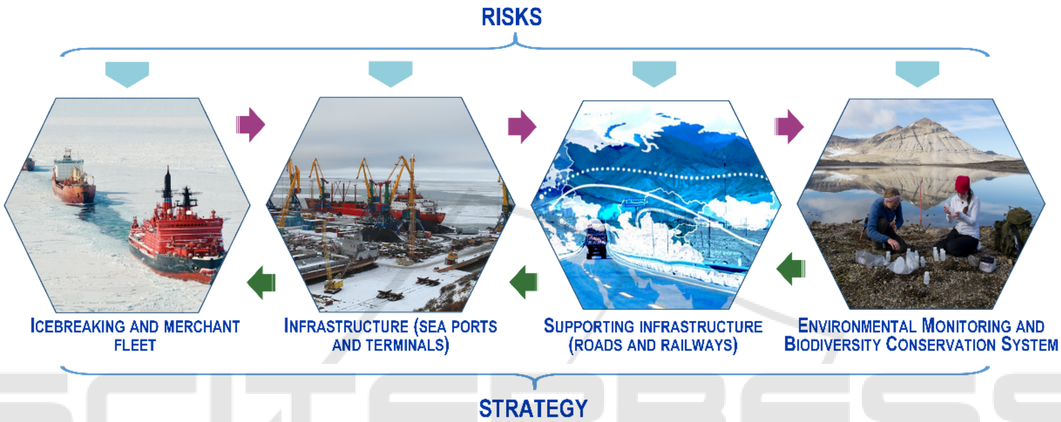

Figure 2: Groups of risks per activity types.

Since a transport framework is being created to implement the development strategy for the Arctic zone, the supply chains will include various transport types (Almetova et al., 2019; Shepelev et al., 2019; Galkin, 2019; Kush et al., 2018). In this case, the total time of cargo delivery can be estimated as it is presented in formula (1), where:

w, p = {1 – road transport, 2 – water transport, 3 – rail transport, 4 – air transport}, $w \neq p$;

t_i is the travel time on the i-th section by the w-th transport type;

y_j is the time of customs documents registration at the j-th point;

s_k is the time of loading, unloading and storage at the k-th point;

A_w, B_w, C_w are the sets of transportation sections, customs clearance points and points of loading and unloading by w-th transport type, respectively.

r is the duration of unplanned repair impacts on the vehicles' fleet and infrastructure facilities;

D_w is the number of downtimes for the w-th transport type, taking into account unplanned repair actions;

v is the downtime duration associated with the working and resting periods of drivers;

z is the downtime duration or an increase in the travel time associated with bans on the heavy vehicles movement;

E, F are the number of vehicle's downtime, taking into account the specified reasons, respectively;

x_o is the transshipment time at the o-th point from the w-th to the p-th transport type;

$G_{w,p}$ is the set of transshipment points from w-th to p-th transport type.

$$T = \sum_{w=1}^{4} \sum_{i \in A_w} t_i + \sum_{w=1}^{4} \sum_{j \in B_w} y_j + \sum_{w=1}^{4} \sum_{k \in C_w} s_k + \sum_{w=1}^{4} \sum_{l \in D_w} r_l + \sum_{m=1}^{E} v_m + \sum_{n=1}^{F} z_n + \sum_{w=1}^{4} \sum_{p=1}^{4} \sum_{o \in G_{w,p}} x_o \qquad (1)$$

At the same time, the risks that characterize each transport type should be additionally taken into account. Evaluating the route efficiency can also include price indicators and other factors.

Creation and development of infrastructure and supply chains is inevitably associated with potential risks: environmental, social and economic. Usually they appear due to errors in the planning and implementation of the development strategy. The Tree-like method is widely used to assess the likelihood of such problems' occurring. Particular attention should be paid to the problem of underdevelopment and imperfection of infrastructure, since there is a high risk of man-made disasters. Therefore, we built a tree that helps to analyse various situations, highlighted the root causes and consequences (Figure 3).

The complex risk of event G is estimated as the sum of basic events and can be calculated using the formula:

$$Q(G)=\sum_{k=1}^{n} q(x_k)=\sum_{k=1}^{n}\sum_{j=1}^{m_k} q(x_{kj})=\sum_{k=1}^{n}\sum_{j=1}^{m_k}\sum_{p=1}^{r_{kj}} q(x_{kjp}) \quad (2)$$

where Q is the upper event's probability (namely the G event); n is the number of child events for G event; m_k, r_{kj} are the number of child events for events x_k, x_{kj}; $q\ (x_k)$, $q\ (x_{kj})$, $q\ (x_{kjp})$ is the probability of events x_k, x_{kj}, x_{kjp} of the first, second and third levels, respectively. The basic events' probability $q\ (x_{kjp})$ can be estimated by statistical analysis of historical data on operation.

To manage risks, a balanced scorecard (BSC) can be used. For this purpose, key performance indicators (KPI) are developed. Figure 4 shows a conceptual model of a System to manage risks using BSC.

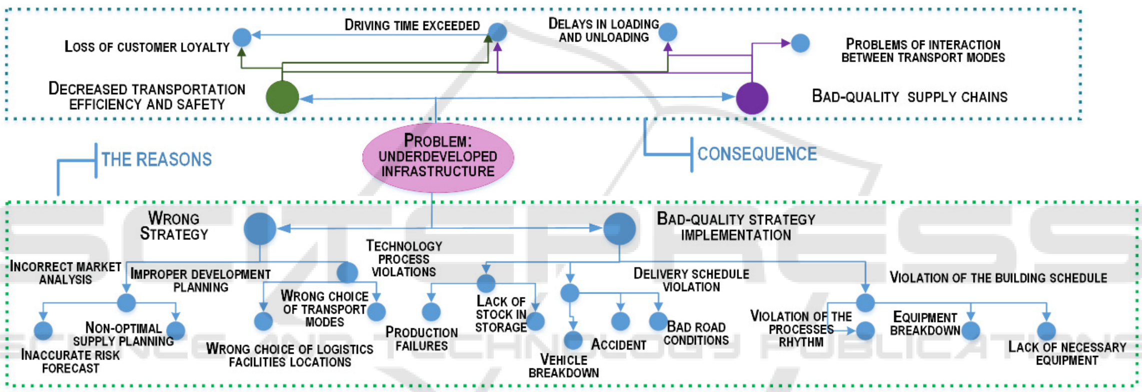

Figure 3: Problem tree to streamline the causes and consequences of the underdeveloped infrastructure of the NSR.

Figure 4: Conceptual model of a Risk Management System.

4 CONCLUSIONS

Climate change opens up wide opportunities for the development of the Russian Arctic, including the NSR. However, along with the positive effects due to the development of the Arctic zone, there will be problems caused by the vulnerability of its ecosystems. Authors of the paper analyse economic and environmental aspects of the Arctic region's development, including the use of the NSR for the transportation of resources extracted in the Arctic, development of cruise tourism in the Arctic zone, and also as an alternative route from Europe to Asia. It is shown that it is necessary to implement projects for the creation and development of the Arctic support zones, as well as to modernize and expand the capacities of the nuclear icebreaker fleet, since the pace of implementation of the Arctic projects will directly determine the volume of traffic along the NSR, which will be the main route as an export channel for raw materials from the Arctic. Efficient functioning of global logistics systems is possible only when implementing complex projects, taking into account various factors: transport costs, optimal routes, environmental impact. To overcome barriers and constraints that impede sustainable development, it is necessary to build an effective risk management system. For these purposes, the article identifies factors that negatively affect ecological state of the Arctic territories, classifies possible types of risks, and develops a conceptual model of the risk management system. Using the example of the Kola support zone, it is shown that various types of activities are associated with environmental risks and methods for reducing negative consequences are given. Possible actions to reduce black carbon emissions are presented. Thus, the proposed methodology and the set of presented solutions may be of significant interest in terms of reducing the negative anthropogenic impact on the Arctic territories, and will also contribute to their sustainable development.

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