Forming and developing a green transport corridor in the Arctic

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Abstract. The paper discusses problems related to transport infrastructure in the Russian Arctic, including one of the most important international transport corridors, the Northern Sea Route. We have established that Arctic ports are one of the weakest components of the transport corridor of the Northern Sea Route. We have carried out comparative analysis of the main ports and their infrastructure, considering the possibilities for developing the Northern Sea Route as part of the infrastructure of a green transport corridor. We have constructed a strategic map for the green transport corridor (i.e., a sustainable transport system including five components: sustainability, stakeholders, industry and entrepreneurship, qualifications and personnel, financial resources and budget). Causal relationships between the components have been found and key performance indicators for the sustainability component have been formulated.

1. Introduction
As Russia is increasingly integrated into the system of international transport corridors (ITC), this provides not only additional opportunities for development of the country's transport system, but also opens up the potential for improving its infrastructures for production, information and technologies, as well as for growth of the gross national product.

The Northern Sea Route (NSR) is one of the largest international transport corridors, vitally important not only for Russia but also for the entire global community.

The problem we have considered is clearly urgent; issues related to developing the Arctic's abundant resources as a whole and the Northern Sea Route in particular are a matter of considerable interest for the Russian and global scientific communities.

Problems of environmental safety impose additional restrictions on organization of oil transportation; this is described in detail in both Russian and foreign studies [1–7]. The impact that new Arctic trade routes have on marine habitats and ecosystems, especially in coastal regions, is considered in [8–13]. A number of studies [14, 15] were dedicated to analysis and forecast of the key factors affecting the potential for developing navigation in the Arctic. These factors include sea ice, economy, infrastructure, bathymetry and weather [16–19]. Comprehensive analysis of these factors taken together can produce useful forecasts for strategic planning of NSR development.

2. Experience in using the Northern Sea Route
An International Transport Corridor (ITC) is a high-tech transport system combining communication networks with infrastructure, intended to generate international traffic between major trade hubs. The international transport corridor covers transportation between two or more countries. The purpose of the
ITC is to create an international transport infrastructure based on common parameters and common transportation technologies, bringing national legislations to unified standards. The countries participating in agreements on international transport corridors should establish the conditions satisfying the needs of consumers by providing high-quality services complying with international standards, including a sufficiently developed transport infrastructure on the territory of the corridor.

ITCs are divided into: intracontinental; sea; combined land and sea; air.

There are currently three international sea transport corridors:
- Northern sea route (NSR) runs along the northern coast of Russia along the seas of the Arctic Ocean and partially the Pacific Ocean;
- sea route through the Suez Canal (unofficially called the Southern Sea Route);
- Northwest Passage (NWP) runs along the northern coast of North America through the Canadian Arctic Archipelago.

Until 1991, Russia’s northern territorial waters were used solely for domestic needs, so 1991 can be considered the year of opening of the Northern Sea Route. Nowadays the NSR is a strategic sea transport route playing a major role in Russian and global economy.

The transport system of the Arctic varies greatly in different parts of the region. Air transport plays a crucial role for continental Arctic, where it is primarily used for handling express shipments and transporting passengers, particularly in case of medical emergencies.

River transport operates for a very short period in the summer. Only local railroads often not connected to the national railway network operate in many areas of the Far North. Pipeline transport is used mainly in the Yamal-Nenets Autonomous Okrug.

The sea transport system is of key importance for the Arctic for the following reasons:
- long coastlines, extremely low population density;
- poor infrastructure for land transport in the Far North;
- water routes and railways in the northern part of the country are mostly longitudinal, so sea transport has to be used as the connecting link.

Administrative boundaries of the NSR are set in Article 5.1 of the Merchant Shipping Code of the Russian Federation No. 81-FZ of April 30, 1999. The NSR runs along the northern coast of Russia along the seas of the Arctic Ocean (Barents, Kara, Laptev, East Siberian and Chukchi seas), also covering parts of the Pacific Ocean (Bering Sea). The depth of the continental shelf in these seas does not exceed 200 m. The NSR extends from the western entrances to the Novaya Zemlya strait and the meridian passing north from Cape Zhelaniya to the Bering Strait in the east at the 66th parallel north and the 168°58′37″W meridian. The NSR is 5,610 km long, from the Kara Gates to Provideniya Bay.

Navigable river routes adjacent to the NSR are about 37,000 km long. Vessels departing from Murmansk and Arkhangelsk head east, making a call to Dikson, Dudinka and Igarka in the Yenisei Gulf. Passing through the Laptev Sea, ships sail to Nordvik and Tiksi, near the Kolyma River, to Ambarchik.

The NSR terminates in Pevek and Provideniya. The seas that make up the NSR have an extremely harsh climate. Monthly summer temperatures along the Northern Route average about +7 °C, winter temperatures about -33 to -35 °C. This means that the NSR has a very short navigation season of 2–4 months, making it necessary to use atomic icebreakers to overcome ice masses.

3. Analysis of transport infrastructure of the ports of the Northern Sea Route
The Northern sea route is an ITC whose operation is connected to a great number of difficulties hindering the development of the route and diminishing or even completely eliminating the benefits it provides. A
schematic in Fig. 1 below clearly demonstrates the existing problems that negatively affect (or may do so in the future) the role of the NSR in the ITC system.

**Figure 1. Problems of NSR operation**

The seaports of the Arctic are the weakest link in the NSR, as their owners do not have enough funds for modernization. Let us consider the problem of poorly developed infrastructure of Arctic ports in more detail. Most ports have a number of serious drawbacks:

- berthing facilities require overhaul and reconstruction (wharfs and container cranes are worn out; gantry and crawler cranes used for loading and unloading have worked for more than 30 years with large variation between day and night temperatures and are worn out by more than 90%);
- sea bottom has to be deepened to receive modern large-capacity vessels;
- there are no services for bunkering of ships or collection of sewage and solid waste;
- there are either no facilities for oil spill response and for collection and disposal of ship-generated waste, or these facilities are in critical condition;
- protective structures, signaling and warning systems have fallen into disrepair due to lack of proper control, security services for inspection and admission to special facilities are poorly developed [20].

Cargo traffic in the Arctic seas has been steadily increasing, amounting to 54.3 million tons in 9 months of 2017, to 66.9 million tons in 2018 and to 78.6 million tons in 2019. In total, 70 transshipment facilities and ports are located along the NSR. Dudinka is located on the border between the Western (from Murmansk) and the Eastern (to Chukotka) sections of the NSR. According to the data of the Federal Agency for Sea and Inland Water Transport, the Register includes 12 ports of the Western Arctic and the main ports of the NSR: Murmansk, Arkhangelsk, Naryan-Mar, Varandey, Sabetta, Dudinka, Igarka, Dikson, Khatanga, Tiksi, Pevek. Only two of these ports (Murmansk and Arkhangelsk) are large cities and have a developed coastal infrastructure.

Comparative characteristics of the main ports on the NSR are given in Table 1. It can be seen from Table 1 that most of the ports handle freight transportation. Communication with settlements is mainly
### Table 1. General characteristics of main ports of Northern Sea Route

| Name                   | Namskoy | Naryan-Mar | Saboeta | Dudinka | Dikson | Chantayga | Tiksi | Pevek |
|------------------------|---------|------------|---------|---------|--------|-----------|-------|-------|
| Settlement             | Shift camp | City | Shift camp | District town | Urban settlement | Rural settlement | Urban settlement | City |
| Population             | intended for 180 | about 24,800 | about 30,000 | over 20,000 | over 500 | 4,500–5,000 | about 4,500 | about 4,500 |
| Sea                    | Barents Sea | Kara Sea | Laptev Sea | East Siberian Sea |
| Administrative division| Novotsky Autonomous Okrug | Nenets Autonomous Okrug | Yamalo-Nenets Autonomous Okrug | Krasnoyarsk Krai |
| Coordinates, N/E       | 68°48'/57°59' | 71°16'/72°04' | 70°56'/102°28' | 71°138°/128°53' |
| Port area (ha)          | 1.47 | 22.56 | n/a | 24.92 | 4.37 | 10.62 | 7.29 | 19 |
| Port water area (km²)   | 24.98 | 5.63 | 1.38 | 10.22 | 0.182 | 5 | 96.78 | 8.9 |
| Number of piers         | 2 | 6 | 12 | 9 | 2 | 5 | 2 | 3 |
| Total berthing length (km) | 199.86 | 703.66 | 2697.05 | 1723.6 | 243 | 400 | 315.0 | 500 |
| Throughput capacity of freight terminals (thousand tons per year) | 12,100.4 | 501,016 | 16,500 | 1,885 | 120 | 95 | 67.0 | 330 |
| Passenger terminal capacity (passengers per year) | - | - | - | - | - | - | - | - |
| Maximum dimensions of vessels (draft/length/width) (m) | 3.5/120/15 | 3.6/90/16 | 12/315/n/a | 11.8/260/32 | 8/100/20 | 4/136/16 | 4/130/16 | 9/172/25 |
| Area of | 1.94/9.37 | 5.2/23.35 | n/a | 30.05/105.24 | 4.9/1.1 | 1780/2500 | 3.83/32.35 | 4.18/77.8 |
| indoor/outdoor warehouses (thousand m²) | - | - | n/a | 136 | - | - | - | - |
| Capacity of tanks for storage of petroleum products (thousand tons) | - | - | n/a | - | - | - | - | - |
| Connection by motor vehicles | No | Yes | No | No | No | No | Yes | |
| Connection by railway | No | No | No | No | No | No | No | No |
| Airport                | Namskoy Airport | Naryan-Mar Airport | Saboeta Airport (4 km) | Abkelsk Airport (10 km) | Dikson Airport (6 km) | Khanty-Mansiysk Airport (1 km) | Tiksi Airport (3.8 km) | Aspolensk Airport (16 km) |
| Navigation season in port | June 1 to December 30 | June to November | January 1 to May 30, June 15 to December 31 | June to October | June 1 to October 1 | July 15 to September 30 | July 3 to October 25 |
| Operators of sea terminals | LLC Namskoy Terminal | LLC NAO Ackerport | LLC NAO Sorvash | LLC NAO Namskoy Terminal |
| LLC Stevedores Yamal Division | 1, LLC Stevedores Yamal Division | JSC Nortik Nickel | JSC Nortik Nickel | JSC Nortik Nickel |
| Services provided by operators of sea terminals | 1. Oil loading terminal; 2. Cargo terminal | Loading and unloading; cargo transportation; | Loading and unloading for dangerous goods in sea ports (class 1, 2, 3, 4, 5, 6, 8, 9) etc. | Loading and unloading of cargo; loading and unloading of petroleum products | Loading and unloading in port; handling of cargo; stevedoring of cargo; etc. | Loading and unloading for dangerous goods in sea ports (class 1, 2, 3, 4, 5, 6, 8, 9); |
by air (airports and helipads), there is no direct railway connection, and even travel by road is sometimes impossible.

Ports provide support for navigation in the Arctic. They are equally important for successful operation of the NSR, which is why effort should be made to modernize and improve them.

4. Green Transport Corridor
The current natural conditions (Arctic ice melting) and emerging innovative technologies favor intensified extraction and transportation of unique natural resources of the Arctic. Development of the Arctic coasts provides additional opportunities for extraction of natural resources but also entails a corresponding increase in the volume of traffic (mainly sea), and, as a consequence, amplifies the load on the marine ecosystem. This means that any issues related to economic activity in the Arctic should be analyzed not only in terms of the ratio of economic costs to benefits but also taking into account the environmental load [21].

Industrial accidents accompanied by oil spills due to deteriorating fixed assets and lack of response measures for promptly eliminating the consequences can be particularly damaging to the environment of the Russian Arctic. This damage can only increase as the NSR carries progressively larger volumes of traffic. Notably, according to [22], the specific impacts of different types of emissions from industrial enterprises in the Arctic zone significantly exceed the average level of impacts in Russia. Analysis of sustainable development of sea transport in view of complex environmental and economic dynamics of the Arctic calls for comprehensive assessment of all the consequences from further exploration of the territories, obtaining reliable forecasts [23].

The length of the Arctic coasts means that each port participating in local or international trade must make efforts to mitigate negative environmental impacts. The international experience [24] should serve as the foundation for developing selection criteria for sea ports, minimizing their number and, accordingly, reducing the environmental load on marine systems. On the other hand, the number of sea ports should be reduced within the framework of the strategy for development of an integrated transport system (balanced development of the transport system), where sea, rail, river routes and highways complement each other, making up a network with a relatively large number of nodes (hubs), in other words, a sustainable transport corridor (STC). The cargo transported along an STC moves from one hub to another using different modes of transportation. This process (cargo transportation/organization of transportation via the NSR) can be effectively managed by monitoring and controlling transportation costs and time along the entire route, striving to minimize the negative impact of transport on the environment at the same time. We propose to perform monitoring and control using a strategic map that we constructed for development of the green transport corridor (sustainable transport system) and the corresponding key performance indicators characterizing the implementation of the given strategy (Fig. 2).

The strategic map is based on the concept of the Green Transport Corridor, introduced in 2007 within the EU Freight Transport Logistics Action Plan. The GTC serves to maintain growing volumes of traffic while preserving a favorable environmental situation at all stages of cargo transportation, reducing the harmful effects of transport on air and water, increasing safety and efficiency of vehicles.

The proposed strategic map includes five components: sustainability, stakeholders, industry and entrepreneurship, qualifications and personnel, financial resources and budget; all of the components are connected by cause and effect relationships (Fig. 2). The constructed map is based on the following objectives:
- increasing environmental safety in the region;
- improving the efficiency of services performed by port operators;
- using innovative environmentally effective technologies;
- searching and substantiating sources for financing environmental sustainability.
The following characteristics are the key indicators of environmental safety:
1. Criterion for environmental safety measures in the port.
2. Criterion for safety measures for port employees and life of the population in adjacent territories.

We understand the required level of environmental safety in the port as the level of development of the transport infrastructure that meets the following requirements:
- complying with currently applicable environmental standards for the main directions of industrial impact;
- reducing the harmful effects of transport on the waters and adjacent territory of the port with increased safety and efficiency of the services provided by port operators;
- ensuring that the goals and objectives set by the strategy for sustainable development of the region are achieved.

In addition, the sustainability component including three targets (achieving economic, environmental and social sustainability) should be given special attention. We propose to use the indicators given in Table 2 to estimate these targets.

| Table 2. Targets and Indicators |
|--------------------------------|
| **Target**                  | **Indicator**                        |
| Economic stability          | Total cargo                           |
|                            | Delivery on time                      |
|                            | Corridor capacity                     |
| Environmental sustainability| Total energy used                     |
|                            | Greenhouse gases                      |
|                            | Engine standards                      |
|                            | Dangerous Goods ISO 9001              |
|                            | Alternative fueling stations          |
Social stability
ISO 31 000
ISO 39 000
Safe truck parking
Enclosed terminals

The task then consists in constructing a system of indicators for all components of the strategic map to monitor and control how the strategic goals for development of the NSR as a green transport corridor are achieved.

5. Conclusions and discussion
A sustainable transport system can only be created through balanced and effective development of all types of transport, including air, road, rail, river, sea, and related infrastructure. Furthermore, the era of digital economy calls for innovative solutions, for example, using new modes of transportation, such as airplanes, submarine freight and passenger trains, ground-effect vehicles, airships, etc. Introducing innovative technologies to form the GTC gives a substantial multiplier effect, stimulating activity in other sectors of the regional economy, allowing to efficiently develop resources and territories with the poorly developed transport infrastructure, reducing harmful impacts on the environment. Thus, forming a green transport corridor is not only a costly project but allows to combine the tasks of preserving the environment of the territories lying along the NSR with the tasks of improving the quality of life of the population, achieving both environmental and economic security.

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