Selecting the optimal development strategy of the Northern Sea Route

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Abstract. The main objective of the study is to work out a set of measures to improve the Northern Sea Route (NSR) with an account of the existing trends in its development. Moreover the graph theory has been applied in order to select for the optimal development roadmap. This work is based on the graph theory that is applied to the issues of constructing a strategy for the development of complex economic and logistic systems. The article studies some essential issues of formation and selection of the development and modernization strategy of transport and logistics routes in the Arctic zone of the Russian Federation. Special attention is paid to the main Arctic route - the Northern Sea Route. Based on the study of the main development problems of this transport corridor, the work proposes a consistent series of steps that include such measures as upgrading the existing NSR infrastructure, increasing its capacity, creating of an information system that ensures safe and efficient navigation, as well as corresponding changes in legislation in order to create special economic port areas. According to the authors, these steps will significantly improve the competitiveness of the NSR compared to alternative transport and logistics corridors. The study also proposes an algorithm for choosing the most optimal way of strategy implementation, which will make it possible to achieve the main goal - to ensure the NSR capacity at the level of 30 million tons of cargo per year by 2030. The materials presented in the article indicate the special importance of the Arctic transport and logistics corridors for the socio-economic development of the country and the respective regions. One of the most important transport arteries in the Arctic is the Northern Sea Route. The article analyzes the development dynamics, problem aspects, as well as the prospects for the future of the NSR. Based on the graph theory the authors have proposed a methodology for choosing the strategy of modernization and development of the NSR up to 2030.

Keywords: transport corridor, Northern Sea Route, development strategy, transport and logistics route, Arctic zone of the Russian Federation

1. Introduction

In the globalized environment, the volume of international trade is growing rapidly, which determines the need for accelerated development of transport systems. At the same time, sea transportation today being the cheapest accounts for more than half of all world cargo transportation volume and shows a faster growth dynamics as compared to the other types of transport. In the last decade, environmentalists are increasingly talking about global warming. Climate changes lead to a sharp rise of interest to the routes that previously were not that popular because of ice cover - the North-West Passage and the Northern Sea Route. Given the importance of the maritime transport
system in the context of globalization, the emergence of a competitive sea route will be a significant event.

The main trading powers of Europe and Asia, especially Germany and China, are analyzing their strategies and opportunities in anticipation of the emerging of such a new sea route, the Northern Sea Route (NSR). Although the obstacles are impressive, the current trend of ice melting in the Arctic Ocean, the projected increase in commercial maritime traffic by 2020 and both piracy and potential political instability along the existing route through the Suez Canal - all this prompts big players to hedge their stakes. The NSR in the Russian Arctic waters is not the only well-defined way; there are some alternative routes between Novaya Zemlya and the Bering Strait. Most likely, the routes to the less developed Northwest Passage through the Canadian Archipelago will begin to function, since ice retreats faster on maritime routes from Siberia than on average throughout the Arctic as a whole. The current intercontinental traffic between Western Europe and Asia is negligible, but exports of raw materials from Russian ports on the route to Western Europe and China have increased since 2000. Regular intercontinental transit along the route would not only depend on climate changes: technological innovations of icebreakers would be stimulated by the physical limitations of the Suez Canal for larger vessels. These technological innovations could be even accelerated, even under adverse climatic conditions, as a result of disruption of the existing trade route.

The process of globalization, the growth of international trade, the increase of the competition in the maritime transport all these processes require an immediate creation of an appropriate strategy for the development of transport systems in new economic conditions. And climate changes determine the need for strategy of further development of the Arctic routes.

The research is all about the elaboration of the Northern Sea Route development program, which should help to increase the capacity of the route, including the transit traffic. The aim of the study is to work out a development strategy for modernization of the Northern Sea Route, namely, increasing its transport capacity up 30 million tons of cargo by 2030.

2. Materials and methods

The notion of “international transport corridor” is considered in the works of such authors as Kimmo Juurmaa (Juurmaa K., 2011), Chizhkov Yu.V., Katsman F.M., Borzunov V.F. Many foreign authors are concerned with environmental and safety aspects of the further development of Arctic shipping. Kimmo Juurmaa [1] in his work explores the organization of cargo transportation along the NSR, that is a wide range of questions, starting from the border crossing system and up to the characteristics of icebreakers. Other researchers deal with the economic fundamentals of transport corridors, emphasizing their importance for the development of the Arctic regions. Transport corridors can also increase the investment attractiveness of the corresponding regions [2, 3]. Some authors focus on the study of the geopolitical aspects of the development of transport routes in the Arctic [4]. The importance of transport and logistics processes is already reflected in the classical and the other economic schools, in particular, in the works of Adam Smith, Ricardo and other founders of the economic theory. Approaches of contemporary authors, such as Steven M. Suranovich (2010), Milskaya E.A., were also examined with the focus on the role of transport cost parameter in the theories, as well as on the role of the national development strategy in raising the standard of living [5]. In the work of Rünnho Lumiste (2011) [6] the organization of the Baltic transport corridor is analyzed, as well as in the work of K. Hunke and G. Prause (Hunke, K., Prause, G.) [7], where the concept of a so-called “green” transport corridor is proposed. The concept is based on a supply chain management approach, which takes into account the environmental, informational and cooperation aspects of the participating countries. This concept is further developed in the study of G. Prause and T. Hoffman [8]. Undoubtedly, this approach may be useful in the context of the NSR development strategy.

Many studies are devoted to economic parameters and costs of the NSR, especially in comparison with alternative routes. In particular, researchers H. Zhao and H. Hu (2016) in their work [9] analyze the costs of a particular vessel following the NSR and conclude that this route exceeds the
Suez Canal in terms of total costs and carbon dioxide emissions. The rationality of using the NSR is also researched in the works of N. Otsuka, K. Izyumiyama and M. Furuichi (2013) [10, 11], where the authors point out the benefits of commercial use of the NSR, calculating total transportation costs. A similar study, but touching upon both the economic and environmental aspects of transportation, was conducted by Z. Raza and H. Shoyen (2014) [12]. The authors in the work point not only to significant savings, but also to the reduction of harmful emissions when using the NSR compared to the Suez Canal. A much broader study on the same topic was conducted by T. Kiiski (2017) [13]. The author also explores the possibility of using the NSR in various aspects - economic, infrastructural and market. His conclusions are also made in favor of the NSR, provided that some important steps for the general modernization of the route and the infrastructure are made.

This article uses methods of comparative and economic analysis to localize problematic aspects in the development of transport and logistics corridors in the Arctic zone of the Russian Federation. On the basis of the performed analysis, the method of graphs is used to create a strategy for the development of the Northern Sea Route until 2030.

3. Results
The international transport corridor is a high-tech transport system that includes high throughput efficiency in the major directions, developed infrastructure, public transport (rail, sea, road, pipeline), and telecommunications, etc. Thus, transport corridors accelerate freight and passenger traffic, reducing costs due to economies of scale. Several interacting types of transport in the corridor provide an additional positive effect.

At the moment, there is no single official definition of an international transport corridor. The UNECE Inland Transport Committee proposes the following definition: “The international transport corridor is part of a national or international transport system that provides significant freight and passenger traffic between separate geographic areas, includes rolling stock and stationary devices of all types of transport operating on this direction, as well as a set of technological, organizational and legal conditions for these shipments.” Transport corridors also play a system-forming role in the socio-economic development of territories. The creation of such corridors is associated with projects for development of the economy and the social sphere of the corresponding regions.

The Arctic, as a strategically attractive region with huge natural resources, is a spot of crossing interests of many states. Thus, the industrial development of the Arctic in order to exploit various natural resources - hydrocarbon, biological, etc. - is another reason for the development of transport and logistics infrastructure of the Arctic region.

The key problems impeding the achievement of the main objectives of the development of the Arctic region are difficult natural conditions in the region and the resulting difficult transport accessibility of the territories and marine spaces of the region [14]. The problems of development of transport infrastructure in the Arctic zone of the Russian Federation are discussed in [15, 16, 17-22]. One can also add to the main transport problems of arctic routes listed above such obstacles as the weakness of the infrastructure, both the port and logistics, and the low population of the region. Thus, it can be concluded that the solution of the transport problem will be the key point for the full-scale development of the Arctic zone. Therefore, the issues concerning strategy for the development of the Northern Sea Route require additional study and research.

The Northern Sea Route is the shortest sea route between the European part of Russia and the Far East. In the legislation of the Russian Federation, the Northern Sea Route is defined as “the historically established national unified transport route of Russia in the Arctic”.
Analyzing the current state of the NSR, first of all, it is necessary to consider the dynamics of its cargo flows in different periods. Below is a table of cargo traffic of the Northern Sea Route (see Table 1).

**Table 1.** NSR cargo flows, thd.tn.

| Period                  | Year | Thd. tons |
|------------------------|------|-----------|
| The initial development period |      |           |
|                         | 1934 | 134       |
|                         | 1935 | 176       |
|                         | 1936 | 201       |
|                         | 1938 | 194       |
|                         | 1939 | 237       |
|                         | 1940 | 350       |
|                         | 1942 | 177       |
| The last years of the USSR |      |           |
|                         | 1980 | 4952      |
|                         | 1981 | 5005      |
|                         | 1985 | 6181      |
|                         | 1987 | 6579      |
|                         | 1989 | 5823      |
| Contemporary transportation |      |           |
|                         | 2003 | 1700      |
|                         | 2005 | 2023      |
|                         | 2006 | 1956      |
|                         | 2007 | 2150      |
|                         | 2009 | 1801      |
|                         | 2010 | 2050      |
|                         | 2011 | 3111      |
|                         | 2012 | 3752      |

In the contemporary period a noticeable increase occurred only since 2011, when the volume increased 1.5 times, reaching 3.11 million tons of cargo. The trend continued in 2012 - only transited goods accounted for about 1.26 million tons against 834 thousand tons in 2011. It should be noted that the number of vessels did not increase, which indicates a more efficient use of them.

The development prospects of the NSR are primarily related to the development and extraction of raw materials in the fields of the Arctic shelf: the Shtokman gas field (Barents Sea), the Yamal Peninsula field, coal basins (Taimyr Peninsula, Irkutsk Region, Krasnoyarsk Territory, Yakutia, Chukchee Autonomous Region, Timano-Pechersk oil and gas province (Komi Republic and Yamal-Nenets Autonomous Region), non-ferrous metal deposit (Kola and Taimyr Peninsula), gold deposits (Yakutia, Chukotka Autonomous Region), tin deposits (Chukchee Autonomous Region) [17, 23].

The main objective of the study is to create a strategy for the development and modernization of the Northern Sea Route. In this section, we will propose a strategy to increase the capacity of the NSR by increasing the transit traffic along the route, starting with the decision-making stage and ending with the final stage where the strategy being implemented.

In the process of the research the following stages of the strategy for increasing the capacity of the NSR were determined:
1. Formation and decomposition of the general goal.
2. Formation of directions for the necessary changes for infrastructural and institutional objects where the problem will be solved.
3. Determining of problems to be solved for the objects in each of the selected areas.
4. Working out of a plan of actions to address the highlighted problems.
5. Developing of an effective set of strategies.

Further, a general methodology for working out a strategy for development and modernization of the Northern Sea Route will be presented. It is constituted by the steps discussed beneath. The steps are in brief as follows:
1. To formulate the general goal of the strategy
2. To describe the current state of the Northern Sea Route transport corridor
3. To define the concept of “international transport corridor”
4. To define the concept of “strategy for development and modernization”
5. To study the ways of development and modernization of the international transport corridor
6. To decompose the general goal of the strategy for the development and modernization of the NSR
7. To develop a "Strategy for the development and modernization of the NSR"
8. To carry out the procedure for selecting an effective set of strategies for the development and modernization of the NSR
9. To select the best strategy out of the defined set of strategies within then given limitations
10. To test the selected strategy for development and modernization of the NSR

The results on the progress of the presented above methodology are presented below.
1. To formulate the general goal of the strategy. So, the first step in the methodology is the formulation of the general goal of the strategy. The general goal of the developed strategy is to increase the annual capacity of the Northern Sea Route up to 30 million tons of cargo by 2030.
2. To describe the current state of the Northern Sea Route transport corridor. In the course of analyzing the current state of the NSR, as well as the existing development trends of the transport corridor, the SWOT-analysis was used. After the analysis several conclusions were made. Today, the Northern Sea Route is the important national transport facility of the Russian Federation, which indicates the significance of this route for the country, and, therefore, it determines a flow of domestic investment in its development. The NSR is a shorter, cheaper and faster route from Europe to Asia. The Russian icebreaking fleet is the largest in the world, while the nuclear icebreaking fleet being the only one in the world. Climate warming is also beneficial for the development of the route, the melting of the ice increases the time for navigation along the transport corridor. The weak points of the Northern Sea Route at the moment are the absence of a unified legal regime, geopolitical instability, absence of a single governing authority, and competition with the railway transport.

There are many opportunities for the development of the NSR, among them could be mentioned: development of transit traffic, growth opportunities of domestic freight traffic, development of coastal areas of the Russian Arctic. But simultaneously there are some threats: the problems of the legal regime of the NSR, problems of using the near-pole zone, internationalization that gives rise to a conflict of interests of neighboring countries.
3. To define the concept of “international transport corridor». The Northern Sea Route is a promising international transport corridor. Therefore, in order to achieve the general goal, the NSR development should be in the direction of transit traffic. Based on the analysis, it was found that at the existing transit traffic has a very small impact on the development of the route, which indicates the need to realize the potential of the NSR. The international transport corridor is part of a national or international transport system that provides significant freight and passenger traffic between separate geographic areas. It includes rolling stock and stationary devices of all types of transport operating in this direction, as well as a set of technological, organizational and legal conditions for the implementation these shipments. The following definition was proposed in the course of the study: an international transport corridor is a high-tech transport system that concentrates on the key areas with the highest throughput capacity and high level of infrastructure, combines railroad, sea, road, pipeline transport and telecommunications. Thus, transport corridors accelerate freight and passenger traffic,
reduce costs through the economy of scale. An additional effect becomes possible in the interacting of several types of transport in the same transport corridor.

4. To define the concept of “strategy for development and modernization”.
A development and modernization strategy is an algorithm for taking necessary actions and making decisions from a given pool. The selected algorithm should contribute to an increase of the throughput capacity of the Northern Sea Route.

5. To study the ways of development and modernization of the international transport corridor. At this stage, the foreign experience in the development of international transport corridors was deeply analyzed; also here the possibility of choosing the way of obtaining the innovative development technologies. The first option is purchase of technology abroad combined with the local production; the second option is import of finished innovative product, and, finally the third one - development and production of the product within the country. The approaches to investing in the project are also considered on the stage of study. These approaches are: the concept of "internationalization", the concept of public-private partnerships and government funding.

6. To decompose the general goal of the strategy for the development and modernization of the NSR. The decomposition of the general goal into minor sub-goals will allow for more detailed strategy development. The list and hierarchy of the objectives are based on the development of a tree of objectives. The tree of objectives has several levels of hierarchy, each of the levels has its own goal structure. All goals are sub-goals in relation to the general goal. The sub-goals were selected according to the key problems identified both during preliminary comparative analysis and on the basis of the characteristics of the current state and development trends of the NSR accomplished in the research.

The icebreaking fleet of the Russian Federation is one of the most powerful in the world; Russia is the only country in the world with the nuclear-powered icebreaker fleet. These facts make it possible to perform the tasks of the presence of the Russian Federation in the Arctic. The expansion of the icebreaking fleet will provide support for a large number of freight ships, so the uninterrupted icebreaking support will make the Northern Sea Route accessible at any time of the year.

Improving the competitiveness of the ports means an update of existing port facilities by increasing port capacity, as well as the introduction of innovative elements to the port facilities. The growing scale and importance of the Northern Sea Route as an international transport corridor requires further development of port infrastructure. Currently the only port along the coastal line of the Northern Sea Route that meets all the requirements is the port of Murmansk.

Another important point in development is an increase in transit traffic along the Northern Sea Route. The analysis of the NSR development showed, that at the moment the impact of transit traffic on the development of an international transport corridor is extremely small. In order to fulfill the sub-goal, the two areas have to be distinguished: providing compliance with international rules on transit traffic and ensuring the safety of functioning of the port infrastructure and maritime transport. The last but not the least important goal is development of the information and telecommunication environment. It is necessary to create all conditions for continuous operation of information and telecommunication sphere for the uninterrupted operation of the northern route. It may include creation and support of information monitoring systems, as well as creation and support of onshore safety systems for navigation, search and rescue.

So, the general goal of the strategy is to increase the throughput capacity of the Northern Sea Route to 30 million tons of cargo per year by 2030.

In order to achieve the general goal, it is proposed to increase the volume of transit traffic on the Northern Sea Route, which is the goal of the second level.

The increase of transit traffic entails such sub-goals as: increasing port capacities, developing the information and telecommunication environment, uninterrupted icebreaking support, ensuring compliance with international transit traffic rules. These activities are the objectives of the third level. The objectives of the fourth level are tasks that have to be accomplished to achieve the objectives of the third level. The tree of objectives at all levels can be presented below.
The general goal is to increasing the capacity of the Northern Sea Route up to 30 million tons of cargo per year by 2030
The sub-goal of the first level:
- to Increase the transit traffic on the Northern Sea Route.
The sub-goals of the second level:
- to increase the port capacities.
- to develop the information and telecommunication environment.
- to maintain an uninterrupted icebreaking support.
- to provide compliance with international transit regulations.
The sub-goals of the third level:
- to create port special economic zones (PSEZ).
- to make necessary changes in the tariff policy.
- to create and maintain the information systems for safe shipping.
- to create and maintain coastal systems for safe navigation, search and rescue, communication systems.
- to provide safe functioning of port infrastructure and maritime transport.
- to enhance the icebreaking fleet.
- to strengthen the innovative infrastructure of the ports along Northern Sea Route.
- to create new port terminals

7. To develop a "Strategy for the development and modernization of the NSR"
The development and modernization strategy of the Northern Sea Route is a set of interrelated (in terms of costs and duration) activities that are aimed at achieving the general goal of increasing the carrying capacity of the Northern Sea Route up to 30 million tons of cargo by 2030. Through the decomposition of the general goal, as well as on the basis of [17, 23], the following steps to be done were identified:

1. Enhancing the port capacities;
1.1. Creation of new port terminals;
1.2. Strengthening of the innovative aspects of the port infrastructure in the development of the Northern Sea Route.
2. Development of the info-telecommunication environment;
2.1. Creation and maintenance of an information shipping-monitoring system;
2.2. Creation and maintenance of coastal systems for safe navigation, search and rescue, communication systems.
3. Uninterrupted icebreaking support;
3.1. Providing for the safe operation of port infrastructure and maritime transport;
3.2. Expansion of the icebreaking fleet.
4. Providing for the compliance with international transit transport regulations;
4.1. Creation of port special economic zones (PSEZ);
4.2. Changing of the tariff policy.

Each of the problems involves a complex of measures that are necessary to achieve the goal. Each measure was characterized in terms of cost and time needed for implementation. The proposed graph includes measures with alternative outcomes, which also means the selection of an obtaining method for a new technological product: import; purchase of technology, but local production; local development and production. Several options for financing the events were envisaged. They include government funding, foreign investment, as well as implementing the concept of public-private partnership where the co-financing of the state and private investors takes place. The choice of partners can be also made either though the creation of technological platforms or via the creation of territorial clusters.
In order to display all the development stages in a single structural form, the graph of a non-deterministic structure is represented. The graph consists of the starting point, decision points and alternative outcomes, as well as the ending point. Each link in the graph is quantified.

The graph can be depicted in two ways [24]:
1. Work / event is depicted as a circle, and arrows show the sequence of the performed works.
2. Work / event is represented by an arrow, while the circle shows the beginning and end of the work / event.

Arrows between the nodes will be the costs and time needed for the execution of a particular point of the event. Fig. 1 is a procedure for developing a strategy for the development and modernization of the Northern Sea Route.

Description of the graph:
S – the starting point;
m1 – Selecting of a method to increase the capacity of the NSR;
m2 – Decomposition of the general goal into several directions;
m3 – Finding the ways to develop the information and telecommunication environment;
m7 – Preparation works for the creation and maintenance of shipping supervision information systems;
m8 – Preparation works for the creation and maintenance of coastal systems for safe navigation, search and rescue, communication systems;
m4 – Finding the ways of providing the compliance with international transit transport regulations;
D1 – The decision point about the way of providing the compliance with international transit transport regulations:
d1.1 – Preliminary work on the creation of port special economic zones (PSEZ);
d1.2 – Preliminary work on changing the tariff policy;
m19 – Work on changing the legislation;

Figure 1. The graph of the strategy for modernization and development of the NSR
Developed by the authors based on this study and [24].
m5 – Finding the ways of maintaining an uninterrupted icebreaker support;
m9 – Finding the ways of providing safe functioning of port infrastructure and maritime transport;
m11 – Works on creation of an organizational-technical emergency system of rescue and support;
m10 – Works on determining the need for expanding the icebreaking fleet;
m12 – Preliminary works for the construction of special ice class vessels and reinforced ice class vessels, tankers with additional emergency supply;
m13 – Preliminary works for the construction of multifunctional vessels (icebreaking, pilot, sweep, bunker and other functions);
m6 – Finding the ways of increasing the port capacities;
m14 – Finding the ways for enhancing the innovative port infrastructure along the NSR;
m15 – Preliminary works for the modernization of hydraulic infrastructure;
m16 – Preliminary works for automation and upgrade of loading and unloading equipment;
m17 – Works on implementation of logistics and transport systems;
m18 – Preliminary works for the construction of new port terminals;
D2 – The decision point about the way of obtaining the innovative technologies:
d2.1 – Preliminary works for local production of high-tech equipment;
d2.2 – Works on finding the production technology abroad;
d2.3 – Works on finding the imported high-tech equipment;
m20 – Finding the ways of training the research, engineering and IT personnel;
D3 – The decision point about choosing the way of funding:
d3.1 – Preliminary works for organizing the public funding;
d3.2 – Works on the implementation of the public-private partnership concept;
d3.3 – Works on attracting foreign investments;
D4 – The decision point about choosing the way of finding partners:
d4.1 – Preliminary works for the creation of a technological platform;
d4.2 – Preliminary works for the creation of territorial clusters;
F – Ending point.

4. Discussion

The proposed graph with alternative outcomes makes it possible to choose the optimal variant for achieving the main goal. Alternative outcomes are an advantage of such a graph. The set of effective strategies allows you to choose the best strategy by comparing the timing and cost parameters of each strategy. Moreover, we suggest that the algorithm for finding the optimal Pareto-set should be used.

It should be noted that the proposed strategy development way is of a methodological nature, since real data on the level of development of the Northern Sea Route and adjacent territories do not reflect the real state of things.

So, based on the constructed graph, some strategies will be selected, and the optimal variant will be chosen thereafter. The optimal variant is one with the shortest execution time and the lowest costs. Below are the costs and time needed for the implementation of each strategy, the values are given arbitrarily (see Table 2).

Table 2. The costs and time expenditures for the strategy of development and modernization of the Northern Sea Route

| Code | The name of work | Time expenditure (month.) | Costs (thd. USD.) | Result |
|------|------------------|---------------------------|-------------------|--------|
| S    | Starting point   | -                         | -                 |        |
| m1   | Selecting of a method to increase the | 2 | 7.7 | The decision on increasing the transit |
| m_2 | Decomposition of the general goal into several directions | 2 | 12.3 | The tree of goals |
|-----|----------------------------------------------------------|---|-------|------------------|
| m_3 | Finding the ways to develop the information and telecommunication environment | 1 | 4.6 | The list of possible ways of developing the information and telecommunication environment |
| m_7 | Preliminary works for the creation and maintenance of shipping supervision information systems | 12 | 769 | The plan of preparatory measures for creating and maintenance of information systems |
| m_8 | Preliminary works for the creation and maintenance of coastal systems for safe navigation, search and rescue, communication systems | 12 | 769 | The plan of preparatory measures for the creation of coastal security systems |
| m_4 | Finding the ways of providing the compliance with international transit transport regulations; | 1 | 3 | The list of possible ways of providing the compliance with international transit transport regulations |
| D_1 | The decision point about the way of providing the compliance with international transit transport regulations: | | | |
| d_1.1 | Preliminary work on the creation of port special economic zones (PSEZ) | 18 | 15.4 | The list of documents, that are needed for creation of PSEZ |
| d_1.2 | Preliminary work on changing the tariff policy | 12 | 12.3 | Changing the rules for cargo transportation and transit along the NSR |
| m_19 | Work on changing the legislation | 12 | 15.4 | The list of possible ways of maintaining an uninterrupted icebreaking support |
| m_5 | Finding the ways of maintaining an uninterrupted icebreaking support | 1 | 4.6 | The list of possible ways of maintaining an uninterrupted icebreaking support |
| m_9 | Finding the ways of providing safe functioning of port infrastructure and maritime transport; | 2 | 9.2 | The list of possible ways of providing safe functioning of port infrastructure and maritime transport; |
| m_11 | Works on creation of an organized technical emergency system of rescue and support | 12 | 1077 | The plan of preparatory measures for implementation an organized technical emergency system of rescue and support on the NSR |
| m_10 | Works on determining the need for expanding the icebreaking fleet | 2 | 7.7 | The decision on building of icebreakers of certain types |
| m_12 | Preliminary works for the construction of special ice class vessels and reinforced ice class vessels, tankers with additional emergency supply | 12 | 1077 | The plan for preparatory measures for construction of the vessels of special types |
| m_13 | Preliminary works for the construction of multifunctional vessels (icebreaking, pilot, sweep, bunker and other functions) | 12 | 1077 | The plan for preparatory measures for construction of multifunctional vessels |
| m_6 | Finding the ways of increasing the port capacities | 2 | 7.7 | The list of possible ways of increasing the port capacities |
| $m_{14}$ | Finding the ways for enhancing the innovative port infrastructure along the NSR; | 2 | 7.7 | The list of possible ways for enhancing the innovative port infrastructure |
| $m_{15}$ | Preliminary works for the modernization of hydraulic infrastructure | 12 | 615.4 | The plan for preparatory measures for the modernization of hydraulic infrastructure |
| $m_{16}$ | Preliminary works for automation and upgrade of loading and unloading equipment | 12 | 615.4 | The plan for preparatory measures for automation and upgrade of loading and unloading equipment |
| $m_{17}$ | Works on implementation of logistics and transport systems | 18 | 1077 | The plan for preparatory measures for implementation of logistics and transport systems |
| $m_{18}$ | Preliminary works for the construction of new port terminals | 24 | 769 | The plan for measures for the construction of new port terminals |

$D_2$ The decision point about the way of obtaining the innovative technologies:

| $d_{2.1}$ | Preliminary works for local production of high-tech equipment | 20 | 1077 | The plan for preparatory measures for local production of high-tech equipment |
| $d_{2.2}$ | Works on finding the production technology abroad | 12 | 1538 | The plan for preparatory measures по поиску технологии производства за границей |
| $d_{2.3}$ | Works on finding foreign high-tech equipment | 12 | 769 | The plan for preparatory measures по поиску технологии производства за границей |
| $m_{20}$ | Finding the ways of training the research, engineering and IT personnel | 6 | 12.3 | The list of possible ways personnel training, also a list of possible for cooperation educational institutions |

$D_3$ The decision point about choosing the way of funding:

| $d_{3.1}$ | Preliminary works for organizing public funding | 12 | 7.7 | Conducting of preparatory measures on organizing public funding |
| $d_{3.2}$ | Works on the implementation of the public-private partnership concept | 10 | 7.7 | Conducting of measures on implementation of the public-private partnership concept |
| $d_{3.3}$ | Works on attracting foreign investments | 15 | 15.4 | Conducting of preparatory measures on attracting foreign investments |

$D_4$ The decision point about choosing the way of finding partners:

| $d_{4.1}$ | Preliminary works for the creation of a technological platform | 2 | 7.7 | The plan for preparatory measures on creation of a technological platform |
| $d_{4.2}$ | Preliminary works for the creation of territorial clusters | 6 | 4.6 | The plan for preparatory measures on creation of territorial clusters |

F Ending point

Developed by the authors based on the research.
8. To carry out the procedure for selecting an effective set of strategies for the development and modernization of the NSR.

Hereafter we will calculate the costs and the time expenditure for every possible strategy (Table 3).

**Table 3.** Duration and total expenditures for the strategies

| Strategy | Time expenditure, mnth. | Costs, mln. USD. |
|----------|-------------------------|------------------|
| 1        | 84                      | 9.04             |
| 2        | 84                      | 9.05             |
| 3        | 88                      | 9.04             |
| 4        | 89                      | 9.05             |
| 5        | 93                      | 9.05             |
| 6        | 72                      | 9.5              |
| 7        | 72                      | 9.51             |
| 8        | 76                      | 9.51             |
| 9        | 77                      | 9.52             |
| 10       | 81                      | 9.51             |
| 11       | 60                      | 8.71             |
| 12       | 60                      | 8.72             |
| 13       | 64                      | 8.72             |
| 14       | 65                      | 8.73             |
| 15       | 69                      | 8.82             |
| 16       | 84                      | 8.89             |
| 17       | 84                      | 9.04             |
| 18       | 88                      | 9.04             |
| 19       | 89                      | 9.05             |
| 20       | 93                      | 9.05             |
| 21       | 72                      | 9.49             |
| 22       | 72                      | 9.5              |
| 23       | 76                      | 9.5              |
| 24       | 77                      | 9.51             |
| 25       | 81                      | 9.51             |
| 26       | 60                      | 8.71             |
| 27       | 60                      | 8.72             |
| 28       | 64                      | 8.72             |
| 29       | 65                      | 8.73             |
| 30       | 69                      | 8.73             |

Developed by the authors based on this study.

Thus, we have quantitatively evaluated all 30 possible strategies of development and modernization of the Northern Sea Route. The strategies obtained are a combination of the costs that are the same for all strategies (7.93 million USD and 42 months), and costs that vary depending on the strategy chosen. We propose to use an algorithm for finding the optimal Pareto-set [25]. This approach allows us to evaluate all the options and choose the best option from the effective set. The last stage of the work is the approbation of the obtained strategy. We will set the limitations for the strategy, i.e. the costs should not exceed 9.2 million USD and the total duration should be up to 7 years. The limitations are chosen arbitrarily.

9. To select the best strategy out of the defined set of strategies within then given limitations. All the variants of the strategy can be represented in the coordinate system, where the total duration is
measured along the horizontal axis, and the costs are represented along the vertical axis. Now we can determine the strategies that are within the set limitations. As a result, two strategies were identified that are closest to the origin of coordinates (or with minimum duration and costs), namely strategies 11 and 26.

10. To test the selected strategy for development and modernization of the NSR

The closest strategy to the origin of coordinates is strategy 26. The costs of its implementation are added up as follows:
1. The process of selecting a method to increase the capacity of the NSR - 2 months and 7.7 thd. USD;
2. Decomposition of the general goal into separate directions - 2 months and 12.3 thd. USD;
3. Finding the ways to develop the information and telecommunication environment - 1 month and 4.6 thd. USD;
4. Conducting of works for creation and maintenance of shipping supervision information systems - 12 months and 769 thd. USD;
5. Preliminary works on creation and maintenance of coastal systems for safe navigation, search and rescue, communication systems - 12 months and 769 thd. USD;
6. Finding the ways to ensure compliance with international rules on cargo transit - 1 month and 3 thd. USD;
7. Selection of the way to ensure compliance with the international rules on cargo transit: Preliminary works on changing the tariff policy - 12 months and 12.3 thd. USD;
8. Works on changing the legislation - 12 months and 15.4 thd. USD;
9. Finding the ways to maintain an uninterrupted icebreaking support - 1 month and 4.6 thd. USD;
10. Finding the ways of providing safe functioning of port infrastructure and maritime transport - 2 months and 9.2 thd. USD;
11. Works on creation of an organized technical emergency system of rescue and support - 12 months and 1077 thd. USD;
12. Works on determining the need for expanding the icebreaking fleet - 2 months and 0.50 mln. RUR;
13. Preliminary works on construction of special ice-class and reinforced ice-class vessels, tankers with additional emergency supplies - 12 months and 1077 thd. USD;
14. Preparations for the construction of multifunctional vessels (icebreaking, pilot, sweeping, bunker and other functions) - 12 months and 1077 thd. USD;
15. Finding the ways for increasing the port capacities - 2 months and 7.7 thd. USD;
16. Works on finding the ways for enhancing the innovative port infrastructure along the NSR - 2 months and 7.7 thd. USD;
17. Preliminary works for the modernization of hydraulic infrastructure - 12 months and 615.4 thd. USD;
18. Preliminary works for automation and upgrade of loading and unloading equipment - 12 months and 615.4 thd. USD;
19. Implementation of logistics and transport systems - 18 months and 1077 thd. USD;
20. Preliminary works for the construction of new port terminals - 24 months and 769 thd. USD;
21. Decision about the way of obtaining the innovative technologies: performing the preliminary work for local production of high-tech equipment - 20 months and 1077 thd. USD;
22. Finding the ways for training scientific, engineering and IT personnel - 6 months and 12.3 thd. USD;
23. Decision about the way of funding: implementation of the public-private partnership concept - 10 months and 7.7 thd. USD;
24. Selection of the way of finding partners: performing the work on creation of a technological platform - 2 months and 7.7 thd. USD.

In the end, the proposed strategy for the development and modernization of the Northern Sea Route
lasts for 5 years and it demands 8.71 mln.USD for realization.

5. Conclusion

Eventually, the proposed strategy for the development and modernization of the Northern Sea Route is realizable for 8.71 million USD, its total duration is 5 years. In the course of this research, the following results were obtained.

The theoretical aspects of development of international transport corridors were considered. A new definition of transport corridor was introduced: an international transport corridor is a high-tech transport system that includes high throughput efficiency in the major directions, developed infrastructure, public transport (rail, sea, road, pipeline), and telecommunications, etc. Thus, transport corridors accelerate freight and passenger traffic and reduce costs due to the economy of scale. Several interacting types of transport introduce an additional positive cumulative effect. The current state of the transport corridors of the Arctic has been analyzed, special attention is paid to the Northern Sea Route. Major trends and problems of development of the NSR are considered. An approach for working out a strategy for the development and modernization of the Northern Sea Route has been proposed. Within the research it was proposed to develop a strategy with a help of a graph with alternative outcomes.

The approbation of the strategy for development and modernization of the Northern Sea Route has been carried out. As the result the most optimal strategy was selected. The work resulted in determining a strategy of development of the Northern Sea Route by increasing the carrying capacity of this transport corridor up to 30 million tons of cargo by 2030.

References

[1] Juurmaa K 2000 Future development of Northern Sea Route ship design – Technology and price. In: Ragner C.L. (eds). The 21st Century – Turning Point for the Northern Sea Route? Springer, Dordrecht., pp 177–184.
[2] Chizhkov Yu V 2015 International transportation corridors – the communication basis of Russia. Transport of the Russian Federation; 5(60) pp 9-15.
[3] Katsman F M 2002 Functioning of international and national transportation corridors. St.Peterburg: Russian transport academy 292 p.
[4] Borzunov V F 2001 Trans-Siberian Railway Route in the World Politics of Great Powers Part 1. M., 167 p.
[5] Suranovic S 2010 A New Guide to Policy Choice in an Era of Globalization. A Moderate Compromise. Palgrave Macmillan, New York pp 205–239.
[6] Lumiste R and Prause G 2011 Baltic States Logistics and the East-West Transport Corridor. Wismar: Wismar University.
[7] Hunke K and Prause G 2013 Management of Green Corridor performance. Transport and Telecommunication. 14(4) pp 292–299.
[8] Prause G and Hoffmann T 2017 Cooperative Business Structures for Green Transport Corridors. Baltic Journal of European Studies Tallinn University of Technology.; 7(2) pp 3-27.
[9] Hui Zhao and Hao Hu 2016 Study on Economic Evaluation of the Northern Sea Route Taking the Voyage of Yong Sheng as an Example. Transportation Research Record: Journal of the Transportation Research Board. 2016; (2549) pp 78–85.
[10] Otsuka N, Izumiyama K and Furuichi M 2013 Study on Feasibility of the Northern Sea Route from Recent Voyages. Proceedings of the 22nd International Conference on Port an Ocean Engineering under Arctic Conditions, June 9-13, Espoo, Finland
[11] Furuichi M and Otsuka N 2013 Cost Analysis of the Northern Sea Route (NSR) and the conventional Route Shipping//Proceedings of the IAME Conference, July 3-5, Marseille
[12] Raza Z and Schøyen H 2014 A Comparative Study of the Northern Sea Route (NSR) in Commercial and Environmental Perspective with Focus on LNG Shipping. 6th International conference on maritime transport, Barcelona, Spain.

[13] Kiiski T 2017 Feasibility of Commercial Cargo Shipping along the Northern Sea Route. Doctor thesis, Annual proceedings of the University of Turku - ser. E, vol. 12, Turku.

[14] Kuvatov V I, Koznovskiy DV and Shatalova N V 2014 The potential of the Northern sea route in the Russian Arctic. Factors and development strategy. Internet-magazine “Scientific research”. 6(25).

[15] Dodin D.A. 2005 The sustainable development of the Arctic (problems and prospects). St.Peterburg: “The science”, 283 p.

[16] Semenikhin Ya N and Novoseltsev E M 2015 Some characteristics of transport development in the Arctic. In: Scientific and technical problems of Arctic development. Moscow: “The science”, 490 p.

[17] Pavlov K V and Selin V S 2015 The problems of cargo flows of the Northern sea route and some possible solutions. Bulletin USUES. Science, education, economy. Series economy. 2(12) pp 73–80.

[18] Didenko N I and Chernekov V I 2018 Economic and geopolitical aspects of developing the Northern Sea Route IOP Conf. Series: Earth and Environmental Science (Institute of Phys. Publishing Press) 180(1) 012012

[19] Didenko N I, Kulik S, Skripnuk D and Samylovskaya E 2018 A country competitiveness analysis. Adl-model involved Int. Multidisciplinary Scientific GeoConf. Surveying Geology and Mining Ecology Management (Albena: Bulgaria) 18(5.3) pp 3-10

[20] Didenko N I and Romashkina E S 2018 Assessment of the Influence of the Extraction of Energy Resources on the Environment IOP Conf. Series: Earth and Environmental Science (Institute of Phys. Publishing Press) 180(1) 012014

[21] Skripnuk D, Kikkas K N, Safonova A S and Volodarskaya E B 2019 Comparison of international transport corridors in the Arctic based on the autoregressive distributed lag model IOP Conf. Series: Earth and Environmental Science (Institute of Phys. Publishing Press) 302(1) 01209

[22] Bashmakova E P, Biev A A, Vassiliev V V et al. 2015 Factor analysis of cargo flows of the Northern sea route. Monograph. Apatity: Institute for economic problems of G P Lousine within the Kola Scientific center of RAS (town of Apatity). 335 p.

[23] Selin V S 2016 Driving forces and development problems of cargo transportation through the NSR. The Arctic and the North. (22):87–100. DOI: 10.17238/issn2221-2698.2016.22.87

[24] Didenko N I 1985 Management of leading research-technical organization. Monograph. Moscow: Leningrad University publishing house; 216 p.

[25] Podinovskiy V V and Nogin VL 1982 Pareto-optimal decisions of multi-criteria tasks. Moscow: “The science” Publishing house; 256 p.