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The Role of Multimodal Transportation in Ensuring Sustainable Territorial Development: Review of Risks and Prospects

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Abstract: The Russian Arctic development is an investment direction, which is planned through a system of so-called "support zones" of various development degrees, it is a priority for Russia and can have a positive effect. Since integrated territorial development is associated with significant cargo flows of raw materials, materials and goods, logistics chains will include various transport modes, which will lead to the development of infrastructure (including the construction and reconstruction of seaports, the network of the railways and roads expansion) and the emergence of new international transport corridors (ITCs). A scientifically based solution to the problems of constructing a delivery route, including the location of transshipment points, logistics terminals and the rolling stock selection, will ensure the sustainable territories development through which ITCs pass. However, these tasks, which constitute the activity of organizing multimodal transportation, are associated with various types of risks, the successful solution of which, in this case, depends on the sustainable territorial development of these territories. Therefore, the research objective is to establish the relationship between the development of transport networks and the development of the Arctic region, the designation of possible prospects for the development of both multimodal transportation as a whole as a strategic event, and the contribution of each kind of transport, as well as the risks of creating and using international transport corridors, including cumulative impact on the environment. As a result of the literature analysis, we have considered the causes and consequences of the improper planning of supply chains and infrastructure, then we have indicated the role of new transport corridors in the development of territories. We have built a tree of problems in order to systematize risk situations and identify root causes and consequences. A method for calculating the cargo delivery time is proposed, taking into account the multimodality of logistics chains as well as measures that help reduce risks.

Keywords: arctic development; support zones; risks; multimodal transportation

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1. Introduction

The issues of sustainable territorial development acquire particular 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 new sources. The new territories' development is associated with a number of problems caused by their inevitable urbanization and disruption of ecosystems due to various activity types, which poses the greatest danger to the Arctic zone [1,2]. In the Russian Arctic, a number of complex projects are being implemented, including the development of the industrial economy's sectors and the tourism industry, which is possible only if transport corridors are created for the export of raw materials and goods delivery, as well as solving the problems of population mobility. These activities are accompanied by a variety of risks that can lead to serious consequences. To reduce possible damage, we must understand the risk situations' causes, as well as possible ways to prevent them and minimize the likely consequences. The relevance of an ecosystem-based approach to the integrated stewardship of the Arctic's natural environment is clear. This is mirrored not only in the work of the Arctic Council and its working parties but also in the wider international efforts to implement the Sustainable Development Goals. Therefore, strategic and foresighted planning that takes into account short- and long-term risks and results is important when designing development programs and infrastructure projects [3–5].

The 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 for creating new transport and logistics corridors due to global climate change. A specific role in the implementation of projects for the Arctic development is played by the Northern Sea Route (NSR), which has 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 high carrying capacity of the ships makes it possible to transport large quantities of cargo; mobility of ships), from the point of view of technical and economic characteristics, the following disadvantages of water transport can be mentioned: low speed of cargo delivery; high labor input and the cost of ship production; significant costs for ship operation and infrastructure (seaports, terminals, etc.); and ship operation is inherently connected with environmental problems, namely emissions from diesel engines of ships, mainly in coastal areas of the Baltic Sea. From the above, it can be summarized that in addition to a detailed and thorough analysis of the possibilities of a particular mode of transport, environmental and economic circumstances and threats and risks need to be borne in mind.

The task of ensuring the connectivity of territories is typical for many countries with varying degrees of economic and social development. In our study, we consider the connectivity of the Arctic region with the rest of the territory of the Russian Federation—the country with the largest area. The necessity of this analysis lies in the fact that there are no examples of other countries of a similar size with the same climatic conditions. In addition, it should be noted that existing studies focus on individual kinds of transport without considering the problem as a whole. That's why the research objective is to establish the relationship between the development of transport networks and the development of the Arctic region, the designation of possible prospects for the development of both multimodal transportation as a whole as a strategic event, the contribution of each kind of transport as well as the risks of creating and using international transport corridors, including cumulative impact on the environment.

2. Methods and Materials

The issue of sustainability is a priority in the implementation of major strategic projects that are associated with the development of the mining industry, industrial production and urbanization of territories. We have chosen the Arctic region for research because, in connection with global warming, opportunities for the development of territories are opening up, a significant part of which was previously sparsely populated. The uniqueness of this territory necessitates separate scientific research and the development of development measures that take into account the specificity of the cold climate and the scale of the territory.

The creation and development of infrastructure and supply chains are inevitably associated with potential risks: environmental, social and economic, which arise due to errors in planning and implementing the development strategy. To assess the likelihood of such problems, the tree method is widely used. Particular attention should be paid to the problem of underdevelopment and imperfection of infrastructure since, in this case, there is a high risk of developing man-made disasters.

For this reason, we have analyzed the main strategic directions for the development of infrastructure, as well as each of the possible kinds of transport (sea, road, air and rail), the development of which should be carried out in parallel in order to ensure the required efficiency, sustainability and safety of the transport system as a whole. At the same time, information for analysis was taken from open sources, development strategies and scientific articles. The specificity of the Arctic causes a small number of researchers with unique single studies. We searched the SCOPUS database for keywords, then analyzed the abstracts and then the full texts, filtering the articles sequentially at each stage.

It is important to determine how different situations can be managed in order to reduce the impact of risks and create the most favorable conditions for both the individual and the environment. The more complex the system we are analyzing, the greater the number of risks that can arise in it and the risky situation can be caused both by the sequential action of various factors and by their combination and simultaneous impact. In order to manage risks, it is necessary to understand which of them are most likely and can have the most significant consequences. For these purposes, fault trees serve—as a graphical representation of a logical structure, which presents the relationship between undesirable risk events ("failures") and their causes. As a result of establishing logical relationships between the events that make up such a tree, a qualitative risk analysis is carried out and by analyzing the probability of individual events, a quantitative risk analysis is carried out.

As a result of the literature analysis, the causes and consequences of improper planning of supply chains and infrastructure are considered, and the role of new transport corridors in the development of territories is indicated. A failure tree was used to systematize risk situations and identify root causes and consequences.

3. Transport Role in Territorial Development

3.1. The Concept and Characteristics of Modern Multimodal Transportation

Mixed or multimodal transportation of goods is delivery by various kinds of transport: sea, road, rail or air transportation of goods in any combination. The main purpose of using multimodal transport is to reduce delivery time and costs. A distinctive feature of this type of transportation is the presence of a single organizational, controlling and coordinating center of the transport company.

The article [6] defines the current state of the organization and the effectiveness of multimodal transportation along the Trans-Siberian Railway in the supply chains of Northeast Asia. Importance and efficiency analysis methods are used to measure the levels of importance and efficiency of the logistics service that provides multimodal transport services across the Trans-Siberian Railway from South Korea to Europe. The analysis is based on five criteria (price, timeliness, reliability, equipment systems and customer service) from the customer's point of view.

The purpose of the article [7] is to identify factors that experts consider important for the effective operation of multimodal transportation along the Trans-Siberian Railway. As a result of the analysis, using a hybrid MCDM analysis of Korean logistics companies, three operating strategies were proposed: foreign, direct and small investment in the Russian Far East, Korean logistics companies implementing cold chain logistics service in the fish industry and the government-led "Block Integration System -trains" to ensure the minimum threshold volume of cargo for small- and medium-sized companies.

The authors of the article [8] explore the concept of multimodal transport and provide motives and main trade-offs when using multimodal transport. The study shows that the optimized use of multimodal transport, taking into account their trade-offs, can increase the competitiveness of shippers in a globalized world.

The article [9] examines the impact of intermodal transport between Europe and Asia on territorial development, as well as the main trends in the implementation of projects, such as sea routes, "One Belt—One Road" and others. The intensive use of modernized powerful transport corridors can become an incentive for the development of the territories through which they pass. The authors consider the positive impact of international transport corridors on the development of supply chains.

The high interest in the Arctic development is caused by geopolitical, economic and other factors. The uniqueness of the territories with rich, natural and raw material resources is arousing growing interest both in the Arctic countries and in countries geographically distant from the Arctic. Efficient use of raw materials and logistic potential, biological and water resources, expansion of activities in shelf zones, development of fishing in traditional areas, etc. depends on the development of transport infrastructure, including ITC. Numerous scientific studies have been devoted to the role of transport in regional development.

The transport corridors development, including the NSR as one of the links, will make it possible to organize goods transportation in the north–south direction, uniting the Eurasian space with the help of the international transport corridors (ITC). At the same time, a number of problems appear, the solution of which is associated with the strategic projects' implementation.

3.2. Problems in the ITC Formation and Their Solution

3.2.1. Infrastructure Development Challenges

As a result of active land development in the Arctic zone, a transport and logistics complex are being formed, which serves as the basis for the transport infrastructure development: railways, waterways and roads [10]. To minimize transport problems that may arise in the near future in the Arctic zone, this study identifies the main ways to solve them. To minimize the accident rate and eliminate this transport problem, which is typical for many regions of the Arctic zone, two solutions were proposed: the construction of new transport hubs and road sections and the introduction of new technologies for integrated transport system management.

The article [11] focuses on the potential opportunities for the strategic development of the Russian Federation transport industry. At the same time, special importance is attached to the strategy of advanced development of transport corridors in the regions of the Far East and the Arctic, which have geographical advantages and prospects for the implementation of export–import and transit cargo transportation along domestic and ITC, which is of particular importance in modern global geopolitics in the implementation of the advanced development strategy transport corridors for the realization of export–import and transit transportation of goods, ensuring consolidated and stable cargo flows in transport and logistics chains.

The article [12] is devoted to the study of scientific and technical infrastructure aspects of substantiating the conditions for the deeply integrated development of Siberia, the Far East and the Arctic zone of Russia (AZR), which is based on the creation of transport and logistics corridors between Europe and Asia on the basis of the Northern Sea Route (NSR), as well as the Trans-Siberian and Baikal–Amur Mainlines (BAM). These corridors should contain multimodal terminals and logistics centers integrated into the transport infrastructure of the respective regions. For the further development of the infrastructure of the Macroregion, according to the authors, the strategy's activities should have a cyclical sequence of "fundamental research—applied developments—methods and techniques—algorithms—programs—implementation".

The study's [13] purpose is to identify and formalize modern trends in ITC construction and formation. The authors consider the systems of existing Euro–Asian transport corridors, regions of economic cooperation and agreements on international routes of various transport modes classification as international transport systems. The authors believe that the processes associated with the formation and development of international transport systems at the present stage require additional research, including determining the feasibility and sustainability of their functioning.

The article [14] examines the current state and problems of complex logistics systems development. The authors identified the main elements of the global logistics system in the implementation of various threat types that form cargo flows and proposed promising models and methods for end-to-end scenario analysis of changes in international logistics flow along international transport corridors (including East to West), taking into account the restrictions (border, customs, sanitary, phytosanitary and others).

For the development of the northern Russian regions, new opportunities are created to apply logistics methods in all areas of activity. As shown in the article [15], at the initial stage, the search for optimal transportation schemes for cargo delivery and the distribution of cargo flows in the regions will be engaged in transport and expedition firms, and then these functions will be concentrated in special terminal logistics centers (TLCs), for which the most important will be the most important Safe and reliable transport infrastructure. Decisions on the organization, algorithmic and software of multimodal TLCs can become the basis for their design and introduction in the nodes of the transport network AZR.

Since in interregional transportation land transport is an alternative to international sea shipping, several cross-border land corridor projects have been implemented. It should be borne in mind that although sea transportation is cheaper, it takes more time. The study [16] is aimed at identifying the factors that influence the choice of transport mode for interregional cross-border transportation over long distances. The authors use the Tobit model to estimate the dependent variable, considering eight significant variables: distance, industrial exports, landlocked country/area, neighboring country/area, country risk, infrastructure level, port access time and shipping frequency. The results obtained can facilitate the cross-border land corridor project development to carefully consider factors affecting the optimization of land transport infrastructure through increased investment in paved roads and railways. A limitation of this study is that factors related to environmental impact were not considered.

The main goal of the article [17] is to determine the main technical and technological criteria affecting the traffic synchronization efficiency in the East–West Transport Corridor (EWTC) in the southern corridor part of the Baltic Sea Region (BSR). The study results showed that the main technical criteria affecting synchronization are railway infrastructure and road transport infrastructure at the terminals. The most important criteria for technological interaction are the availability of seaports and railway distribution stations. According to the authors, future studies should use these factors to create models and facilitate synchronization in order to build an interconnected transport system covering all modes of transport.

The article [18] outlines the main provisions of the methodology for designing the integrated development of a multimodal transport network, which are used by the authors to solve the problem of designing the development of a multitype transport infrastructure in the region under study. The paper considers the method of forming the appearance of a multimodal transport network and presents a variant of the regional multimodal transport network of the Far East and the Arctic zone, which will allow this region to combine the growth of extraction, processing and transportation of natural resources to seaports and the implementation of the country's transit potential.

The article [19] discusses the prospects for the development of the transport infrastructure of the Arctic Basin and its subjects, in particular, the strategy for modernizing the transport infrastructure of seaports.

The potential impacts of climate change on transport can affect both transport infrastructure and operations. Paper [20] explores the possibility of direct as well as indirect impacts of climate change and other variables on transport.

The study [21] analyzes the development of a network of railways, roads and transport infrastructure in the northern and Arctic regions of Russia, taking into account natural and climatic conditions, as well as possible ways to overcome these problems. The projects under consideration require scientific justification since their implementation will affect the regional economic and social development since a number of projects may turn out to be economically unfeasible or not have a significant social effect.

The article [22] proposes the use a comprehensive analysis of transport logistics parameters when choosing an international route, for the goal of which a consulting logistics center is being formed. This will make it possible to identify profitable options for the use of vehicles or their combinations in the transport market and make high-quality logistics decisions on the rational international transportation route choice.

Since making decisions on the management of transport infrastructure is a complex task, it is necessary and important to assess its development, at least at the strategic level. The main article's [23] goal is to determine and quantify the contribution of a transport infrastructure project to the economic system during its life cycle. A digital application is designed to evaluate a project to create a new freight transport corridor from the Black Sea to the Southeast Mediterranean, connecting the ports of Burgas (Bulgaria) and Alexandroupolis (Greece), for cross-border traffic that stimulates new business opportunities.

The article [24] presents a systematic approach, including theoretical and methodological aspects of the demand formation analysis for the use of the transport and logistics region infrastructure in the formation of the intelligent module of the regional transport and logistics information system (RTLIS). This system accumulates information about transport and logistics operations in the region or carried out throughout the region. According to the authors, this will make it possible to effectively use the transport and logistics region system, increase the efficiency of production enterprises activities and improve the transport services' quality for the population.

The study's [25] purpose is to analyze the possibilities of blockchain technology and Industry 4.0 for moving supply chains toward sustainability. The authors use the existing literature for these purposes, considering three main areas: (1) energy management in smart enterprises using the Internet of Things (IoT); (2) smart logistics and transportation; and (3) smart business models. The authors conclude that although the blockchain is still developing and there are certain drawbacks, the opportunities that the blockchain offers to increase sustainability can be applied in four directions: (1) development of incentive mechanisms and tokenization to encourage sustainable consumer behavior; (2) increasing the product life cycle transparency; (3) increasing the systems' efficiency while reducing development and operating costs; and (4) promoting sustainability monitoring and reporting across all supply chain networks.

3.2.2. Improving the Efficiency of Road Transport

According to the authors [26], the Arctic region is characterized by the predominant development of extractive industries, the underdevelopment of the transport and logistics infrastructure, an increased level of costs for its operation and technological problems caused by natural features. As part of the study, an innovative approach has been developed to solve the problem of increasing road transport reliability and its interaction with other transport modes in the Arctic, which will ensure the sustainable development of transport in the North of Russia.

In connection with the systematic growth of transport construction in the Russian North and in the Arctic territories, the issues of ensuring the operation of construction equipment, including the organization of its maintenance and repair, are becoming very relevant. The article [27] considers solutions to the problem of locating repair facilities that perform current and restoration repairs, and in some cases major repairs, near construction sites, taking into account the specifics of both the equipment used and the region's natural and climatic conditions.

The article [28] analyzes the limitations of the existing system for accounting for the resource of transport-technological machines in terms of operating time and mileage. It is proposed to evaluate the operating time of the machine by the amount of mechanical work in joules performed by the internal combustion engine, which will optimize the maintenance schedule and increase the readiness of machines and mechanisms in the harsh conditions of the Arctic and Siberia. The authors come to the conclusion that this can contribute to solving the problem of optimizing the maintenance and repair of transport and transport-technological machines.

The article [29] considers the conditions for the continuous operation of road vehicles in the Arctic due to the fuel system modernization and changes in the composition and type of fuel. It is shown that, due to additional operations, the fuel used in the Arctic is more expensive, and when operating at low temperatures, vehicles must be equipped with additional systems (filter electric heating, fuel intakes, etc.). It should be taken into account that the Arctic region is ecologically vulnerable, which means that it is necessary to abandon the use of outdated, environmentally hazardous and expensive technologies, including the use of hydrocarbon fuels.

Based on existing methods for selecting vehicle models for a fleet of excavators and dump trucks, it is proposed [30] to use a generalized selection algorithm that takes into account, among other things, factors that dynamically change over time and negatively affect the performance of production facilities in the Arctic. As part of the transport system modernization of the Lomonosovsky GOK (Arkhangelsk region), in order to adapt to the increasing ore mined volumes, parameters were calculated that lie in the optimal range of dump values for excavator and dump truck models.

The article [31] analyzes the main directions for improving the maintenance and repair of vehicle units in the Far North. The authors found that in order to improve the efficiency of vehicles maintenance and repair in the Far North, it is necessary to develop an integrated system using promising forms of organizing work to restore the operational resource using the "service with responsibility" method, the assembly method or the centralized restoration of units.

The article [32] presents the theory of marginal utility in conjunction with the system of maintenance and repair of motor vehicles. The proposed method makes it possible to increase the utilization rate (efficiency) of vehicles both in the Arctic zone of Russia and in hard-to-reach areas. The application of the provisions of the theory of marginal utility in solving issues of bus service will improve traffic safety and the quality of transportation, which, in turn, will have a positive impact on the economic component of the transport industry.

At present, according to the authors [33], there is no set of tools for the qualitative and quantitative assessment of passenger road transport impact on the gross regional product and its components since failures in the transport management system can cause an imbalance in the field of mining, which is key for AZR. The authors have developed an analytical platform that allows the transport authorities of the Arctic regions and municipalities to respond in a timely manner to changes in the national economic needs and cause adequate reactions in the mining field.

The article [34] proposes a methodology for planning a bus routes network tested in the Norilsk municipality. In cities beyond the Arctic Circle, transport operates in difficult natural and climatic conditions, which creates a difficult traffic situation, and the significant remoteness of industrial enterprises leads to large peak loads due to an increase in passenger traffic during peak hours. The planned route network must meet demand, connect all public places and cover the entire service area. As a criterion for determining the variant of the route network, it is proposed to minimize the time spent on the road to work or other public places.

3.2.3. Sea and River Transportation and Their Development

The problems that create difficulties for the development of rich mineral deposits are analyzed in the article [35] on the example of delivering goods logistics to the Chayandinskoye oil and gas field located in the remote mountainous area of central Yakutia. The authors substantiate a return to the experience of developing navigation on the great rivers of Siberia—the Lena, Ob and Yenisei. The development of large-scale oil and gas projects in the Arctic zone of Siberia requires the active and urgent involvement of inland water transport, which can be sold or leased out when the main planned facilities are completed.

The article [36] uses a two-stage Delphi approach to gather high-quality expert data on what actions the Nordic countries (including Denmark, Norway, Sweden, etc.) can take to prepare for the NSR and reap the potential benefits from trading across the global transport network and obtain and maximize the benefits. Future studies may determine whether cargo owners and shippers will be interested in changing their supply chains to include the NSR, taking into account global trends in the future, as well as exploring the overall cost of using the NSR and its impact on global trade flows.

The priority direction associated with the active Arctic zone (AZ) development is the study of the prospects for the modification of gas carriers (GT). Article [37] includes an analysis of this problem on a macro scale. The authors received a vector for the future transformation of a vehicle for navigation along the NSR into an innovative marine vehicle-tanker-platform-gas carrier. The resulting transformation vector can be used as an idea for designing a sea vessel that solves a number of current tasks and reduces the time T as a priority transformation criterion, which will contribute to the activation of a unique transport route in the AZ.

As shown in article [38], over the past few years, Russian companies have begun to replace the nuclear icebreaker fleet and build new floating nuclear power plants to be located in various ports on the Arctic coast. In parallel, the authorities issued a number of policy documents to create a strong national hydrogen industry. Many public and private corporations, as well as research institutes evaluating projects for the production of hydrogen (including those using nuclear energy), are located in the AZR, especially in the Murmansk region and Yamal.

3.2.4. Arctic Aviation and Prospects for Its Development

Article [39] discusses approaches to deliveries in the Far North conditions from a single center based on the specifics of the aviation enterprises' work and the requirements for the services' quality in this area. It has been proven that the formation of an integrated logistics support system by creating a single supply center to manage the spare parts supply to transport operators at the airports of the Arctic region will reduce their waiting time. This approach reduces the high costs of providing spare parts associated with the difficulties of organizing transportation in the polar regions.

In article [40], the authors identified the most significant hazards and made recommendations to reduce the negative impact of the airfield pavement state on aircraft operation. The results and a thorough analysis of the aircraft structural elements loading, changes in the life characteristics of airframe and landing gear units at the ground stages of the flight showed excessive damage and wear on the aircraft landing gear during long-term operation at airfields in the Far East, North and the Arctic, so if the aircraft life is 30,000 landings, then for the aircraft operating in extreme conditions, it is required to control individual structural elements after 6000 landings.

Study [41] systematized data on the actual avionics failures of modern aircraft with on-board digital systems during operation in extremely low temperatures. It is shown that low-temperature avionics failures are mainly of a critical nature, which requires radical measures to eliminate them. It is also noted that in addition to critical system failures, there are hidden avionics defects at extremely low temperatures, as well as little-studied failures and failures of unknown origin.

Article [42] discusses the features of the air transport network of the Arctic zone of Eastern Siberia based on an assessment of the state of the existing airport network in the Arctic regions. An analysis of the route network showed that the underdevelopment of the route network is due to the low population air mobility of the Arctic zone due to the low population density, the high cost of air travel and the high operating costs of airports in the North.

3.2.5. Rail Transport in the Arctic: Problems and Prospects

Among the main national interests of Russia in the Arctic, one can single out the use of the NSR as a national transport and logistics system, not only through the development of air and sea transport routes but also, through the development and maintenance of the railway (multimodal corridors), which in the future will contribute to the sustainable functioning of the AZR and integrate their regions into a single economic space. Article [43] describes the main tasks in the construction and operation of railway corridors in permafrost soils.

As shown in [44], transport megaprojects, which have institutional and physical-geographical features, can be divided into latitudinal and meridional ones. Some interesting cases are temporary roads and unrealized projects (for example, the Ural Industrial–Ural Polar megaproject, which aims to connect the processing enterprises of the Urals with the raw material base of its Arctic and northern regions by roads along the eastern slope of the Ural River), as well as completed, but subsequently abandoned (for example, the Vorkuta–Salekhard–Igarka railway).

One of the main factors in solving the strategic tasks of Russia in the Arctic is the formation of a single Arctic transport system within the NSR, as a complex of vehicles for the sea and river fleets, aviation, pipeline, rail and road transport, as well as coastal infrastructure (ports, navigation aids, hydrographic and hydrometeorological support and communications). The Russian Arctic, as an LNG source, is an ideal place to use mobile traction driven by a gas engine [45]. LNG trains can be effectively used on the Ob–Kara section of the Northern Latitudinal Railway.

Paper [46] discusses issues related to the use of digital technologies and, in particular, RFID technology in railway transport. It is shown that the introduction of RFID technology will reduce costs while increasing the prestige and safety of railway transport, which will positively affect its competitiveness, as well as optimize transaction costs during shunting operations and reduce train parking time by eliminating the time for checking the correctness of the compilation wagons to trains.

3.3. ITC Europe—Asia

China's Belt and Road Initiative (BRI) has become a central issue in international transport and global logistics since its inception, as infrastructure development and economic and transport corridors affect the interconnectedness of countries along the Belt and Road. Document [47] provides an overview of the logistics, supply chain and transport (LST) literature in the BRI context since 2013, containing 190 English articles on four main topics: (1) maritime and intermodal transport combined with MSR, (2) rail transport in relation to sustainability, supply chain management and cross-border issues, (3) the role of infrastructure in economic and transport corridors, ports and railways for the development of trade and regional economies, and (4) energy supply chain development and carbon emissions.

Editorial [48] sets the context for a discussion of the great global convergence of world economies and the role of the Belt and Road Initiative in reconfiguring key global transport hubs and trade corridors. The importance of technological innovation and structural reforms is highlighted to help businesses manage the growing supply chain complexity and potential failures during the fourth industrial revolution in a sustainable way.

Transport logistics [49] has become one of the important forces shaping the regional economic spatial model and guiding the evolution of the economic spatial model. In the context of the "One Belt-One Road" Initiative, Northeast China is actively participating in the construction of the "Belt and Road", accelerating the construction of its outward-opening logistics channels and developing an advanced transport organization scheme, which is of great importance to give new impetus to "short boards" with low opening rates and lagging opening processes to promote the revitalization of Northeast China.

Chapter [50] discusses the infrastructure of land railways for the development of Russia's transit potential, taking into account the Chinese initiative "One Belt, One Road". As part of the concept of a transit economy, the authors introduce and empirically test the idea of connecting the Northern Sea Route under the auspices of the "Ice Silk Road", providing for the mutual connection of companies from non-Arctic states (primarily Chinese) in the development of natural resources in the Arctic and on the shelf of the Arctic seas with the involvement of additional freight bases for transit, including transportation along the NSR and overland communications along the Asia–Russia–Europe, Asia–Russia–America and Europe–Russia–America routes. The authors believe that at the same time, a large-scale program of transport operations decarbonization on global trade routes should be created in the Arctic, which should contribute to the world economy decarbonization. This will also be facilitated by the creation of innovative industrial belts of land and sea trade routes in the Far North.

Central Asian countries are attracting investment in transport infrastructure to rehabilitate the Silk Road routes and reap economic benefits from participation in international trade. Work [51] is aimed at assessing how the transport corridor "Western Europe–Western China" (WE–WC) influenced the economic potential connecting cities and regions from the transport infrastructure quality to their export potential. The study takes a modest step towards developing a culture of evidence-based decision-making in policymaking in Kazakhstan.

Analysis [52] results show that Russia can play the role of a transit country in the goods transportation from the Asia-Pacific region to Europe, receiving economic benefits from this since there is a redistributing possibility existing and future volumes of container transit from China–Europe through the border crossings, Dostyk, Zabaikalsk and Zamyn-Uud. To realize these opportunities, it is necessary to solve a complex of legal, organizational and technical problems with the help of infrastructure solutions, as well as harmonization of international transport legislation in the field of freight traffic in the China–Europe transportation.

Article [53] proposes a methodology for assessing the region's economic potential affected by transport corridors, as part of the implementation of the Great Silk and Tea Road initiatives, based on the integral indicator calculation, which includes five indices: industrial, labor, food, innovation and financial. The methodology was tested in 28 regions of China, Mongolia, Russia and Kazakhstan in the context of five alternative transport corridors: three routes of the China–Mongolia–Russia economic corridor, the Western Europe–Western China corridor, and the Dostik–Ashankov–Mikhailovka–Uba corridor. According to the authors, the methodology makes it possible to assess the existing region's economic state, compare alternative options for the development of transport corridors, identify priority routes as well as problematic points of regional development.

Work [54]'s goal is to formulate recommendations for improving the Russian national logistics system (NLS). The authors point out that logistics development in the international market is important for any country. After analyzing Russian NLS using six dynamic indicators over eleven years, the authors derive recommendations for its development, grouped into a priority list with two different resulting scenarios. According to the authors, it is necessary to separate measures since the lack of resources may not allow to completely eliminate all identified bottlenecks in logistics at once.

3.4. ITC Infrastructure and Regional Development

Article [55] examines the creation and functioning of multimodal transport and logistics hubs (Multihub), including possible options for their placement in promising "growth points", with the aim of including the Samara province in the new ITC Europe–America and the Arctic–Southwest Asia, which contributes to the development of a multipolar multifunctional region structure. According to the authors, the transport infrastructure not only fixes the city's planning structure but also determines its further development.

Article [56] analyzes the NSR's potential as an ITC in terms of its economic and geopolitical factors in modern conditions, as well as the opportunities and threats of its activities. Based on the ITC characteristics analysis and the requirements for them based on the participants in the international goods movement, the necessary conditions have been formulated that must be met by the ITC. The conclusion about the potential compliance of the NSR with the ITC requirements is based on the following: The NSR meets the requirements of the main transport line; it is linked to rail transport systems, and this link is developing; the icebreaker fleet and port infrastructure are being developed; security technical means are being created and modernized.

The focus of the authors of [57] is the NSR of Russia, which is regarded as a transcontinental Eurasian maritime transport corridor. According to the authors, the NSR will be modernized, even if the Chinese idea of the "Polar Silk Road" is not implemented at all. Among the vulnerable areas of the Silk Road project implementation are harsh natural conditions, restrictions on the navigation season, insufficient capacity of the icebreaker fleet, economic sanctions from the United States and Western Europe as well as the complexity of creating a modern transport infrastructure along the NSR.

The authors of [58] analyze the expert assessment role in addressing the AZR development and ensuring the connectivity of all its territories, which is a national priority. An effective approach in these conditions could be the introduction of innovative programs and projects aimed at reducing the costs of creating and maintaining transport, telecommunications and social infrastructure, improving the life quality and thereby consolidating the population of the region.

Article [59] analyzes typical algorithms and programs based on them for determining the optimal routes for the movement of goods in road transport systems. It was revealed that one of the topical issues related to routing is the search for a solution to the optimization problem according to several efficiency criteria, including the reduction of computational procedures. The purpose of article [60] was to develop proposals for the digitalization of the transport infrastructure of the Arctic in the digital economy.

Prospects for the development and improvement of the transport and logistics system of AZR involve intellectualization at its various levels using innovative technologies. Article [61] summarizes the most significant problems associated with the development of the Arctic region and gives an assessment of the increase in cargo traffic. The result of the analysis was the development of the maritime intelligent transport system's architecture to AZR, which combines the existing modern concepts of autonomous shipping, autonomous unmanned vehicles, maritime unmanned navigation and commercial autonomous shipping.

Article [62] is devoted to a comparative analysis of the state and dynamics of economic development of two constituent entities AZR: the Murmansk region and the Yamalo-Nenets Autonomous District. Since the improvement of shipping and logistics operations due to the greater connectivity of multimodal transportation is a priority for the AZR development, a single digital platform is needed that will create an information space for organizing multimodal transportation along the NSR and provide opportunities for integrated work with shipping documents. Based on actual data on transport processes in the Arctic zone, it will be possible to make high-quality and effective management decisions in order to develop the region and speed up logistics operations.

To implement the optimizing cargo flows process within the framework of an intelligent transport system based on digital technologies, it is necessary to develop an appropriate mathematical apparatus adapted to specific tasks. Article [63] presents an approach based on the synthesis of computer modeling methods, which makes it possible to carry out an experimental research program based on a comprehensive methodology for organizing and managing the interaction of terminal and warehouse complexes and transport infrastructure facilities.

Document [64] proposes an innovative forecasting methodology to estimate future transit volumes through a port in Iran using scenario planning, econometrics and heuristic calculations. The assessments take into account major transport corridors, such as ITC North–South, Belt and Road Initiative, Suez Canal Route, TRACECA, Trans-Asian Railway, Central Asia Regional Economic Cooperation (CAREC) and Trans-Siberian Corridor. The proposed methodology is not tied to a specific country, so it can provide port authorities with valuable information that will help to cope with uncertainties in international trade and logistics in strategic planning.

3.5. ITC and Green Logistics

Paper [65] proposes a new quantitative model for assessing the supply chain (SC) structure based on various manufacturing technologies, taking into account environmental and economic aspects, which identifies suitable KPIs for assessing SC in the context of additive and conventional manufacturing. The document has practical meaning; the model can help companies make decisions. The framework allows you to change the number of KPIs, and the relative weights can be updated. In the future, the model can be used to study the effect of additive technology on mixed production.

In [66], the problem of minimizing emissions by dissimilar vehicles in a heterogeneous road and transport network is considered. The procedure is based on an outlier-oriented elementary shortest path problem on a multigraph, which is solved using an inverse labeling algorithm. It is shown that the labeling algorithm can be accelerated by setting up a dual master program and limiting the number of labels in a subtask. The column generation method is used to set up fast heuristics, as well as the transition and price algorithm.

Article [1] describes the main problems of road vehicle pollution, proposes methods to reduce the pollution load and clarifies the relationship between environmental pollution and global warming through its indirect impact on the Arctic climate.

As part of study [67], an ecological model of the SC and logistics was developed using network analysis. The best route for each significant case was the shortest route of the total distance from each recorded stop. The results show that the distribution center can help shorten the distance, leading to a reduction in greenhouse gas emissions.

Study [68] calculates the relative competitiveness of six Norwegian coastal cities as multimodal transport hubs. At the same time, the authors note a correlation between emissions and the cost of routes (the cheaper the route, the lower the emissions). The authors argue that infrastructure investment should be planned with competitiveness in mind while noting that of the six cities analyzed, only Kirkenes can provide an alternative to Rotterdam that is "just competitive".

Article [69] shows that the impact study of China's trade with the countries participating in the Belt and Road Initiative (BRI countries) is important for "green" logistics development. Based on the findings, the corresponding policy implications are suggested. In addition, as a platform, not only will help these countries make a low-carbon transformation but will also contribute to global environmental sustainability.

Foreign corporations have a dynamic potential to improve the environment in developing countries through green supply chain management (GSCM) practices and partnerships with governments and domestic firms to further reduce environmental impact. In this context, article [70] has critically analyzed three strands of the GSCM literature that contributes to cleaner production, identifying the basic methods and driving forces for the adoption of GSCM to improve the environment in developing countries.

In the literature on road freight transport, more and more attention is paid to environmental aspects in order to reduce the logistics contribution to carbon dioxide emissions. Article [71] presents a systematic quantitative review of the literature on road freight transport decarbonization using bibliographic linkage and network analysis methods through systematic literary mapping. Despite its limitations, this study contributes to understanding the intellectual structure and emerging research areas of the literature on road freight transport decarbonization.

Article [72] discusses the new international land–sea trade corridor impact, jointly built by the western provinces of China and the ASEAN countries, on freight transport structures and proposes related proposals for the development of international logistics service providers. In connection with the strengthening of international economic cooperation and the rapid development of the global transport system, the corridor is seen as an important element in regional economic development.

Many national economy sectors are associated with the need to perform various transport, as well as transport and technological processes. These works' effectiveness is directly related to the reliability and environmental friendliness of vehicles operated in extreme off-road conditions in the AZR [73]. In the last two decades, in solving this problem, the stage of creating environmentally friendly off-road vehicles capable of operating efficiently on soil surfaces with low bearing capacity has begun. Further prospective studies of ultra-low-pressure tires involve the use of the particle dynamics method, which will allow us to consider in more detail the process of interaction of a highly elastic tire with deformable soil.

According to the authors of [74], the priority areas for the automotive industry development are improving the environmental performance of vehicles, passive and active safety, autonomization and robotization of vehicles and the use of intelligent safety and control systems. When designing trucks, it is necessary to form layouts and structures with internal combustion engines operating on both liquid oil and gas fuels or electricity.

Given the difficult natural and climatic conditions of the Arctic region, there is a high risk of transport accidents of various types that can potentially threaten the environment, the population and the entire ecosystem of coastal areas. The authors of [75] propose to create an intelligent decision support system that would allow for detecting traffic accidents, predicting their development and justifying appropriate operational decisions.Additionally, the authors describe the implementation of the elements of such an intelligent system, which allows for predicting the volume of environmental load [76] and optimizing traffic light operation modes [77].

Taking into account natural and climatic factors in the AZR is extremely important for organizing successful loading and delivery of various cargoes and passengers. The well-known advantages of road vehicles over other transport modes make its mode indispensable in the conditions of the Far North and the Arctic. However, the requirements for the reliability and safety of transportation are significantly increasing. Article [78] considers a method for predicting the operating time of temporary transport routes (winter roads) used for transportation most of the year. The development of satellite navigation, on the one hand, and the equipping of vehicles with onboard systems for informing drivers about the weather conditions on the route, on the other hand, have created the basis for the use of intelligent transport systems. In this regard, highly automated vehicles, or unmanned transport systems, are a necessary link in the development of the northern territories and in solving the problem of "territorial connectivity".

4. Results and Discussion

Development of the Arctic is carried out through the «support zones» (SZ) system. A total of nine zones have been identified for the purpose of uniting all projects and resources in each of the regions to develop and maximize synergistic among the socioeconomic activities, communications and resource potential of the Arctic region. These regions will use the transportation capacities of the NSR, river crossings, aviation and rail transport [79].

4.1. Support Zones and Their Role in the Arctic Development

The development of SZ has a social context, allowing to develop both local regions and the Arctic part of Russia as a whole. This contributes to bringing the life quality of the population living and working here to a new level. Considering the significant size of the territories and the massiveness of the project as a whole, it is advisable to use a combination of state and private investments. At the same time, the state plays the role of a strategic partner, defining development milestones and private partners that are involved in the implementation of tactical measures. The framework of the support zones will be formed by enterprises of the transport and industrial complex, first of all: (1) roads, the tasks of which are to unite NSR, support zones and new raw material centers into a single network; (2) centers of mining, processing and transport infrastructure.

The basic difference between the emerging state program on the socioeconomic development of Russian AZ is a new, comprehensive development way for the specific Arctic territories. A new mechanism for regional development (via SZ) was proposed by the Ministry of Economic Development of Russia in March 2016 based on the existing administrative-territorial division, resource base and operation of transport hubs, including NSR.

1. Kola SZ. Advantages: favorable geographic location, year-round ice-free ports, mineral reserves, as well as relatively developed transport and energy networks, a system of industrial enterprises, a scientific and educational sphere.
2. Karelian SZ—includes about 40% of the territory of the Republic of Karelia (these are five northern regions and the Kostomuksha city). Advantages: a common long border with Finland, a developed border and road infrastructure and the formation of all-Russian corridors on the territory of the Republic of Karelia.
3. The Arkhangelsk SZ—advantageous geographic location: a developed network of railroads and an all-season port (from March to November for any ships, from November to March only for ice-class ships or with icebreaker assistance).
4. The Nenets SZ is associated with the economic prospects for the development of the NSR and mining.
5. The Vorkuta SZ includes the municipal formation of the urban district "Vorkuta" (MO GO Vorkuta) of the Komi Republic.
6. The Yamalo-Nenets SZ belongs to the most promising and is capable of providing a stable cargo flow to the NSR sea ports.
7. The Taimyr-Turukhansk SZ on the territory of the Krasnoyarsk Region has a resource extraction and industrial focus. It includes a large agglomeration in the Arctic—the Norilsk industrial region (centered in the city of Norilsk).
8. North Yakutsk support zone, located in the Republic of Sakha (Yakutia). Its center is the port of Tiksi, one of the key ports in the eastern part of the Northern Sea.
9. Chukotka SZ—on its territory there is a number of transport infrastructure objects that are backbone for the Chukotka Autonomous Okrug, which can become the main points of growth in the NSR eastern sector and the Russian AZ.

The creation of the "Arctic development support zones" (Figure 1) includes an integral project approach to the development of the area based on the principle of ensuring the interconnection of all "sectoral" measures at the stages of planning, goalsetting, financing and implementation. This will reduce all types of financial costs. Focusing the support zones on the Northern Sea Route seaports will make it possible to intensify the work of ship-building and ship-repair enterprises of the Arctic zone as well as in other constituent entities of the Russian Federation.

The directions of the region's development depend on the resource, raw materials and infrastructure characteristics, which differ for different support zones. In accordance with this, among the support zones, there are zones with a developing transport frame—Arkhangelsk, Kola and Karelian; with a frame that is at the stage of formation—Yamalo-Nenets and North Yakutsk; with a frame at the design stage—Nenets and Vorkuta; with a frame which requires reconstruction and modernization—Taimyr-Turukhansk and Chukotka. Taking into account the peculiarities of the region-specific transport framework, differentiated goals are set as either investment and activation of all types of transport (for the Arkhangelsk, Karelian and Kola zones); or construction and connection of a railway line to the port of SPM (for the Nenets and Vorkuta zones); the "sea–land" and "sea–river" corridors are strengthened with the modernization of seaports (for other zones).

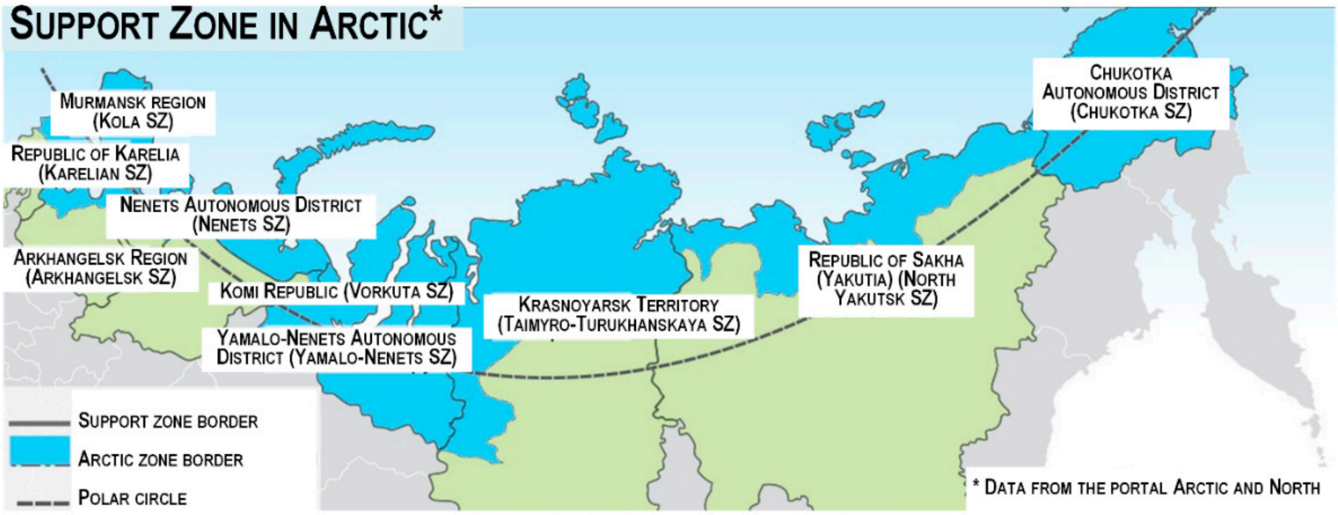

Figure 1. Support zones in Arctic [80].

4.1.1. Mineral Resource Centers

The Yamalo-Nenets SZ will be based on the oil and gas chemical cluster. Already, more than 80% of Russian gas is produced at the Okrug's fields, which is one fifth of the world's production. Due to the projected depletion of the continental subsoil, it is planned that the prospect will be produced in the north of the Yamal Peninsula, on the shelf of the Obskaya and Tazovskaya bays of the Kara Sea, which will be able to compensate for the falling volumes of such fields as Urengoyskoye, Medvezhye, Vyngapurskoye and Yamburgskoye. New gas production areas will provide more than a third of gas production in the country, which will allow the development of the eastern export direction and the new terminals for the liquefied gas production construction in the Arctic.

The development of the Kola SZ is associated with the wealth of the Murmansk region in minerals. To develop this potential, the program envisages supplying the region with qualified personnel through local educational institutions, including the recently established Center for Arctic Competencies and Murmansk State Arctic University. The program includes investments in the Kola SZ educational infrastructure development and the attraction of about two thousand high- and medium-level specialists from other Russian regions.

The Murmansk region is one of the largest and most economically developed regions of the Russian European North. The enterprises of the mining complex form the basis of the Murmansk region economy. There are four large mining enterprises operating in the Murmansk region, which employ about two hundred mining dump trucks, consuming up to 85% of the industry's diesel fuel.

JSC Kovdorsky GOK (Kovdor Mining and Processing Plant) is the second largest producer of apatite concentrate in Russia in terms of production, a major producer of iron ore concentrate, and the only producer of baddeleyite concentrate in the world, the city-forming enterprise of Kovdor. The enterprise has 68 quarry dump trucks.

JSC "Olkon" (Olenegorsk Mining and Processing Plant) develops deposits of ferruginous quartzites of the Zaimandrovsky iron ore region, located in the vicinity of Olenegorsk city, which is one of the raw materials of the world's largest steel and mining company Severstal PJSC. It is Russia's northernmost producer of high-quality iron ore concentrate with a content of over 68% iron, the main consumer of which is the Cherepovets Iron and Steel Works of PJSC Severstal. Olcon JSC has about 30 open pit dump trucks.

Mining company JSC NWPC is the main raw material asset of Acron Group, one of the leading producers of mineral fertilizers in Russia and the world. The Oleniy Ruchey mining and processing enterprise mines ore by open and closed methods to produce high-quality apatite concentrate with a volume of up to two million tons per year, using twenty-one mining trucks.

The Kirovsk branch of JSC Apatit, PhosAgro's base enterprise, has been operating on the basis of the apatite-nepheline ore deposits of the Khibiny massif for more than 90 years. This is the world's largest enterprise for the production of high-grade phosphate raw materials, and the only producer of nepheline concentrate in Russia. The Vostochny mine is mining the Koashvinskoye and Nyorkpakhkskoye deposits in an open pit. The work is carried out in difficult mining and geological conditions: the complex structure of the ore deposit, the presence of cover moraine, significant water inflows into the career and avalanche slopes. The company operates 73 dump trucks.

The main economic sectors that will ensure the Arkhangelsk SZ development will be shipbuilding, mechanical engineering, logistics, timber industry and tourism. In addition, it is planned to develop new areas, such as the extraction of lead, zinc and silver. Moreover, the Arkhangelsk Region will focus on transport infrastructure development in order to provide a full-fledged corridor for Arctic development.

The Taimyr–Turukhansk SZ formation is expected on the territory of the Taimyr and Turukhansk districts of the Krasnoyarsk Territory and Norilsk. The Norilsk Nickel company is already operating on this territory. The company's Polar Division produces more than 90% of the Russian volume of nickel, more than 40% of copper and 98% of platinum group metals. The company plans to implement projects to expand the ore base. In addition, the development of the Norilsk Metallurgical Center can be supported by the development of deposits of platinum group metals "Chernogorsk" and "Norilsk-1" (southern part) by the company "Russian Platinum", as well as the development of the Maslovskoye deposit. Moreover, within the framework of the project for the creation of the Taimyr–Turukhansk SZ, it is planned to develop coal deposits. The Severnaya Zvezda company plans to build an open pit, an enrichment plant, a thermal power plant and a 120 km branch line to the Dikson settlement on the Syradasay prospective area. The Vostok Ugol management company, which has licenses for the geological study of coal in the Taimyr coal-bearing basin, plans to export it to Western Europe and the Asia-Pacific region. For this, the possibility of building a coal terminal in the Dikson port in the area of Cape Chaika with a cargo turnover of ten million tons of coal per year is being considered. It is planned to create new centers for hydrocarbon production. In the SZ, the subsoil structure of the companies Lukoil and Rosneft is being studied.

4.1.2. Transport Infrastructure

The formation of the North Yakutsk SZ is a pilot project; its experience is subsequently planned to be extended to the entire territory of the Arctic zone. The emphasis will be placed on the development of transport infrastructure. It is mostly water and is formed around the NSR and navigable rivers of the Lena basin. Reconstruction of ports, creation of a high-tech Zhatayskaya shipyard, construction of river vessels of various types and purposes as well as the construction of "river–sea" class vessels are envisaged. In addition, it is planned to reconstruct regional and local airports (Chersky, Chokurdakh, Tiksi, Deputatsky).

The creation of a transport infrastructure based on a unified system of the NSR, air traffic and highways are also important for the Chukotka SZ. To increase the transport accessibility of this region, it is necessary to reconstruct the airports of regional and local significance: Bay of the Cross, Keperveem and Beringovsky. Air transport is the only main mode of transport that connects these settlements with the rest of Russia.

4.1.3. Development of the Shelf

In the Nenets Autonomous Okrug, the stake will be placed on the continental shelf development. It is planned that by 2020 the production of oil and gas in the region will grow to 32–35 million tons of oil equivalent, the growth of industrial production in 2030 compared to 2007 will increase by 2.5 times and the real income of the population will increase by 3.5 times. However, in order to achieve these indicators, the region will have to eliminate the discrepancy between the scale of industrial projects unfolding here and the development of new deposits on the Arctic shelf. For this, several large projects for the construction of new transport routes and the development of port infrastructure will be implemented in the NAO at once.

The Komi SZ includes the municipality of the urban district "Vorkuta". Today it is a single-industry town and the largest coal mining center in the Pechora coal basin. It is expected that the activities of the Vorkuta support zone can contribute to an increase in coal production to 21.4 million tons per year.

Another area that is actively developing is fishing and fish processing. A total of 15% of all Russian fish is caught near Murmansk. According to the Federal Agency for Fishery, in 2019, almost 659 thousand tons of fish were caught in the region (mainly horse mackerel, mackerel, sardines and codfish), 90% of which was processed in Murmansk and shipped to retail chains. Three seaports in the region were loaded, including the leader in the transportation of goods in the northwestern part of Russia—Murmansk Commercial Sea Port JSC.

4.2. New Transport Corridors and Their Role in the Territories Development

4.2.1. Northern Sea Route

NSR can potentially become a new transport corridor that will provide most of the traffic; this direction is valuable because the NSR guarantees the delivery of imported goods to the Baltic ports and, in particular, to St. Petersburg. This project as a whole will be beneficial for the country's economy, but it is important to ensure the flow of goods in both directions in order for the project to become cost effective. Today, the NSR is called the only accessible water route connecting the Far East region with the Central and Northwestern ones, as well as the shortest route between Europe and Asia. The development of the NSR opens up prospects for obtaining state orders for a wide range of St. Petersburg enterprises that have the opportunity to apply competencies from dredging and port construction to ensure the safety of navigation in high latitudes.

The plan for the development of the NSR until 2035 includes more than 150 measures aimed at creating the infrastructure of the NSR, ensuring the reliability and safety of the transport framework for the delivery of goods to the Arctic zone. Projects are also envisaged to increase the investment attractiveness of the region in order to intensify its development. As part of the Arctic LNG-2 project, it is planned to build a terminal for the liquefaction of natural gas and gas condensate "Utrenny". An oil loading terminal is being built with a fleet for receiving and storing oil of the terminal in the port of Sever Bay, which will ensure the transshipment of oil from the Vostok Oil fields along the NSR, and the Yenisei coal terminal is also being built. In addition, the plan includes measures to create coastal and hydraulic structures for the needs of the Baimskoye field, the creation of marine transit hubs for reloading liquefied natural gas in the Kamchatka Territory and the Murmansk Region and a transit hub port in Vladivostok. There are also plans to create a transport and logistics hub in the Sakhalin seaport of Korsakov, increase the functionality of the Murmansk and Arkhangelsk transport ports and equip Tiksi and Dikson with ship bases for bunkering and maintenance.

A separate section of the plan is devoted to the creation of the icebreaking fleet ships, including the lead icebreaker of the "Leader" project and the development of Arctic shipbuilding and ship repair production facilities. In addition, it is planned to build an emergency rescue fleet of 46 ships and equip the Arctic emergency rescue centers of the Ministry of Emergency Situations with helicopters. If it is possible to ensure the regularity and predictability of deliveries through the NSR, this will boost the development of St. Petersburg as one of the largest transport hubs in Russia and create additional jobs not only in the transport and logistics complex but also in industries that will receive an impetus to development reduction in transport costs. These are processing and distribution of fish and seafood, mechanical engineering, production of equipment for mining and energy production and food production.

Murmansk seaport is the largest port in the world beyond the Arctic Circle; ice free and with deep water, this is the only port in the European part of Russia with free access to the open ocean with a relatively low intensity of navigation, as well as the largest junction of the ITC "North–South" and "East–West". The main advantage of the Murmansk port is the ability to receive vessels with a deadweight of more than 300 thousand tons, a draft of up to 15.5 m and a length of more than 265 m all year in the NSR waters round. The Murmansk port includes a commercial port, a fishing port and a passenger terminal. The commercial port has 17 berths with a total length of about 3 km. The transport infrastructure of the commercial port ensures the reception, maintenance and repair of ships, as well as the transshipment of apatite concentrate and mineral fertilizers, bulk (oil, oil products), bulk (ore, imported alumina, etc.), general and container cargo. The fishing port includes an oil depot, two cargo areas, a railway facility, an ice plant and repair shops; it has 50 berths with a total length of about 4 km.

The marine passenger terminal includes a passenger pier with two 148 m long berths for the liner fleet, three floating berths for local vessels and a marine terminal. The passenger terminal serves passengers all year round on the socially significant inter-municipal sea lines along the coast of the Kola Peninsula Murmansk–Ostrovnoy–Murmansk and Murmansk–Ostrovnoy–Chavanga–Ostrovnoy–Murmansk. In addition, the world's only nuclear-powered icebreaker fleet is based in the Murmansk port, as well as ships of many shipping and fishing companies (Murmansk Shipping Company, Murmansk transport branch of the Norilsk Nickel GCM, Murmansk trawl fleet, the Union of Fishermen of the North, etc.).

Murmansk port is also closely connected with the industrial centers of Russia and foreign countries by air (Murmansk international airport, Apatity co-based airport), by road (federal highway P-21 "Kola", international automobile checkpoints "Lotta" (average annual traffic intensity is about 950 vehicles per day), "Salla" (about 700 units) and "Borisoglebsk" (1600 units) [4]) and by rail (Murmansk railway). That is why there is no doubt that the port of Murmansk is the base port of the Arctic basin for ensuring cargo transportation along the NSR, and its integrated development will allow the formation of a qualitatively new transport infrastructure in the Arctic capable of providing a solution to the problem of socioeconomic development not only of the Arctic territories but also of the Russian economy generally. Murmansk is one of the key ports. Its capacity is planned to be increased by 18 million tons.

Five investment projects will be implemented in the region to create a transport and logistics complex on the NSR. In particular, it is planned to build the Tuloma, Udarnik, container cargo terminals, the Lavna coal, the general cargo transshipment complex, and the terminal for the transshipment of liquefied natural gas (LNG).

The Tuloma terminal is being built mainly for the needs of the fertilizer company PhosAgro. Its commissioning is scheduled for 2023. The terminal's capacity will be four million tons of cargo per year, with the possibility of increasing up to six million tons. Norebo Group plans to implement a modern refrigerated terminal, "Udarnik", for servicing fishing vessels and delivering fish products to domestic and foreign markets. The terminal will provide loading and unloading services, warehousing and storage of frozen and refrigerated cargo. Its planned capacity is 800 thousand tons. The construction of the terminal is at the initial stage; the launch is scheduled for 2026.

The terminal for the container cargo in the Murmansk region is being built by the logistics operator of the state corporation Rosatom, LLC Rusatom Cargo, whose tasks include the implementation of the Northern Sea Transit Corridor (NSTC) project to create a comprehensive logistics proposal for the transit of container cargo through the NSR. The company's goal is to annually transport 800,000 containers along the NSR at the start and increase the capacity of the artery to 4 million containers. The start of the construction work of the Murmansk container terminal was in 2021, and the start of operation is scheduled for 2024.

The complex for the transshipment of coal and general cargo, “Lavna”, is being built in two stages. In the first stage, its capacity will be 9 million tons per year, at the second stage, after reaching full capacity, it will be 18 million tons. Initially, it was planned to complete the first stage in 2020 and the second stage—in 2021. However, due to a change in shareholders and the preparation of a concession agreement, construction began only in September 2021. The 660 m long deep-water berth under construction will be able to simultaneously receive two large-tonnage bulk carriers with a deadweight of 20,000 to 150,000 tons. The Kola Bay does not freeze, so the terminal will operate year round without the involvement of icebreakers.

In Ura Bay, near Murmansk, Novatek has begun construction of the port’s largest LNG handling complex. The terminal’s capacity will be 41.4 million tons. The total investment is estimated at 70 billion rubles. The project was approved by the Government of the Russian Federation in July 2019. It is planned to launch the complex in 2023.

A deep-water area of the seaport is being built in Arkhangelsk. The project includes two specialized terminals—for mineral fertilizers, bulk oil cargo and gas condensate, as well as four universal terminals with a total capacity of up to 38 million tons. The project is being implemented in two stages: 2018–2023 and 2026–2028. The declaration of intent to invest in construction was approved by Rosmorrechflot back in October 2017. Then, preliminary geological and survey work was carried out, and the proposed construction site was determined. It is planned to build access roads and railways to the deep-water area. The cost of construction is estimated at 149.8 billion rubles. Thus, the program for the development of the Arkhangelsk port involves the diversification of the cargo base through the creation of specialized terminals for various types of cargo.

4.2.2. ITC “North–South”

The ITC “North–South” is a multimodal route with a length of more than seven thousand km, which should connect St. Petersburg with the ports of India and Iran and compete with the transfer of goods through the Suez Canal. “North–South” consists of three routes: the first runs along the western coast of the Caspian Sea through Dagestan, Azerbaijan and Iran; the second is maritime and provides interconnections between the ports of all states of the Caspian Sea basin; the third route runs along the eastern shore of the Caspian Sea from Russia through Kazakhstan and Turkmenistan to Iran. The first and third routes provide both rail and road transportation. This is a multimodal route that starts in St. Petersburg and ends in the port of Mumbai (India). When bypassing the Caspian Sea, the corridor is divided into western and eastern branches and also includes a trans-Caspian multimodal section. Moscow and St. Petersburg will become the endpoint of the ITC “North–South”, passing through the Volga–Caspian Sea Shipping Canal (Figure 2a,b).

As a result of increased activity to modernize and improve the ITC “North–South”, Russian exporters located in the Northwestern, Central, Southern, Volga, North Caucasus and Ural federal districts will have access to new markets.

To manage the goods flow, harmonize border control procedures and ensure the seamless passage of goods from the ports of the Persian Gulf to the Baltic and vice versa, Russia, Azerbaijan and Iran are negotiating the creation of a tripartite transport and logistics operator of the western route of the ITC “North–South”. The dredging and reconstruction of the Volga–Caspian Sea shipping channel is underway, as well as the development of the ports of Astrakhan, Olya and Makhachkala in Russia. The Alyat port in Azerbaijan is being expanded. Iran is starting to work on modernizing and integrating its ports with the country’s railway system. Investments will also be made in the development of terminals and the construction of logistics centers in the ports of Bandar Abbas and Chabahar.

It is expected that by 2030, the volume of Russian cargo along the North–South corridor will almost double—from the current 17 million to 32 million tons. The Baku Declaration dated 9 September 2022 notes that by 2030 the carrying capacity of the western route of this corridor should be increased from the current 9 million tons to a level of at least 15 million tons of cargo.

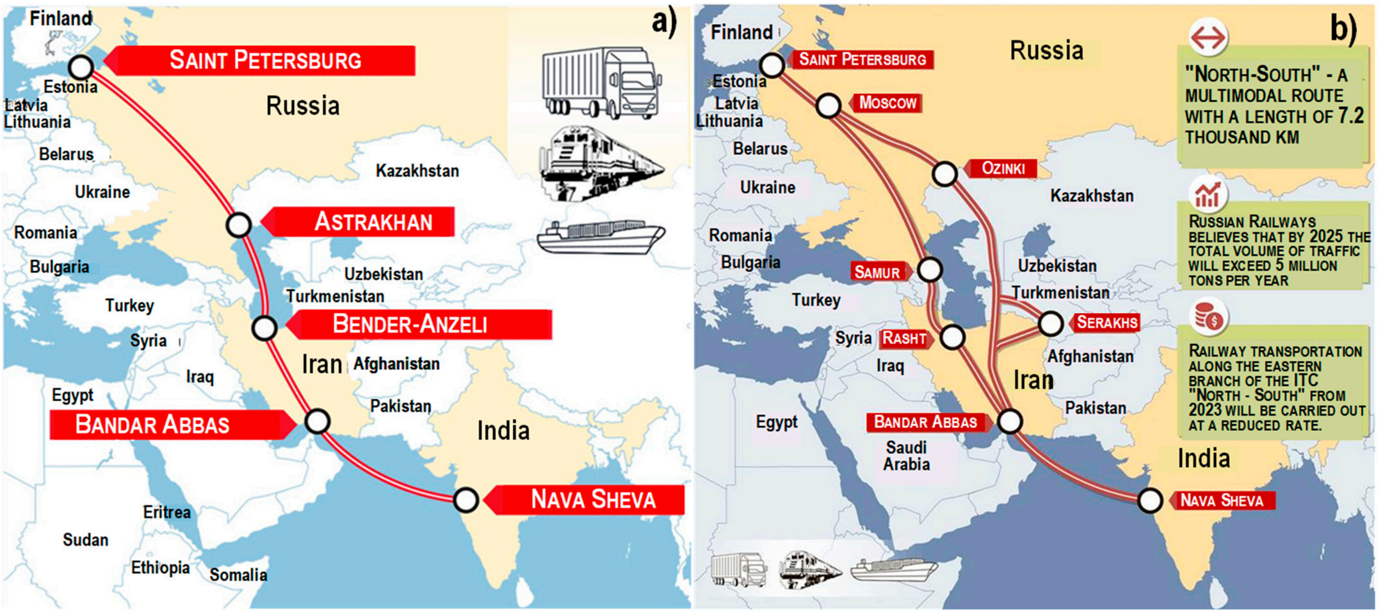

Figure 2. ITC "North–South" (route options: (**a**)—including the Caspian Sea, (**b**)—bypassing the Caspian).

Kazakhstan has already increased cargo transportation through the Caspian by more than 2.5 times. Main export items from Kazakhstan: ferrous and non-ferrous metals, chemicals and soda, grain crops, oil products, consumer goods, etc.

Russian Railways plans to launch a regular container transportation service along the eastern branch of the ITC "North–South"; in this direction, the transportation of metallurgical products through Turkmenistan to Iran and the UAE is being worked out

According to the agency, within the framework of the Trans-Caspian International Transport Route (TITR), a regular container service has been established between the ports of Aktau and Baku, as well as a ferry service on the Kuryk–Baku line. A 2.5-fold increase in the volume of cargo transportation through these routes has been noted since the beginning of 2022.

On 14 July 2022, the first Russian rail transit cargo for India arrived in Iran, marking the official launch of the eastern section of the North–South rail transport corridor.

The main product categories of the ITC "North–South" suitable for containerization are food (21.2%), metals (16.6%), wood and paper (9.5%), machinery and equipment (8.3%) as well as mineral fertilizers (4.9%). According to the authors of the EDB analytical report "North–South International Transport Corridor: Creation of the Eurasian Transport Framework", the potential volume of transportation unsuitable for containerization of cargo will be from 8.7 to 12.8 million tons by 2030, mainly due to transportation grain crops. Ultimately, taking into account the potential of two types of product categories—suitable and unsuitable for containerization, the total potential for freight traffic along the ITC "North–South" is expected to be from 14.6 to 24.7 million tons in the future by 2030.

In the event that favorable conditions are created for the development of transportation along the North–South ITC (elimination of infrastructure bottlenecks, simplification of border crossing procedures, an agreed tariff policy, the formation of a corridor management mechanism and so on), the list of interested countries and countries participating in the agreement may expand. These may include some countries of the Persian Gulf, the Indian Ocean and East Africa, as well as Turkmenistan, the Kyrgyz Republic and the Republic of Uzbekistan in Central Asia, China (in terms of developing trade with Iran) as well as some states of Central and Eastern Europe.

The contribution of the North–South ITC to the implementation of international initiatives and programs is important, such as the Vienna Program of Action for Landlocked

Developing Countries for the period up to 2024, the UNESCAP Regional Action Program on Sustainable Transport Connectivity in Asia-Pacific Region (APR)" (I stage 2017–2021), planned for adoption at the Fourth Conference of Ministers of Transport of UNESCAP (14–17 December 2021) and "Regional Action Program for Sustainable Development of Transport in the Asia-Pacific region for 2022–2026". It is obvious that the development of the North–South ITC will contribute to the policies of the Sustainable Development Goals (SDGs), the UN General Assembly resolutions on sustainable transport and transit transport corridors as well as the recommendations of the two global UN conferences on sustainable transport, which were held in November 2016 in Ashgabat and in October 2021 in Beijing.

In prospect, the ITC "North–South" can become a transport artery that contributes to the achievement of the Eurasian Economic Union goals. The creation of such large-scale transport corridors allows, on the one hand, to reduce the time and cost of transportation, and on the other hand, it diversifies delivery methods and, therefore, contributes to sustainable development globally.

The ITC, in addition to solving the main task—the growth of trade volumes between the final connecting regions, also contributes to the construction of industrial parks and special economic zones along the transit route. In particular, strong ties are being created, and production and logistics cooperation is developing between the member states of the Eurasian Economic Union and the major developing countries of the Persian Gulf and the Indian Ocean, including Iran, India and Pakistan. This contributes to international integration, the exchange of experience and technology, the creation of jobs, and, in general, improves the standard of living of the population. The global strategic task of reducing the environmental load on the surrounding territory is also being solved. The creation of land ITCs involves the replacement of sea routes with rail delivery, which is more environmentally friendly in terms of CO emissions.

4.3. Risk Management of Transport and Logistics Processes

With the implementation of the Arctic Development Strategy, the logistics chain will include various modes of transport after the creation of the appropriate transport infrastructure transport structure. In this case, in general, we can estimate the delivery time of goods as follows:

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

w,p = {1—automobile transport, 2—water transport, 3—railway transport, 4—air transport}, $w \neq p$;
i—movement section;
j—customs documents registration point;
k—point of loading and unloading;
t_i—travel time on the i-th section by w-type of transport;
y_j—time of customs documents registration at the j-th point;
s_k—time of loading, unloading and storage at the k-th point;
A_w, B_w, C_w—a set of traffic sections, customs clearance and loading-unloading points by w-type of transport, respectively;
r—duration of rolling stock and infrastructure facilities unplanned repair;
l—downtime of transport due to unplanned repair impacts;
D_w—the number of the w-transport's downtime, considering unplanned repair;
m—downtime associated with the work schedule and rest of drivers;
v—the duration of downtime associated with the drivers' work and rest schedule;
n—downtime or increase in driving time associated with bans on the movement of heavy vehicles;
z—the duration of downtime or an increase in the movement time associated with bans on heavy vehicles movement;

E, F—the number of vehicle downtime, considering the above reasons, respectively;
o—point of transshipment from one type of transport to another;
x_o—transshipment time at o-th point from w-th to p-th type of transport;
$G_{w,p}$—a set of points of transshipment from the w-th to the p-th type of transport;

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

The creation and development of infrastructure and supply chains are inevitably associated with potential risks: environmental, social and economic, which arise due to errors in planning and implementing the development strategy. To assess the likelihood of such problems, the tree method is widely used. Particular attention should be paid to the problem of underdevelopment and imperfection of infrastructure since, in this case, there is a high risk of developing man-made disasters. Therefore, we built a tree that helps to analyze various situations, highlighting the root causes and consequences (Figure 3). When forming logistics chains along the ITC, it is necessary to take into account both the peculiarities of natural and climatic and the country due to transport modes used. The complex risk of event G is estimated as the sum of basic events and can be calculated using the formula:

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

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

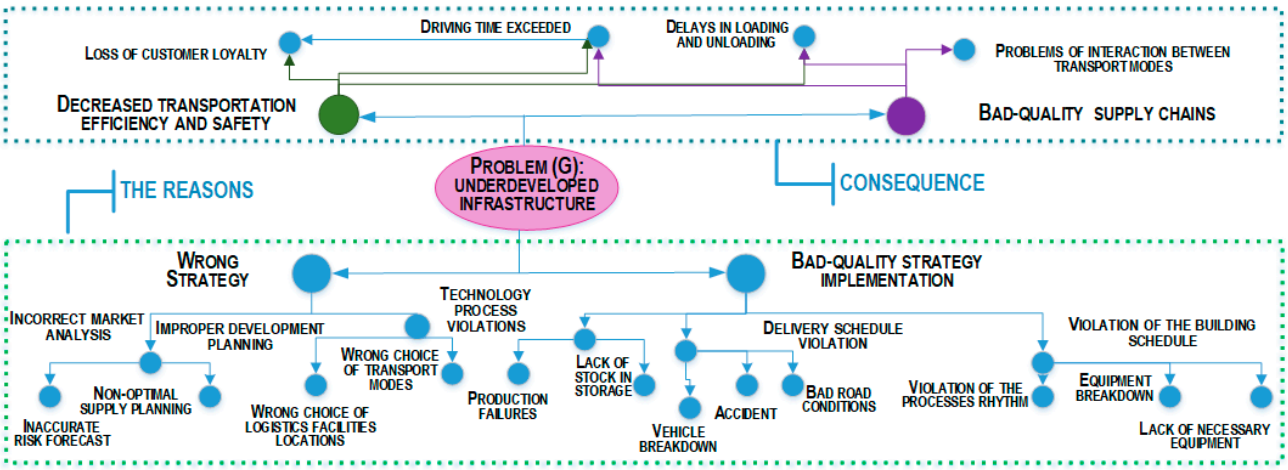

Figure 3. Problem tree to streamline the causes and consequences of the underdeveloped NSR infrastructure.

Now all the prerequisites have been created for creating a single end-to-end logistics chain (based on a single digital space and smart technologies), all facilities in which will use common data, on the basis of which all logistics processes will be implemented (Figure 4). This will not only optimize the processes themselves based on more accurate forecasts but also reduce risks. At the same time, the interaction of the participating countries at the informational level should be ensured.

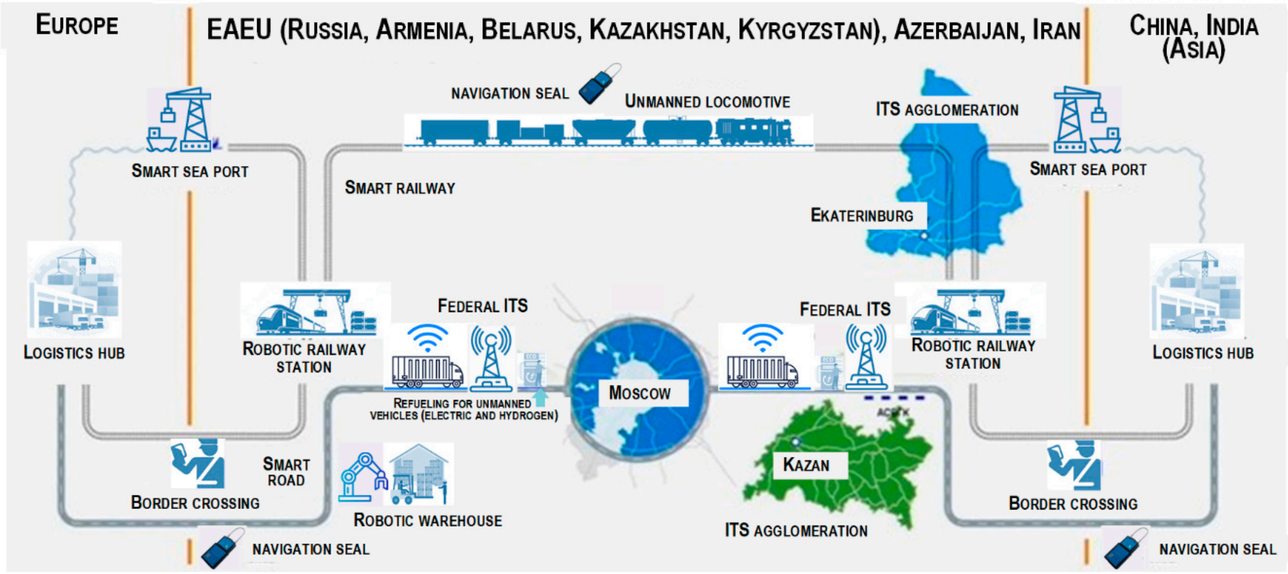

Figure 4. A single end-to-end supply chain (digital supply chain).

5. Conclusions

Climate variability offers strong possibilities for the region's development in the Russian Arctic involving the NSR. The region's abundant mineral resources and the ease of shipping crude oil and liquefied natural gas by sea have positioned it as a prospective and significant energy source. This investment direction is a priority for Russia and may have a positive effect. The development of the Arctic is planned through a system of so-called "support zones" for the creation and development of which projects are being implemented with active state participation. Sustainable development is possible only through the implementation of complex projects in which transport infrastructure is an important component. Since integrated territorial development is associated with significant cargo flows of raw materials, materials and goods, logistics chains will include various transport modes, which will lead to the construction and reconstruction of seaports, and the expansion of the network of railways and roads. When planning a development strategy, one should take into account transport risks that can upset the balance in the developed territory. In addition, the territories' connectivity should be ensured, which is possible with the integrated development of transport corridors. At the same time, a stable cargo flow will be ensured. A scientifically based solution to the problem's delivery route building, selecting rolling stock and determining the location of transshipment points and logistics terminals will contribute to the sustainable development of not only the AZR but also the territories through which the ITC passes. The article discusses the causes and consequences of improper supply chain planning. A tree of problems has been built to systematize risk situations and identify root causes and consequences. A formula for calculating complex risk has been introduced. A method for calculating the time of cargo delivery is proposed, taking into account the multimodality of logistics chains, as well as improving the planning of supply chains for the ITC by creating a single information space.

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