

The Construction of Seaports in the Arctic

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The Arctic zone of the Russian Federation is of strategic importance for the country. Considering the fragility of Arctic ecosystems, special attention needs to be paid to the sustainable development of transport and related infrastructure within the framework of the “blue economy” concept, which is relevant for Arctic waters. At the same time, it is necessary to identify the main factors and tasks of creating transport and port infrastructure, building a modern fleet, and organizing fisheries and tourism in an environmentally sound manner.

“blue economy”

seaports

Northern Sea Route (NSR)

environmental safety

1. Introduction

The Russian Arctic zone is among the key directions in the development of the Russian national economy, contributing to the development of mining and transportation of minerals, accessibility and autonomy of remote settlements, international cooperation, and the national image. Russian Federation has the largest Arctic sector among the countries that have an outlet to the Arctic Ocean, a result of which is that it has a leading role as a developer of the Arctic development strategy ^[1]. It is assumed that the Northern Sea Route (NSR), which is a major transport corridor in the Arctic area, will operate uninterrupted and year-round by 2030 according to the Arctic development plan ^[2]. The freight turnover of the NSR is growing annually, and it is planned that in 2024 its volume will reach 80 million tonnes ^[3]. Currently, the coastal infrastructure in the Arctic region is formed by 18 seaports—12 ports in the Western Arctic and 6 ports in the Eastern Arctic. Despite the large number of ports, all of them have a lot of equipment wear, and many ports in the Eastern Arctic were built back in 1940–1950 ^[4]. Despite the complexity of the structure and features in the Arctic region, port infrastructure needs to be significantly modernized and upgraded, and the safe and sustainable functioning of port infrastructure needs to be ensured. For these purposes, technologies for the transition to a “smart port” should be used, including the creation of a risk management system. Digital transformation and modernization of the infrastructure in the Arctic Basin create great advantages for the development of the region. The Fourth Industrial Revolution and digitalization are changing the structure of the Russian region’s economy, requiring a change in technological structure, the use of modern solutions using the Internet of Things, edge computing, and data mining.

A major problem of the Arctic is environmental threats. In this regard, the most important tasks of providing ecological stability during NSR’s development are identification and monitoring of the key contamination factors of the Arctic seas ecosystems and developing a system for managing the safety of maritime operations and ecological safety in the Arctic. Currently, the Russian Federation has accumulated and annually updates a large body of knowledge about the Arctic seas, which should become the basis for making informed environmental

decisions. So, from 1 January 2020, global requirements were put into effect to reduce the sulfur content from 3.5% to 0.5% in all types of marine fuel [5]. In connection with the introduction in 2020 of the requirements of the International Maritime Organization (IMO) prohibiting the use of traditional marine fuel-oil, the rationale for shifting to alternative environmentally friendly fuels becomes apparent.

In this sense, assessing the long-term vision of the development and environmental impact of complex organizational and technical systems and facilities, which include seaports, is undoubtedly an urgent problem.

Arctic port infrastructure development policy should take into account that the new economic paradigm of the XXI century is the concept of the “blue economy”, which was presented to the Club of Rome by Gunther Pauli in 2009 [6], designating a term that has been further developed in scientific research. The term “blue economy” has caused a significant paradigm shift towards the study of the ecology of oceans and coastal areas in connection with the development of ocean and sea management strategies, which together determine whether the use of oceanic and marine resources is sustainable. However, the “blue economy” of the Russian Arctic should be based on business development in the following areas:

- Marine technologies for the safe use, operation and protection of the Arctic marine ecosystem;
- Marine food systems represented by value chains in fisheries, aquaculture and seafood trade;
- Marine biotechnology and bio-products;
- Application of scientific and engineering principles to the processing of materials by marine biological agents for the provision of goods and services;
- Maritime transport via the NSR, which increases the stability of navigation through the use of modern Russian icebreakers.

The growth of the “blue economy” notion in the Russian Federation could potentially play a significant role in advancing its overall economy. Simultaneously, establishing eco-friendlier supply chains is a crucial aspect of cultivating the “blue economy” idea within the Russian Arctic region.

Within the framework of the Sustainable Development Goals set out in the UN General Assembly resolution, all aspects of the “blue economy” based on natural “blue capital” are defined. One of the most important is “Conservation and rational use of oceans, seas and marine resources for sustainable development” [7], which highlights and solves the oceans’ problems and defines specific modern aspects of the concept of the “blue economy”. A risk management system (RMS) is needed to address the challenges of sustainable development and utilization of port infrastructure. It will allow the most efficient organization of the activities of the seaport in accordance with its characteristics.

2. Logistics, Process Management

The NSR has the potential to significantly reduce the distance between the Far East and Europe, influencing both the shipping industry and the environment. In order to reduce the environmental consequences, it will be necessary to get rid of oil sludge, garbage and sewage, including the managing of ballasts. Research [8] has explored the primary threats to the Arctic environment from pollutants and the possibility of implementing pollution control methods in the region. Environmental concerns stem mainly from accidental and industrial contamination.

In [9], authors evaluate the current ecological state of the Russian Federation's Arctic zone as a promising area for active industrial development. The authors stress the need to consider environmental safety requirements in the Arctic region for all economic and other activities, given the unique susceptibility of Arctic ecosystems and the region's climate-forming significance for the planet. Anthropogenic factors pose substantial environmental risks, which, if ignored, could result in global consequences.

The authors of [10] assessed 1300 of the world's key ports for global supply chains and economies to identify crucial cross-border infrastructure dependencies for some landlocked and island countries that depend on specific ports beyond their jurisdiction. This approach allows for analyzing trade flows at the port level and the utilization of specific transport routes for trading goods between pairs of countries.

The T and E report [11] recommends three priority steps to reduce the adverse effects of Arctic shipping: lowering marine black carbon emissions, which contribute to regional ice melting; banning fuel oil usage by ships in Arctic waters due to toxic air pollution and potential catastrophic consequences for ecosystems following an oil spill; and requiring ships to operate at reduced speeds to minimize the risk of accidents and enhance safety and environmental protection.

Study [12] demonstrates that the latest and largest container ships can effectively decrease vehicle emissions and conserve energy, while emissions reductions can also cut down ship docking times. Docking times are influenced by hub port efficiencies, including terminal operations. These vessels can also enable hub ports to receive increased trans-shipment from Asian or Middle Eastern ports. Besides fuel type, vessel speed is crucial in lowering emissions. Large container ships can decelerate when entering or exiting ports to lessen the impact of their emissions on port air quality and nearby cities. Employing the newest and largest container ships on primary Far East–European routes can reduce operating costs and promote environmental sustainability.

3. Tourism

Cruises are a maritime activity that has been constantly growing for more than three decades, and therefore cruise seaports are becoming increasingly important, the direct and indirect impact of which extends to marina towns or nearby touristic locations, since the travel business requires special services for ships and travelers. A chapter of [13] extensively explores two categories of factors that render “green” development a strategic priority for cruise ports, along with crucial considerations for ensuring their sustainable growth.

One prime cruise destination is the Baltic Sea region, where managing cruise ships and passengers poses several logistical challenges related to both water and land. Article [\[14\]](#) aims to investigate service offerings for the cruise industry within the framework of environmental demands and sustainable logistics in port cities, encompassing both ports of call and turnaround ports for cruise ships. Maritime tourism increases the need for urban infrastructure, such as streets, roads, city facilities, shopping centers and entertainment complexes. Ground services for passengers, particularly transfers between terminals, centers, airports and railway stations at turnaround ports, impact urban mobility and may contribute to congestion. Port authorities are formulating environmental policies to mitigate the adverse effects of shipping on the environment by implementing measures to decrease emissions, pollution, noise from cruise ships and waste disposal.

In recent years, the Arctic region has become increasingly important in terms of the number of cruise liners and passengers, as well as all over the world. As tourism activity in the region expands, the likelihood of environmental pollution increases. The influence of cruise tourism on Arctic environmental pollution is studied in [\[15\]](#). The authors grouped the following identified factors into four main categories and showed them on the “fish skeleton” diagram: geography, industry, infrastructure and legislation. It is shown that there are both controlled factors (rules, infrastructure, operation of ships) and uncontrolled factors (weather and sea conditions). The use of heavy diesel fuel primarily has a negative impact on the Arctic environment. The excessive amount of waste generated on cruise liners is another important factor of possible pollution, since there are no facilities for inspection and reception of waste in remote Arctic ports. The lack of infrastructure can also be a key factor in the event of an oil spill or other spills when considering adverse weather and sea conditions in the region, which can multiply the consequences of such incidents. Reducing the impact of the identified factors can be achieved only with the multilateral cooperation of cruise companies, managing states in the Arctic, international regulatory bodies and intergovernmental organizations.

4. Power Consumption in Ports

In [\[16\]](#), the authors, using a multi-level perspective (MLP), explore the socio-technical impacts of three Norwegian ports actively working towards becoming zero-emission energy centers. The study emphasizes the ports' active participation in the transition to sustainable development. The paper examines the factors influencing the transformation of ports towards sustainable energy and the development of different concepts of ‘zero-emission energy hubs’ adapted to relatively small ports, taking into account their constraints and potential. Energy and transport systems are being transformed and complicated, which is accompanied by a transition from one or more key technologies (for example, fossil fuels) to mixed ones.

Russia has a number of floating power plants along its Arctic coast. The reconstruction of the Far Eastern ports is planned. It is also planned to build at least 15 floating nuclear power plants along the Northern Sea Route [\[17\]](#).

The authors of [\[18\]](#) devised a model for determining the exhaust emissions of vessels maneuvering within port areas. The findings indicate that reduced speeds and utilizing shore power can decrease local air pollution, contributing to a sustainable future. The study reveals that small ships generate the most greenhouse gas

emissions in the port vicinity, and emissions increase as navigation speed rises. Therefore, slower speeds and shore power connections can help mitigate local air pollution.

Continuous monitoring of energy consumption in seaports is essential for controlling escalating energy costs, as seen in the growing demand for fuel. Fishing, an energy-intensive activity in seaports, becomes increasingly significant due to the sharp rise in global fish consumption. Document [\[19\]](#) established a roadmap for transforming fishing ports into carbon-free ports and reducing their reliance on the national grid through local solar energy generation. This developed roadmap will facilitate the creation of a carbon-neutral fishing port ecosystem by incorporating sustainable energy practices, including evaluating the quality of energy utilized within the fishing port.

| 5. Port Emissions, Environmental Risks

The port industry often faces the need to comply with regulatory requirements, including safety, protection or environmental requirements. The results of one study [\[20\]](#) show that, although there is still no clear “economic justification” linking “environmental efficiency” with the direct competitiveness of the port, improving this efficiency should be a priority as a means of meeting current needs and as a supportive condition for the development and improvement of environmental indicators to gain a competitive advantage.

Article [\[21\]](#) highlights that, while ports play a crucial economic role, they also negatively affect the environment through local air and water pollution, greenhouse gas emissions, noise and air pollution, traffic congestion and extensive sediment contamination. As public awareness of environmental concerns increases, efficient environmental management in port operations becomes essential. To address growing social and economic demands and environmental challenges, port authorities need to continually implement strategies to enhance environmental performance and guarantee the sustainability of port operations.

Annually, global shipping activities emit 938 million tons of carbon dioxide, surpassing the emissions of the eighth largest-emitting country. One study [\[22\]](#) suggests a methodology for the distribution of intercontinental responsibilities between trading pairs and ships. Based on the model inventory of emissions from shipping, itself based on satellite observations of the activities of ships, emissions from ships related to trade and their impact on human health are estimated.

The analysis of shipping’s impact, alongside international trade databases, reveals a multifaceted relationship between trade, shipping, air quality, and health effects. The quantitative assessment showed that U.S.–China bilateral trade represents 2.5% of global CO₂ emissions from shipping and 4.8% of worldwide premature deaths due to ship-related air pollution.

Article [\[23\]](#) offers an in-depth review of current technologies and ideas that support and advance the decarbonization of seaports, such as smart grids and virtual power plants for energy management. The study emphasizes the need for a tailored energy regulation landscape. It identifies three primary factors that directly and

indirectly influence the environment: fossil fuel consumption, elevated energy usage of power systems and insufficient professional resource management in seaports.

One study [\[24\]](#) is aimed at assessing the emissions associated with ports and their impact on the environment, since air pollution is caused by the burning of diesel fuel by container ships and port equipment.

Terminals situated near residential areas cause higher levels of pollution in the atmospheric air along major urban roads compared to other locations, with port-related emissions most significantly impacting areas close to these roads where container cargo traffic occurs. The authors suggest promoting a comprehensive “green ports” policy in Shanghai by optimizing cargo delivery systems from the port to the city, improving the energy structure within the port, and incorporating real-time monitoring systems to manage energy consumption and atmospheric pollutant emissions.

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