Contributions to Management Science

Igor Ilin
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Arctic Maritime Logistics

The Potentials and Challenges of the Northern Sea Route

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Preface

The modern shipping industry has reached maturity and currently market demand and landscape shifts force industry agents to find new pathways to successful development. Furthermore, the progress achieved with the extended Northern Sea Route (NSR), offering a new competitive transport corridor between Europe and Russia, has made it possible to construct logistics systems and the associated transport infrastructure. These circumstances make commercial exploitation of the NSR the subject of intense focus in many countries actively involved in sea transportation.

The Northern Sea Route (NSR) brings both opportunities and challenges to global logistics systems. Severe climatic conditions and the lack of necessary infrastructure makes the Arctic region rather complicated and expensive for such a global business initiative. On the other hand, the NSR project becomes more feasible as global warming progresses, and an increasingly wider range of services are provided by modern IT and digital technologies.

The exploration of the Arctic has seen a keen interest from government bodies, scientific communities, and businesses. Special approaches need to be taken to the development of the region due to the following characteristics: extreme climatic conditions; pivotal importance of developing the territories; low population density, insufficient labor force; remoteness from major industrial centers, inaccessibility of regional facilities; high resource intensity, dependence on the supply of resources from other regions; low sustainability of ecosystems. The Arctic is the region with the highest undiscovered hydrocarbon potential in the world. The development of hydrocarbon deposits in the Arctic requires, among other aspects, a sufficient transport and logistics infrastructure for oil and gas transportation from the offshore zone to the next point of the supply chain. The transport and logistics infrastructure of the shelf zone and the region as a whole is one of the key factors for the economic, social, and environmental efficiency of shelf field development. Container shipping along the NSR is supposed to play a major role in the transportation of oil and gas from the Arctic offshore zone.

The same as container shipping has recently revolutionized commercial maritime logistics, digital technologies now serve the same purpose, enabling the shift toward a new paradigm in the industry. The NSR ecosystem requires new (digital) business models to be developed for all the participants and stakeholders of this project. The key players of the logistics market are seaports, shipping lines and other carriers, state authorities, shipbuilders, and IT providers. Nowadays, seaports are supposed to provide the appropriate infrastructure and digital platform for efficient maritime logistics operations. Carriers need to be integrated into the shared data space of the ecosystem. Specially designed ships of the Arctic commercial fleet are intended to incorporate the digital architecture, serving as self-contained elements of the information exchange within the logistics operations process. Stringent requirements for the new digital architectural concepts allow the participants of the Arctic maritime ecosystem to gain competitive advantage, providing strategic alignment of business and IT architecture for further successful development in the region.

Thus, the transformation of all the above-mentioned elements toward integration into the maritime logistics system evolving in the Arctic is essential for the success of the NSR project. Analysis of the existing experience, research, and best practices in the following areas lays the foundations for finding efficient solutions for Arctic maritime logistics system:

- Adopting the Smart Port concept for maritime ports
- Developing digital platforms for supporting communications in the maritime logistics system
- Optimization of port operation
- Decision-making in maritime supply chains
- Digital architectures for shipping lines and other carriers
- Transport and logistics infrastructure management for Arctic projects
- Sustainable development of the Arctic zone
- Logistics solutions for offshore oil and gas exploration

The key research open questions discussed in the book are:

- What are the drivers, incentives, opportunities, and challenges of the NSR project?
- How can the logistics systems of Europe and Asia (seaports, shipping lines and other cargo carriers, oil and gas industry) and the Arctic region benefit from the NSR?
- Which drivers promoting the development of business ecosystems are involved in the NSR project?
- What is the role of digital platforms and data management for the Arctic maritime ecosystem and for the NSR project?
- How can the logistics system of the NSR be integrated with the logistics systems of Europe and Asia?

Solutions to the problems outlined in the book can be found by calling on the accumulated knowledge of researchers and practitioners with competencies from diverse areas, including transport and logistics, Arctic studies, IT and digital technologies, socio-economic systems analysis, hydrocarbon production, transport and business modeling, design of information systems and applications, and requirements engineering for IT services.

This book represents the integrated experience and expertise of the researchers from Peter the Great St. Petersburg Polytechnic University (Russia), Hamburg University of Technology (TUHH, Germany), University of Twente (Netherlands), Business School of Rotterdam (Netherlands) and others, as well as experts from oil and gas enterprises, shipping lines, logistics companies, and IT companies. It consists of 15 chapters that thoroughly examine the logistics of transportation in the Arctic Region, as well as the immense impact of digitization in the realm of the complexity involved in maritime logistics in the region.

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Contents

Northern Sea Route Development Concept

Stanislav Chuy, Igor Ilin, Carlos Jahn, and Tessaleno Devezas

Abstract The issues of the development of the Northern Sea Route are extremely topical at the present time. Moreover, the active development of digital technologies has accelerated the pace of digitalization of logistics in general and sea freight in particular. In this study, a concept for the development of the NSR is proposed, based on the results of the expedition "Digital ship of the Northern Sea Transit Corridor." Among the proposed steps, much attention is paid to the creation of infrastructure, namely digital platforms, the concept and requirements for a digital ship system, digital modeling of the project, the integration of all these systems with each other using cloud technologies, big data, etc. In addition, the paper considers the advantages of the NSR, the importance of logistics in the Arctic zone, as well as the role of logistics in the development of the country's economy.

1 Introduction

The Northern Sea Route (NSR) is considered one of the most promising projects in Russia in the field of transit cargo transportation. The rapid development of the economy of the Asian region, the development of digital technologies, the transition of world-leading companies to a new type of business models based on ecosystems and platform solutions, as well as the emergence of new environmental requirements

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have become reference points for the formation of a new concept for the development of the NSR.

Traditionally, the role of the Northern Sea Route is seen as an alternative to the transportation of goods from Asia along the Southern Sea Route (SSR) through the Suez Canal. The main advantage of the NSR is often declared that it is much shorter (Liu & Kronbak, 2010).

Indeed, the distance from the main ports of Asia (Shanghai) to the ports of Europe (Hamburg) through the Suez Canal is shorter by 40% and amounts to 13,000 km versus 22,000 km. However, according to the NSR, taking into account the average annual speed of 19 knots, the vessel can pass the route through the Suez Canal in 26 days without entering the ports, while taking into account the navigational ice situation, the average speed per year along the NSR is 13 knots and the time of delivery Europe will average 23 days per year.

Thus, the hypothesis that the Northern Sea Route is shorter and thus the cargo will be delivered to Europe faster is no longer a sufficient competitive advantage that will force the main sea freight carriers to change routes. Also, passage along the NSR routes requires ships to have an Arctic class, which means it becomes more expensive to build and even has significant restrictions on speed and seaworthiness in open water due to the specifics of the hull for passage through ice (Moe, 2020).

Therefore, it can be concluded that the development of the Northern Sea Route as a competitive transport route of the Russian Federation (RF) on the world market, including as a transport corridor of global importance for the transportation of national and international goods, should be based on competitive advantages that are not associated with the traditional perception of the NSR as more short and fast way in relation to the Southern Sea Route (Didenko & Cherenkov, 2018).

Among other things, it is worth noting that in the structure of world logistics, the first place in terms of the volume of transported cargo is taken by sea logistics. Sea freight is not only the cheapest, but also a strategic type of transport, providing an average of 75% of traffic between states. With the production specialization of macroregions in the context of globalization with a sharp increase in the volume of world trade, the role of sea transport in intercontinental foreign trade transportation becomes critical and already reaches 90% of the total freight traffic (Travkina et al., 2019). Therefore, there are sea routes and logistics companies, some of which are state-supported and state-protected with guaranteed reservation of the national cargo base for their carriers. Thus, state protectionism in the field of maritime transport and shipping is a traditional component of ensuring the competitiveness of national merchant fleets: access to the national cargo base, corresponding ports and directions of routes is protected in a legal (and not legal) way. Transnational shipping companies serving maritime transport receive high revenues. At the same time, the cost of freight by sea transportation significantly affects the final price of the products sold and, accordingly, the competitiveness of the transported products, and this stimulates the development of industry in the countries served. The most efficient from the point of view of carriers are container lines transporting products with high added value, minimum volume and minimum weight. The level of containerization of goods in the world has reached 55%, according to forecasts, this figure in the near future will be 70% (Zhu et al., 2018).

Moreover, the development of Russian and world logistics was influenced by the strengthening of the role of the Asian market (Karanina et al., 2020).

Over the past 20 years, the markets in China and India have grown exponentially. According to the purchasing power parity index, the GDP of these countries grew from $6 trillion to $ 33 trillion and accounts for about 30% of the world economy, with 1/3 of the world's population living in these regions in the amount of more than 3 billion people. Due to economic sanctions, the Russian economy began to drift away from traditional European markets. Also, with the transition of cargo traffic to sea transport, the overland busy Great Tea Route between China, Mongolia, Russia, and Europe ended its existence. Thus, taking into account the peculiarities of the development of the Asian economy and traditionally friendly relations, the markets of India and China opened for Russia (Wang et al., 2020).

It should be noted that the traditional "friendliness" of Russia's relations with the countries of India and China, as well as the countries of the Asian region, is a consequence of the similarity of the models of cross-cultural communication with a focus on long-term orientation and respect for cultural and historical traditions. However, due to the traditional communication system that has developed over the centuries, the transport and logistics system of Russia is focused on trade relations and integration with the economies of European countries. To enter new Asian markets, Russia currently has the Trans-Siberian Railway as its main logistics system.

The Trans-Siberian Railway allows to reduce the time of delivery of Eurasian goods from the sender to the recipient up to 7 days. However, its potential capacity is about 100 million tons and does not exceed 5% of the total Eurasian cargo traffic, and taking into account technological and organizational constraints, no more than 1%. At the same time, in reality, all overland inland Euro-Asian networks serve no more than 1–2% of the total volume of Euro-Asian cargo.

It should also be noted that geographically, not all regions of the Russian Federation have access to this highway. As a result, products manufactured in these regions do not have access channels to the markets of India and China. Also, the most important limiting factor is the rather high cost of delivery of goods through the Trans-Siberian Railway—about 3000–5000 $ /TEU (container).

The main Eurasian cargo traffic follows the Southern Sea Route (Pacific Ocean–-Indian–Atlantic). The extreme points of this route are Northeast Asia—Northern Europe (Baltic). However, Russia, which has a significant potential for occupying a decent position in the maritime transport market in the World Ocean, in particular on the Southern Sea Route, has not yet been represented there as a strong player.

Moreover, 95% of all Russian foreign economic cargoes over 800 million tons/year are served by foreign ships, earning about RUB 1.6–2.4 trillion on the freight of Russian cargo, according to expert estimates. Including on sea container transportation 400 billion rubles. For comparison, the volume (in monetary terms) of domestic civil shipbuilding until 2017 was about 40 billion rubles, and in 2019 alone, due to the construction of nuclear icebreakers, it reached the level of more than 120 billion rubles. At the same time, this industry continues to experience an acute shortage of orders.

Russia found itself in a situation of extreme vulnerability and heavy dependence on the freight carriers of transnational companies. Monopolization of the transportation of Russian foreign trade goods by foreign structures or their subsidiaries tends to 100%. Since 2018, these companies have begun to refuse the transportation of export cargo to Russian sanctioned companies, as well as to prevent exports or block existing logistics channels for military-industrial complex products (civil and dual-use).

The only direct exit of the Russian Federation to the World Ocean is the Northern Sea Route through the seas of the Arctic Ocean.

Currently, the NSR provides not only new opportunities but also a new look at the industry in general and maritime logistics in particular.

This work will consider the following aspects of the formation of the concept for the development of the Northern Sea Route on the basis of the expedition "Digital ship of Northern Maritime Transit Corridor" on board the nuclear-powered icebreaker-transport lighter-carrying container ship "Sevmorput:"

- New role of logistics and digital technologies in the development of the economy.
- The importance of sea freight for the economies of Asia and Europe.
- Features of Russian logistics in the international economy of the twenty-first century.
- New competitive advantages of the NSR.
- Digital trading platforms technology for entering Asian markets.
- Marine logistics in the Arctic Zone.
- Creation of infrastructure for the implementation of Northern Maritime Logistics.
- Digitalization: digital platforms, digital ship, digital modeling, and cyber security.

2 Methods

To search for solutions to realize the transport potential of the NSR during 2019–2020, a working group, "Digital Ship of Northern Maritime Logistics" was formed from more than 150 experts and representatives from more than 50 enterprises from various industries, scientific, and design organizations, leaders in the design of Arctic class ships, design, and manufacture of equipment for marine energy, nuclear, hydrogen, and other alternative types of energy, new structural materials, marine instrumentation, radio electronics, telecommunications, navigation, and communications.

The main tasks of the expedition project were:

- Modeling of the cargo base of the Northern Sea Transit Corridor
- Creation of the main fleet of the Northern Sea Transit Corridor
- Creation of digital services for the Northern Sea Transit Corridor system

- Providing external info-telecom infrastructure of the Northern Sea Transit Corridor
- Technologies for digitalization of logistics

Twenty working and strategic sessions were held, at which more than 50 reports, reviews and reports were heard, hypotheses were formed about the development of international and regional cargo transportation on the Northern Sea Route, where the future of shipping lies in the creation of intelligent marine transport ecosystems based on digital smart ships built on digital technologies modeling, digital twins, cybernetic platform services based on technologies of satellite complexes for remote sensing of the earth and the provision of high-speed Internet (Koronatov et al., 2020).

To test the formed hypotheses, an expedition was organized with scientific support and with the participation of leaders of scientific schools on digital modeling SPbPU, MIPT Phystech-Tsifra, Moscow State University named after M. V. Lomonosov, Faculty of Economics, which took place on board the world's only nuclear icebreaker-transport lighter-carrier container ship "Sevmorput" in September 2020.

For 18 days from September 8 to September 25, the expedition members covered 6800 nautical miles along the route from Petropavlovsk-Kamchatsky to St. Petersburg, having visited ten seas and three oceans.

The expedition made it possible to verify the key hypotheses of the formation of a "reverse" cargo base through the development of the non-energy sector of the regional economy through the development of the Northern Sea Route as a competitive national transport communication of the Russian Federation on the world market using digital platform technologies:

- Conditions for the development of the non-primary sector of the regional economy.
- Requirements for digital platform logistics services in the Arctic Zone (AZ).
- Modeling of our own cargo container base for the NSR.
- Creation of a domestic Arctic cargo container fleet.
- Requirements for the creation of an external info-telecom infrastructure.
- Creation of an intelligent maritime transport system in the RF AZ.

The results of the expedition are clearly shown in Fig. 1.

3 Results

Currently, digitalization has a significant impact on all sectors of the economy, and logistics is no exception. The development of digital technologies in water transport has significantly changed maritime logistics (Egorov et al., 2020). The future of shipping is now promoting the creation of intelligent marine transport ecosystems

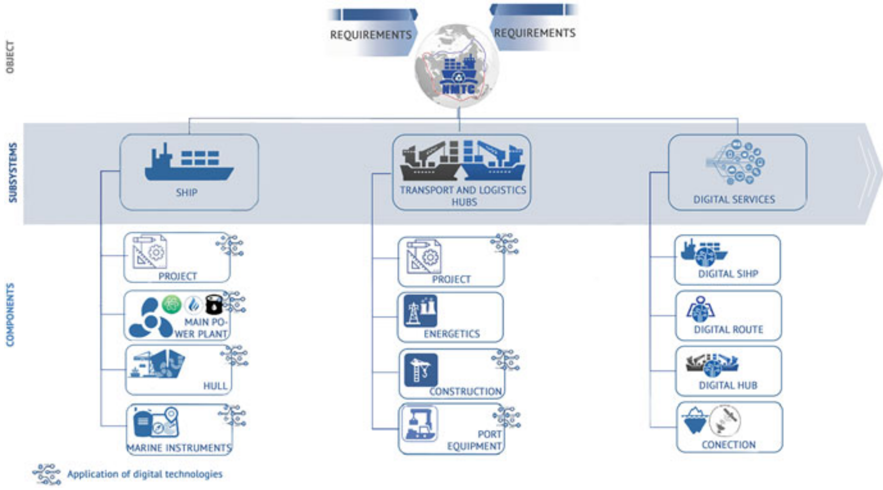

Fig. 1 Navigator of the expedition results in the architecture of the tasks of creating the logistics system of the Northern Sea Transit Corridor (authors' creation)

based on digital platform services built on digital modeling technologies, digital twins.

3.1 Application of Platform Business Models

The emergence of digital eco-platform technologies has made it possible to reduce transaction costs and multiply accelerate the interaction of participants in trade processes related to meeting supply and demand and delivering goods directly to a specific customer. Competitors gain market share not by devices but by entire ecosystems. Platforms benefit because they create new markets and open up new sources of value (Ilin et al. 2020a).

In the twentieth century, supply chain management (logistics) was the main aggregator of business value. In the twenty-first century, the emergence of digital platforms that make it possible to significantly reduce transaction costs and multiply the speed of interaction between participants in trade has become the main dominant in the development of world leaders. So eight out of ten top most expensive companies in the world in 2020, Microsoft, Apple, Amazon, Alphabet (Google), Facebook, Alibaba, Tencent, Visa, do not own production assets in the traditional sense but use a business model based on digital platform services.

The platform business model allows companies to expand at an unprecedented rate. This is the essence of the mechanism of work. Now competitive leadership has become not only the ability to model markets, own standards but also manage distribution channels based on platform business models.

Digital platforms in the implementation of a multimodal method of delivering products using various types of transport, sea, railway, air, auto, have become the determining factor in the competition in the logistics services market.

Thus, logistics based on digital platform business models has become one of the dominant factors (tools) for the development of global business and production.

Traditionally, entering new markets requires a long time, establishing contacts, conducting trade negotiations, business meetings, travel. However, over the past 5 years, due to the development of digital trading platform technologies, entering the markets, searching for goods, counterparties, and concluding a trade deal, purchasing goods can take a fraction of a second, while transaction costs associated with ensuring trade tend to a minimum, many processes are depersonalized and unified, which improves both safety and quality of services.

That is, one of the important tools for the development of the regional economy of the constituent entities of the Russian Federation is the availability and technologies of access to such trading platforms such as Amazon, Alphabet (Google), Alibaba, or the creation of its own domestic platform for the RF-Asia trading ecosystem. Declare about your product and the future buyer will find and buy it.

The presence of social services contributes to the promotion and search for goods, as well as building sales strategies and concluding deals. Networks like Facebook, national vk.com, the formation of their own Big Data databases, their storage, structuring, processing (Ilin et al. 2020c). With such specialized trading platforms, regional products, as well as products from the Asian region, will quickly form their markets.

3.2 Organization of Arctic Maritime Logistics

An important and key element in trade relations is the fact of receipt of the goods, i.e., its delivery. As mentioned above, it was the lack of effective transport routes that was a constraining factor in the development of interaction between the economies of the regions of the Russian Federation with India and China. The only transport highway that works regularly and connects the Russian Federation with the markets of the Asian region is the Trans-Siberian railway, which has significant capacity restrictions (100 million tons of cargo per year).

However, not all regions, especially in the Arctic zone of the Russian Federation, have comfortable access to this artery. At the same time, the cost of shipping a container to China will be about $ 3000–4000/TEU. On average, in the world economy, the cost of delivery of products is up to 10% in the cost structure, in the Russian Federation, transport costs are two times more, up to 20% of the cost of products, which makes the products uncompetitive.

In search of effective transport communication to interact with the markets of India and China, the Northern Sea Route is acquiring new significance.

The NSR should be considered not only as a tool for the implementation of cargo traffic between Asia and Europe but on the contrary, as an independent transport route with its own national cargo base (based on the regional economy of the constituent entities of the Russian Federation) for the delivery of non-resource export products to Asian markets, as well as the delivery of demanded products to regions.

The absence of a national regional cargo base was indicated as one of the main problems in the development of the NSR as a national system of transport communication.

At the same time, the use of digital modeling technologies made it possible to see that the provision of a regular schedule for the movement of transport vessels along the NSR will allow planning the delivery of goods to Asian markets. And the use of digital trading platforms will significantly revive the possibilities of meeting supply and demand and will give a powerful impetus to the development of production in the regions (Li et al., 2021).

A model pilot analysis of the formation of a cargo base in the Komi Republic showed that it is precisely the lack of regular logistics that is the key limiting factor for the growth of the export potential of the region's industry in terms of food products, building materials, mining, and timber industry products.

The results of the pilot modeling showed that the development of the Northern Sea Route opens a window of opportunity for the industry of the Komi Republic and the Ural region to access Asian markets. The potential of the Komi and Ural industries in forming a cargo base from West to East makes the northern maritime logistics project more cost-effective and sustainable.

Further expert analysis showed that for the regions, the presence of rhythmic northern logistics, which opens up effective access to Asian markets, makes it possible to revive industries traditional for these regions, even without significant investments in modernization at the initial stage.

The peculiarity of the geographical and territorial location of the regional economies of the constituent entities of the Russian Federation along the main Siberian rivers makes it possible to develop river-sea logistics at lower costs through inland waterway shipping and the presence of Russian post offices in almost all settlements makes it available to the delivery of freight items of any volume from parcels to consolidation to international transportation in sea containers.

Thus, the levels of Arctic maritime logistics can be classified into the following functional levels:

1. Trunk (ocean)—for the implementation of international freight traffic, incl. Transit from Asia to Europe. In this direction, the most effective use of vessels of the "Panamax" type. Vessels with a cargo capacity of 10,000 TEU.
2. Aggregate (sea)—for the implementation of federal coastal shipping along the NSR with a call to the ports of the Arctic zone of the Russian Federation Murmansk, Arkhangelsk, Naryan-Mar, Sabetta, Salekhard, Dikson, Tiksi, Pevek, including the ports of Kamchatka, Sakhalin, Vladivostok. Vessels with a cargo capacity of 3000 TEU.

3. Regional (river-sea)—for regional access through the main basins of the northern rivers Dvina, Pechora, Ob, Yenisei, Lena, Kolyma: Feeder vessels with a cargo capacity of 300 TEU.
4. Municipal (river)—to carry out the functions of delivering the so-called last mile to the settlement, pier, village, ships with a cargo capacity of 10 TEU.

3.3 Creation of the Arctic Cargo Fleet

A special place in the development of northern maritime logistics is occupied by the construction of a commercial fleet; the costs in this industry can be about 80% of the cost of creating the entire infrastructure (Sergeev et al., 2021).

Thus, the Arctic cargo container fleet is the main core of the project. The service life of Arctic vessels due to their "high cost" due to operation in ice conditions and the payback policy should be 40 years. Such a service life requires the creation of competitive technical solutions that are ahead of the vision of technology development by half a century (Ilin et al. 2020b).

A lot of resource constraints are imposed on the ship's design, associated with its use in a specific environment of "habitat" in harsh and extreme conditions in the Arctic navigation region. At the same time, the vessel must meet all the requirements for environmental friendliness, and solutions for ship power engineering should give a significant economic advantage in relation to traditional solutions on ships of the southern sea route passing through the Suez Canal (Fadeev et al., 2021).

To create an Arctic cargo fleet, it will be necessary to implement an unprecedented program of construction by 2030 of about 30 large-tonnage container ships (700 billion rubles) of the Arctic class with a displacement of more than 100,000 tons with various cargo capacities of 3000, 5000, 10,000. TEU with a competitive power plant incl. on nuclear power plants, LNG, and possibly hydrogen, with the most modern digital ship systems and complexes.

When preparing for the construction of ships, important aspects should be considered:

- Strategic current capacity utilization of SC Zvezda B. Kamen until 2030 (the only place in the Russian Federation where ships of this class can be built).
- Working out the policy of international cooperation with foreign shipbuilders in terms of preventing the transfer of Russia's unique competencies in the Arctic shipbuilding to them.

3.4 Cybersecurity Digital Solutions Procuring

The role of digital technologies in all spheres of life and production is constantly growing, and at the same time, the risks associated with cyberspace are increasing.

Cyberattacks are among the top five threats to humanity, along with natural disasters and climate change, according to a recent report from the World Economic Forum.

Cybersecurity is the process of protecting and restoring computer networks, devices, and programs from any type of cyberattack. Cyberattacks pose an increasing threat to the preservation of sensitive data as attackers use new methods, such as artificial intelligence to bypass traditional security measures. All industries face the threat of cyberattacks, and such an important area as logistics is no exception.

The use of digital technologies and digital platform services at the stages of creating the northern maritime logistics of the NSR, as well as during its subsequent operation, will make it possible to create a project with excellent characteristics—to form a coherent ecosystem of project participants. It is this "comprehensive" service that will have a competitive edge.

Digital technologies proposed for implementation in the project, based mainly on the analysis of big data, the development of smart algorithms for the created ecosystem of the NSR, will allow increasing the speed of the vessel in a complex meteorological situation due to predictive analytics, build optimal routes, expand the list of services provided by digitizing the vessel and its functioning as an element of a single transport ecosystem, minimize the impact on the environment and strictly control its condition, making transportation environmentally friendly and safe (Jahn et al., 2020).

Also, in connection with the latest world unstable trends and the avalanche-like development of digital services, the security of court management in critical situations, as well as ensuring information security and data security affecting commerce and safe operation, is becoming one of the most important factors in the technical issues of ship construction and equipment their respective equipment (devices, communications, navigation).

This is evidenced by the fact that the IMO (International Maritime Organization) issues different regulatory documents and guidelines for cyber risk management in the maritime industry. An important stage in this development is the transition of a vessel from an independent business unit to modern platform business models based on ecosystems, which requires the integration of ship complexes with the cyber platform of digital services of the Northern Sea Transit Corridor (see Fig. 2).

3.5 Export Potential Development

Implementation of the approach to develop the export potential of the non-energy sector of the regional economies of the constituent entities of the Russian Federation with their entry to Asian markets through the development of logistics of the Northern Sea Route will, among other things, allow to form their own national cargo base, as well as launch a program to revive the national merchant marine fleet and create a competitive export infrastructure in Russia and abroad.

It is the development of the domestic regional cargo base that will give stability and competitive advantage for the transition to the next stage in the development of

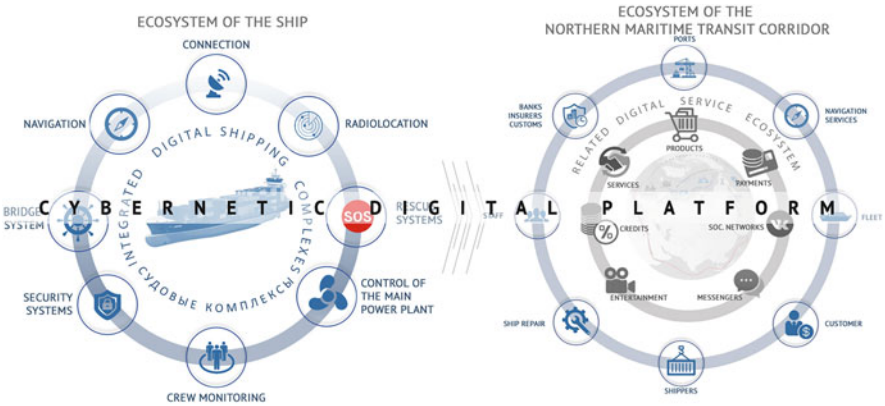

Fig. 2 Transition of a vessel from an independent business unit to platform models (authors' creation)

international maritime logistics and return Russia to the top world leaders in maritime cargo transportation.

About 90% of foreign trade and more than 40% of domestic trade passes through sea routes; in general, about 2 billion tons of cargo are loaded and unloaded annually in the ports of the European Union, more than 400 million people annually use the services of seaports. Marine companies, which are owned by the EU member states, control about 40% of the global flow; The maritime transport sector, which includes shipbuilding, ports, fishing, and related services, employs three million people in the European Union (FSUE Rosmorport, 2013).

When considering this issue, it should be borne in mind that the flow of goods from Europe to Asia is more expensive than from Asia to Europe. It follows from this that the difference in volumetric indicators of oncoming goods flows is even more striking than in value terms.

Foreign shipping companies are already ready to enter beyond the cargo base even into the rivers of Russia, including the Siberian ones across the Arctic Ocean.

Having a reliable cargo or passenger base is the basis for the creation of any transport company. It is this necessary condition that is decisive for the formation of a shipping line company to work on the Asia–Europe–Asia route.

Therefore, the main task for the formation of a domestic shipping container line is the search for a promising commodity base for it in the direction of Europe-Asia, which is solved through the first stage of the development of northern logistics of the NSR through the development of the export potential of the non-energy sector of the regional economies of the constituent entities of the Russian Federation with their entry to the Asian markets through the development of logistics for the Northern Sea Route.

However, the project for the development of SPM through the development of regional economies of the subjects of the Russian Federation has another competitive advantage. The use of river transport within Russia in the formation of the cargo base leads to the possibility of bringing to the Asian markets not only the regional Russian economy but also the economies of Kazakhstan and Afghanistan. Thus, it becomes possible to loop the logistics route through the SCO countries and make the Northern logistics route of SPM completely independent of the cargo base and European markets.

The second most important task is to provide the Russian shipping company with fuel as a factor in increasing its competitiveness. Therefore, the use of nuclear power on ships is practically the only option in the "fuel war."

3.6 Opportunities and Benefits of Digital Modeling in a Project

The Northern Logistics Project of the NSR—Asia has such significant multiplier effects that the implementation of the Project can help in shaping the elements of the digital transformation agenda for a number of authorities and government agencies of the Russian Federation. The development of the project will affect the GRP (gross regional product) of the regions participating in the project, will contribute to the creation of new high-tech jobs, and will give an impetus to restarting sub-sectors based on end-to-end production technologies in the Russian economy.

The project to develop the export potential of the non-energy sector of the regional economies of the constituent entities of the Russian Federation through the development of logistics of the Northern Sea Route and digital platform technologies is an investment project with high multiplier effects on the GDP and GRP of the regions.

To remove all kinds of risks, to select optimal design solutions for the implementation of such mega projects, there is always a stage of conducting a comprehensive technical and economic analysis.

Currently, in connection with the development of digital modeling technologies, the most advanced form of this analysis may be conducting business modeling, checking the business sustainability of the project with the development of a unified scenario dynamic digital model of competitiveness—a digital testing ground for the Asia-Europe Asia international maritime transport system market,—a virtual testing ground making business decisions (Bui-Duy & Vu-Thi-Minh, 2021).

The Northern Logistics Project NSR—Asia may become one of the first largest projects in Russia, initially created on the basis of the principles of a "virtual testing ground." The creation of a "virtual testing ground for the Northern Sea Logistics Project NSR-Asia" will allow working out the compatibility of digital technologies and business models.

Using digital modeling, it is possible at a strategic level to create metamodels that model markets and an ecosystem of new products, allow assessing the cross-industry and cross-country effects of the created business product, as well as simulate the requirements of future standards to ensure competitiveness in world markets. Then, an environment of digital polygons should be created, on which architectural, engineering, and cost solutions are tested, and a digital test of the product's competitiveness is carried out. At the digital twin level, we will be able to optimize the product in terms of competitive advantage and carry out dynamic redesign.

The implementation of digital modeling in the implementation and creation of new businesses based on technical complex products is a demanded advanced competence in the world, especially for the implementation of large infrastructure projects, and now it is a "vacant place" in the Russian economy and business.

Key project indicators (expert assessment)

- The timing of the project is harmonized with the activities of the Strategy for the Development of the Arctic until 2035.
- Source of financing: extrabudgetary incl. with the attraction of foreign investment).
- Growth of budget revenues—1–2 trillion. rub.
- Investment growth of more than 3 trillion. rub.
- Development of the GRP of the regions by 4–5 trillion. rub.
- Growth in income, quality of life.
- Providing employment for more than 10–15 million people in depressed regions.
- Infrastructure and spatial development of the RF AZ.
- Development of the non-energy sector of the economy of shipbuilding, mechanical engineering, space industry, communications, electronic instrument making, digital technologies, building materials, food, tourism.

One of the difficult tasks of the development of the NSR as a national sea transport route of international importance is the problem of forming a national regional cargo base.

The use of digital modeling technologies made it possible to see that with a rhythmic schedule of movement of transport vessels along the NSR (cabotage), it allows enterprises of regional economies of the constituent entities of the Russian Federation located along the main Siberian rivers to plan the delivery of goods to Asian markets for products sold using digital trading platforms, which significantly revives the possibilities of satisfaction supply and demand and gives a powerful impetus to the development of production in the regions.

The presence of Russian post offices in almost all settlements makes it possible to send and receive cargo shipments of any volume, from parcels to consolidation to international transport in sea containers.

The use of river transport within Russia in the formation of the cargo base will lead to the possibility of bringing not only the regional Russian economy but also the economies of Kazakhstan, Afghanistan to the markets of India and China, thus looping the logistics route through the SCO countries and making the Northern logistics route of the SPM completely independent of the cargo base and European markets.

It is the development of the domestic regional cargo base that will give stability and competitive advantage for the transition to the next stage in the development of international maritime logistics, access to the markets of Africa, Central, and South

America, Oceania, and return Russia to the top world leaders in maritime cargo transportation.

4 Conclusion and Discussion

The development of the Northern Sea Logistics and the Northern Sea Route is an extremely important area for research and development at the present time. Moreover, this development of this direction is one of the leading tasks in the Russian Federation and corresponds to the goals and objectives set in the Decrees of the President of Russia.

The purpose of this article was to analyze the results of the expedition "Digital vessel of the Northern Sea Transit Corridor" in accordance with the requirements for the development of the Northern Sea Route as a competitive national transport route of the Russian Federation in the world market for the development of services for obtaining competitive advantages in the maritime transport services market, namely the requirements to:

- To reliability
- To the speed and predictable rhythm of cargo transportation
- To information support
- To safety
- To an effective tariff policy
- To integrated logistics services

The Northern Sea Route is a new economic development opportunity. At the same time, the fact that the Northern Sea Route is the shortest route for delivery to Europe is no longer its advantage, and its use does not make it possible to reduce the duration of transportation. It is believed that this project can no longer develop in this paradigm.

The implementation of platform services, that is, digital trading platforms for trade interaction between the markets of the Russian Federation, China, and India, is one of the key conditions for the formation of a base for the development of the NSR. Also, platform services in conjunction with Northern Maritime Logistics ensure the formation of a cargo base based on the existing production and technological capabilities of various enterprises.

Digital modeling technology is able to provide a competitive vessel design for a specific business model by setting key criteria for a commercial fleet. This technology supports the creation of marine transport ecosystems by developing Northern Maritime Logistics.

The development of the logistics of the Northern Sea Route also creates a potential for the development of export infrastructure, thereby contributing to the program of reviving the national marine merchant fleet.

Digital twin and digital modeling technologies enable the sustainable development of Arctic shipping, contributing to the creation of intelligent marine ecosystems. Also, this direction is influenced by such technologies as remote sensing of the earth and the development of high-speed Internet networks.

Thus, we can conclude that the development of the NSR is a complex task that attracts specialists from different industries to ensure a holistic result that supports such subsystems as ships, ports, and digital subsystems. An important development concept is the seamless integration of these systems, which is possible only thanks to emerging digital technologies, such as cloud solutions, digital twins, big data and others, as well as the creation of digital platform services for the development of the Northern Sea Route as a competitive national transport communication in the world market of the Russian Federation.

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Development of Northern Sea Route and Arctic Maritime Logistics

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Abstract Since the end of the twentieth century, globalization has had a huge impact on the development of all spheres of human activity in the Arctic. In these conditions, as well as considering the climate change, the discovery of new mineral deposits and the estimated assessment of not yet discovered deposits on the continental shelf and international territories, international competition is intensifying for the opportunity to use the Arctic Ocean as a shipping route and to develop Arctic resources. The article analyzes the risks and problems of economic development of the Arctic and possible scenarios for resolving territorial disputes. Obviously, the resolution of controversial issues requires a global consensus, international cooperation, international trade interaction.

1 Arctic Region: Regional Conditions and Challenges

1.1 Arctic and Arctic States

The Arctic is understood as the physical-geographical region of the Earth, bounded along the periphery either by the parallel of 66°33′ north latitude (the Arctic Circle), or bounded by the northern border of the tundra zone. It is sometimes emphasized that the center of the Arctic is the North Geographic Pole. The area of the Arctic, limited by the Arctic Circle, is 21 million km^2, and when limited by the northern border of the tundra zone, the area of the Arctic is approximately 27 million km^2. All this space, called the Arctic, consists of the following spaces: marginal parts of two continents—Eurasia and North America; The Arctic Ocean with all islands excluding the offshore islands of Norway; parts of two oceans—the Atlantic and the

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Fig. 1 Map of the Arctic with the Arctic circle in blue (United States & Central Intelligence Agency, 2019)

Pacific, adjacent to the Arctic Ocean. The length of the coast of the five Arctic countries is 38 700km.of which 22 600km. is the Arctic coast of Russia. http://rareearth.ru/ru/pub/20160804/02368.html, The Rare Earth Magazine, The boundaries in the Arctic will help determine scientists, 4 Aug 2016.

Figure 1 shows a map of the Arctic with the Arctic Circle in blue (United States & Central Intelligence Agency, 2019).

For a long time, the Arctic was considered a territory not adapted for human life ("dead land"), impassable either by water or by land. The Norwegian polar explorer Fridtjof Nansen called the Arctic "the land of icy horror." The first Russian sailors to sail the seas of the Arctic Ocean in the eleventh century. The eastern part of the Northern Sea Route was explored by Russian pioneers Ivan Rebrov, Ilya Perfiliev, Mikhail Stadukhin in the 1930–1940s. Semyon Dezhnev sailed from the mouth of the Kolyma River to the eastern part of the mainland and in 1648 opened the strait between Asia and America. Vsemirnaya istoriya, volume IV-M. 1958, p. 100. Vega Expedition (1878–1880) on the steamer "Vega" for the first time in the world carried out a through voyage (with wintering on the way) by Northeast passage from the Atlantic Ocean to the Pacific and through the Suez Canal returned to Sweden (1880), thus bypassing Eurasia.

Currently, the territory and boundaries of the Arctic have not been determined at the legislative level. Initially, the sectoral approach prevailed, according to which the Arctic was divided between neighboring circumpolar states, with the North Pole being the border of all interested states. The sectoral approach determined the legal status of the islands and lands but did not define the water areas of these sectors. In 1982, the Convention on the Law of the Sea was adopted, according to which the water area of the state extends only to the Arctic shelf, and the offshore zone is international. According to the 1982 Convention, the territorial waters are 12 miles, and the economic territory of the country is a 200-mile zone near the coast.

Countries, territories, continental shelves and exclusive economic zones of which are located in the designated physical and geographical region of the Earth are called "Arctic states." As a rule, two different groups of states are called "Arctic states."

The first group includes five states—Canada, Denmark, Norway, Russia, USA, the coast of which is washed by the Arctic Ocean. They have the coast of the Arctic Ocean, the space of some seas of the Arctic Ocean, they own the continental shelf and can dispose of an exclusive economic zone.

The second group consists of eight states—Canada, Denmark, Norway, Russia, USA and plus Finland, Iceland and Sweden. The coast of Finland, Iceland, and Sweden is not washed by the Arctic Ocean, but they have territories located within the physical-geographical region of the Earth called the Arctic.

The first group of five states until 1982 divided the Arctic into sectors, and this division of the Arctic was quite satisfactory not only for Canada, Denmark, Norway, Russia, USA, but for the whole world. Cold, white silence, icy horror attracted only brave and inquisitive researchers. But global changes in the world led to the abolition of sectoral division and the adoption in 1982 of the UN Convention on the Law of the Sea, but not ratified by all countries. In accordance with the UN Convention on the Law of the Sea, the sectoral division of the Arctic was changed to the country's ownership of the continental shelf within 200 nautical miles. A country can claim a continental shelf and more than 200 nautical miles if certain conditions are met, but with the consent of a special UN Commission created in 1992.

In 1996, at the initiative of Canada, the Arctic Council was created. The Arctic Council includes eight subarctic countries Denmark, Iceland, Canada, Norway, Russia, USA, Finland, Sweden. Six Arctic indigenous peoples' organizations have

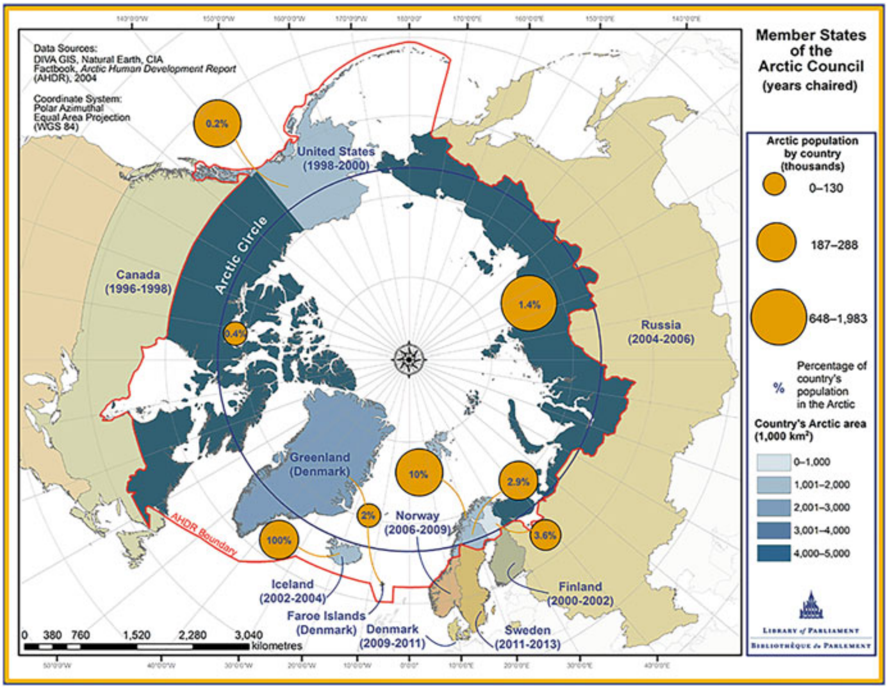

Fig. 2 States of the Arctic council (years chaired from 1996 until 2013) (United States & Central Intelligence Agency, 2019)

special permanent member status. The Arctic Council also includes observer countries, international organizations—observers and non-governmental organizations—observers. Figure 2 shows the member states of the Arctic Council, the population of the Arctic by Arctic countries, the share of the country's population in the Arctic, in percent.

At the end of the twentieth century and the beginning of the twenty-first century, globalization has had a huge impact on the development of all spheres of human activity in the Arctic.

The globalizing world economy is characterized by the openness of national economies, regional integration processes, competition of national economies, competition for geo-economic spaces, population growth in the world, increasing international migration, inequality in the distribution of resources.

In a globalizing economy in the context of climate change in the Arctic, a decrease in the area and thickness of ice, the discovery of natural resources on the continental shelf and international territories, international competition between actors of international activity is intensifying for the opportunity to use the Arctic Ocean as a shipping route and to develop Arctic resources.

The following mineral reserves are located in the bowels of the Arctic: approximately 83 billion barrels of oil; approximately 1550 trillion cubic meters of natural gas; 780 billion tons of coal, including 599 billion tons of energy and more than 81 billion tons of coking coal. The total cost of minerals is $30 trillion. Mineral raw materials include platinum metals, copper-nickel ores, iron, phosphorus, polymetals, gold, diamonds, titanium, tantalum, niobium, fluorite, chromium, manganese, mica, molybdenum, tungsten, vanadium.

The gaze of various countries was fixed on the Arctic. In addition to the Arctic countries, many others want to develop the Arctic space, which is characterized by the desire of countries to have access to the resources of the Arctic Ocean shelf and to develop a transport route along the Arctic Ocean.

Twenty-four countries of the world in addition to the members of the "Arctic Club," including Great Britain, Germany, South Korea, France, the Netherlands, China, and Japan, are showing interest in the development of the Arctic. The countries of the Asia-Pacific region also show Arctic activity. There is a theoretical and practical likelihood of the emergence of military-political, economic, investment pools in resolving controversial issues. The rights on the territory in the area of the Lomonosov and Mendeleev ridge are declared by the countries—Denmark, Canada, Russia, the USA. The NATO countries are building up their aggregate potential in terms of the number of ships in the waters of the Arctic Ocean. The industrial and transport development of the Arctic zone by economic entities is intensifying, and control over the information space of the Arctic is being carried out. A system for monitoring all types of situations is being formed—air, surface, underwater, on land. A set of measures is being taken to provide hydrometeorological and navigational support to control the safety of navigation in Arctic conditions.

Using the example of the Arctic, given its complexity and uniqueness, the apologists of globalization propose to conduct an experiment to introduce a new global model of management of such a geo-economic and geopolitical object—an international management model. The international model of management, according to the apologists of globalization, should (a) be built on the coordination of the interests of the participants in global processes—all states, non-governmental organizations, international organizations, various corporations, (b) provide a solution to existing problems; (c) prevent or reduce potential risks. The authors—supporters of the internationalization of the Arctic, say that globalization is forming a new world-political model of governance based on the triad—"state—business—civil society." At the same time, the Arctic is turning, no more, no less, into an independent political unit. And what should Russia do in this concept, given that it possesses a significant territory of the Arctic? Russia is assigned the role of the country-initiator of the "global historical project," not interested in the opinion of the Russians, and the Arctic is predicted "the century of the Arctic Russia."

When analyzing such concepts, one can see fundamental contradictions between the aspiration of transnational companies to market nature management and the need to save nature for the whole society, between the interests of large corporations and small indigenous peoples of the North, between the norms of national law of individual Arctic countries and the desires of countries dominating in the formation and maintenance of the world economic order.

The territory of the Arctic zone of Russia, in comparison with other Russian territories, is the territory to which the geopolitical, military, and geo-economic interests of various states are more focused, including the interests of countries that are not subArctic.

The Arctic is a territory of international cooperation and rivalry. The richness of the Arctic resources, the strategic position of sea transport corridors—all this creates the basis for the emergence of geo-economic confrontation between the countries of the world as a way to achieve the political goals of states by economic methods. Objective external global environmental trends and processes of internal socio-economic development—categories so diametrical in nature also serve as the basis for the emergence of various risks.

1.2 Risks and Problems of Economic Development of the Arctic

Risk is understood as the possibility of an unfavorable situation for the life of the region. The risks are classified according to the following factors: Arctic climate change; clash of interests of countries on control over the Arctic territories; clash of interests of countries on the regulation of Arctic shipping; increasing anthropogenic and technogenic impact in the Arctic; low level of socio-economic development of the Arctic territories; insufficient level of development of systems to protect the safety of human life in the Arctic; insufficient level of development of Arctic science and technology.

Among the risks due to the warming of the Arctic climate, the following are highlighted: the intensification of the processes of global climate change due to the impact on the Atlantic meridional circulation and the reduction of the ice cap; changes in natural habitats for different types of flora and fauna; melting of permafrost and destruction of the infrastructure built on it; negative impact on the traditional life of the indigenous population.

Due to the clash of interests on control over the Arctic territories, the following risks are highlighted: military confrontation over the delimitation of the Arctic shelf; geo-economic confrontation on the delimitation of the Arctic shelf; loss of control over part of the Arctic shelf due to regulatory changes.

Due to the clash of interests on the regulation of Arctic shipping, the following stand out: military confrontation over the regulation of shipping; geo-economic confrontation on shipping regulation issues; loss of control over shipping along the NSR due to regulatory changes.

Among the risks of increased human activity in the Arctic are increased environmental pollution; changes and declines in the population of Arctic animals; changes in the traditional living environment of the indigenous population; increased pollution of sea waters; negative impact on biological marine resources; reduction of biological marine resources due to their intensive fishing; poaching of biological marine resources; negative impact on the traditional crafts of the indigenous population.

Risks arising from a low level of socio-economic development: lack of labor force; low labor productivity; low production potential; lack or insufficient development of transport and logistics, energy and information and communication infrastructure; absence or insufficient number of objects of housing and civil construction, trade, household, medical, cultural, educational purposes; poor provision of education and health services; lack of government funding; lack of investment for the renewal of fixed assets and the implementation of large-scale projects; wear and tear of the icebreaker fleet; lack of funds for monitoring the Arctic territories and water areas; the low standard of living of the indigenous population; negative demographic processes and population outflow.

Risks of insufficient level of development of science and technology are highlighted: lack of technologies in the field of exploration and production of minerals; lack of technologies for Arctic infrastructure and housing construction; lack of technologies for icebreaking shipbuilding; lack of technologies to ensure environmental safety; lack of energy-saving technologies; lack of technologies in the field of life safety; lack of technologies in the field of determining the boundaries of the Arctic shelf; reduction of joint international research. The importance of the Arctic territories for human life requires the establishment of a procedure for identifying, assessing and monitoring risks and their sources. The following is an analysis of the risk categories.

1.2.1 Risks of the Polar Regions Due to the Warming of the Arctic Climate

One of the global problems, practically not subject to human influence, is climate change towards warming, which provokes a whole range of risks (and not only for the Arctic countries). Climate change in the Arctic is dangerous not only for the ecology of the region. The Arctic region plays an extremely important role in managing the climate in other parts of the world. The warming of the Arctic climate could be considered a negative externality for all circumpolar countries, however, thanks to its influence, new prospects for the development of the Arctic appear.

The problem of global warming is most evident in the Arctic. In other words, the Arctic is warming much faster than other regions. According to NASA, over the past 50 years, the Arctic has warmed by two degrees—this is the highest rate of climate change on the planet. The most obvious manifestation of the warming in the Arctic is the melting of ocean ice. According to the American research center National Snow and Ice Data Center, the total area of oceanic ice cover in the Arctic has decreased by 30% over the past 30 years (Fig. 3).

The melting of ice is multiplied by the decrease in the reflective surface of the ocean. In other words, the smaller the Arctic ice, the faster it melts (This is called the albedo effect). Thus, in the article by (Bintanja & van der Linden, 2013) notes that climate warming in the Arctic occurs at a rate that is much faster than the rate of temperature rise in other regions.

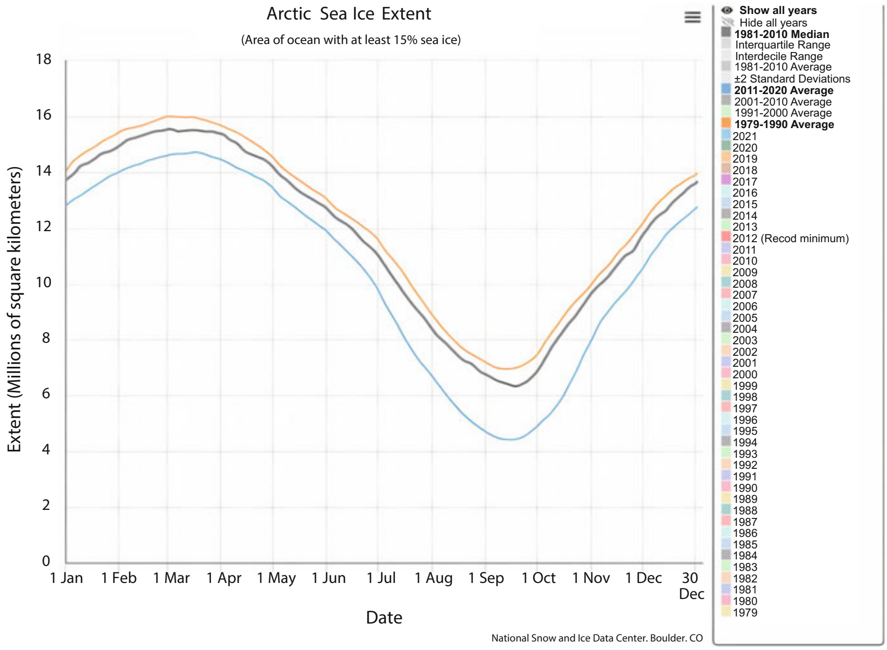

Fig. 3 Arctic sea ice extent. 1981–2010 median (gray line); 2011–2020 (blue line); 1979–1990 (yellow line) (Climate Change in the Arctic. National Snow and Ice Data Center, 2021)

According to Johansson et al. (2012), coordinator of the international research Arctic program INTERACT, the Arctic is an indicator of the ecological health of the planet (After all, too many global ecological processes are associated with the state of this region). According to the author, by 2050, the Arctic waters will be practically free of ice.

The influence on the climate of nearby territories is carried out, first of all, due to changes in the Arctic circulation. At the same time, the melting of Arctic ice can affect ocean currents, which, in turn, will cause a cooling in Europe, as well as reduce the amount of precipitation during monsoons (which is critical for South Asian countries).

Scientists from the Netherlands investigated the effect of melting ice and the resulting increase in oceanic evaporation on the growth of precipitation in the Arctic and regions close to it. According to the authors (Bintanja & Selten, 2014), the consequences of an increase in humidity and precipitation in the Arctic can increase the growth in the amount of snow falling, which will regulate the growth of the Greenland ice sheet and changes in the level of the World Ocean.

The article by Cohen et al. (2014) investigates the problem of the Arctic amplification (amplification of the amplitude of temperature fluctuations in the Arctic compared to the Northern Hemisphere). The authors consider the relationship between climate change in the Arctic and meteorological cataclysms occurring in mid-latitudes (First of all, scientists were interested in excessively high or low temperatures).

Dani and Loreto (2017) draw attention to the relationship between the warming of the Arctic climate and the increase in the concentration of dimethyl sulfide, an organic sulfur compound, in polar waters and the atmosphere. Dimethyl sulfide is naturally produced by some algae and phytobacteria. The melting of Arctic ice stimulates the growth of these organisms, and therefore the concentration of dimethyl sulfide may increase. The release of this substance into the atmosphere can cause a cooling of the climate.

In conclusion, it should be noted (Hammill et al., 2021) the impact of the reduction of the ocean ice cover on the marine fauna. For example, the lack of ocean ice prevents seals from breeding (which endangers the survival of polar bears that feed on them). Reducing the sources of traditional hunting will affect the lives of indigenous peoples.

There is a possibility that fish species traditionally living in the ocean will not be able to adapt to changing conditions (McBride et al., 2014).

Permafrost melting carries a greater risk for the implementation of economic activities. Thus, according to Badina (2021), one should pay attention to the fact that 40% of the infrastructure of Russian cities located in the permafrost zone is in critical condition due to the thawing of frozen rocks. Moreover, the melting of permafrost will lead to emissions into the atmosphere of about 100 billion tons of methane (which is a greenhouse gas and will only enhance the effect of global warming).

Terry V. Callaghan (Johansson et al., 2012) writes that the volume of permafrost will significantly decrease by 2100. This will lead to sinkholes of the soil, drying out wetlands in some areas and the formation of marshes in others, increasing methane emissions and increasing sea level.

The common for the Arctic and subarctic countries of the world, a serious attitude to the environmental consequences of climate change in the Arctic is confirmed by the mention of such risks in almost all of the considered state Arctic strategies.

Analysis of the numerous sources of risks in the Polar Regions due to the warming of the Arctic climate makes it possible to single out the following:

- Strengthening the processes of global climate change due to the impact on the Atlantic meridional circulation and the reduction of the ice cap.
- Melting of permafrost and destruction of the infrastructure built on it.
- Changes in the natural habitat for various species of flora and fauna (as a result—their extinction and disappearance).
- Negative impact on the traditional life of the indigenous population.

1.2.2 Risks of the Polar Regions Due to a Clash of Interests on Control over the Arctic Territories

The Arctic territories are of interest to countries due to the fact that they have significant reserves of crude oil, natural gas, as well as coal and coking coal, deposits of precious, rare earth and non-ferrous metals—gold, nickel, copper, tungsten, uranium, platinum, palladium, molybdenum, and others. Diamonds and other precious stones are mined here. Under the ice of the Arctic, about 83 billion barrels of oil (about 10 billion tons) lie, which is 13% of the world's undiscovered reserves. Natural gas in the Arctic, according to scientists, is about 1550 trillion cubic meters. At the same time, most of the undiscovered oil reserves lie near the coast of Alaska, and almost all of the Arctic natural gas reserves lie off the coast of Russia. Scientists note that most of the resources are located at depths of less than 500 m.

The main risk of the polar countries is the risk of actually losing control over the Arctic territories, both belonging to states in accordance with the current realities of international law, and losing control over territories, control over which is not legally fixed at the current moment for the applicants.

Taking into account the growing geopolitical tension every year over the past 15 years, possible scenarios for resolving territorial disputes (always being potential hotbeds of open conflict) include, among other things, military confrontation up to the use of nuclear weapons.

It is important to note that the Arctic struggle is waged not so much for territories as for direct rights to use polar resources. And if territorial claims exist for an extremely limited list of countries, then economic opportunities are of interest to almost all economically strong actors in the world arena, which significantly expands the list of countries that have their own voice in resolving this issue.

Thus, the resolution of controversial issues of ownership of the Arctic territories, in contrast to standard border conflicts, requires a truly global consensus or the consensus of key actors in world politics.

The actual loss by a polar country of the continental part of the Arctic territories in the current configuration of the world order can occur only under one scenario—a scenario of a military conflict. Despite the fact that most experts consider such a conflict unlikely (especially in view of the disputes between the fundamental nuclear powers, which, technically, are capable of destroying not only each other, but also, according to some estimates, put an end to human civilization), in practice we see strengthening the military presence of all subjects of territorial disputes.

Various forms of military presence are considered. It is proved that from the point of view of the country's defense capability at the moment, none of the Arctic states has a real need to deploy a large number of military facilities in the Arctic territories.

Note that plans to increase the military presence are contained in the national Arctic strategies of a number of states (for example, Norway, Canada, Denmark).

The loss of the disputed Arctic territories, which are perceived as their own, is possible not only in a military conflict. Given the extreme impact of globalization processes, the loss of territories can take the form of a lack of opportunities for economic exploitation, realized with the help of a wide range of information and economic pressure tools.

Any forms of non-military pressure can undoubtedly be overcome by the actual economic development of space, which legally may not belong to the state, with the support of military force as a factor in the absence of foreign economic agents.

One of the key opportunities for using the Arctic territories is international cooperation, international trade interaction (a significant reduction in transport costs). The greatest benefits from the acquisition of the Arctic territories will be received by the states that can ensure the maximum possible openness for foreign economic entities, for foreign capital and technologies while preserving the national interests of the state. Neither the military, nor the economic, nor the information blockade will obviously make it possible to realize these opportunities.

It seems obvious that all applicants to the polar territories are striving not to increase tensions but to create an optimal balance between demonstrating their own interests in the region and demonstrating informational, legal openness, readiness for dialogue and compromise, and for international cooperation. However, in this conflict of interests, different parties have fundamentally different possibilities of pressure on other actors, the only aspect in which relative parity is observed is the military one. Otherwise, there is a likelihood of a situation in which applicants weaker in terms of the totality of factors can be forced out of the region.

Only Russia (relative) and the USA (real) have actual political sovereignty among the polar countries, and all the rest follow in the wake of the USA. Thus, Russia's position in international disputes is the most unstable. In addition, at the moment, the leaders of the USA and some EU countries are demonstrating negative rhetoric towards the Russian Federation.

Therefore, since the 2000s, in the global information field, through the efforts of the countries of the USAs and Western Europe, a negative image of the Russian Federation as a state with an expansionary-imperial worldview has been formed which does not correspond to reality. The logical consequence of this discriminatory approach is economic sanctions, which undermine the country's competitiveness both in the world arena in general and in the Arctic region in particular. Similarly, it is possible to exclude from the process of distribution of the Arctic territories and other players ideologically opposed by the supporters of the unipolar model of the world order.

Summing up, it can be noted that the risks of losing territory can be realized both through a military clash and through geopolitical confrontation in the information and economic field.

A separate item can be highlighted the likely changes in international legal norms, for example, the UN Convention on the Law of the Sea of 1982, which is currently the key document securing the rights of polar states to the respective territories. The withdrawal of politically influential countries from this document may entail irreversible consequences both in the Arctic region and throughout the world. What is especially important, at the moment, the country, which is a recognized world leader—the USA, has not yet joined this Convention.

Thus, among the risks of the polar regions due to a clash of interests on control over the Arctic territories, the following can be distinguished:

- Military confrontation over the delimitation of the Arctic shelf (and the Arctic resources located on it).
- Loss of control over part of the Arctic shelf due to regulatory changes.

- Geo-economic confrontation on the delimitation of the Arctic shelf (Manifested in the form of refusal to implement joint projects, suspension of scientific and technical cooperation, acceptance of tariffs and non-tariff barriers that are unfavorable for other parties, pressure in the media).

1.2.3 Risks of the Polar Regions Due to Conflicts of Interest on the Regulation of Arctic Shipping

The melting of the Arctic ice, in addition to many negative consequences, will undoubtedly contribute to the development of navigation along the Northwest Passage and the Northern Sea Route. Figure 4 shows possible routes for Arctic shipping (Humpert, 2011). The economic benefits of managing shipping and organizing services along the entire Arctic route can be reaped by countries such as Russia and Canada. At the same time, not all states agree with the establishment of national jurisdiction over these sea lanes.

For example, the US Arctic policy emphasizes the need to ensure freedom of the high seas. According to this logic, the Northwest Passage is a strait used for international shipping.

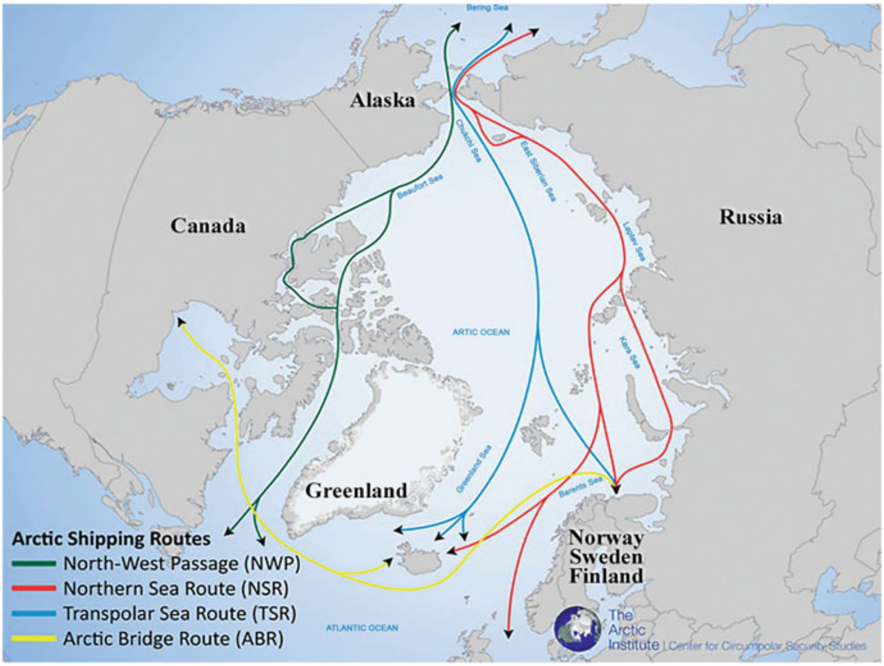

Fig. 4 Arctic sea ice extent. 1981–2010 median (gray line); 2011–2020 (blue line); 1979–1990 (yellow line) (Humpert, 2011)

Note that the dispute over the status of the Northwest Passage has been ongoing since the 1960s. Canada claims that the waterways passing through the Canadian Arctic Archipelago are its inland waters on the basis of "historical right" (Based in historic title) property. Consequently, the jurisdiction of the Canadian state extends to the Northwest Passage. The USA claims that the Northwest Passage is an international strait, which gives foreign states the right to navigate its waterways without the consent of the Canadian side.

The legal and regulatory confrontation between states has been going on for a long time and is complicated by the fact that the USA has not yet ratified the UN Convention on the Law of the Sea. Canada, on the other hand, signed it and, moreover, initiated and promoted the introduction into the 1982 Convention of a special regime in areas covered with ice, enshrined in Article №234 of the document.

According to the Convention, "coastal states have the right to enact and enforce non-discriminatory laws and regulations to prevent, reduce and control pollution of the marine environment from ships in ice-covered areas within the exclusive economic zone, where climatic conditions are particularly severe and the presence of ice covering such areas during most of the year create obstacles or increased danger to navigation, and pollution of the marine environment could seriously harm the ecological balance or irreversibly disrupt it. Such laws and regulations take due account of shipping and the protection and conservation of the marine environment on the basis of the best scientific evidence available."

Canadian scientist Michael Byers (Byers & Lodge, 2019) writes that the Northwest Passage is a network of several sea routes through the Canadian Arctic Archipelago, consisting of 19,000 islands, many rocks and reefs. However, the Northwest Passage is deep enough for heavy ships (which the Panama Canal does not pass). According to M. Byers, the ownership of the Northwest Passage is beyond doubt: after all, the path runs past the islands of the Canadian archipelago. The US claims that the NWSC meets the criteria for an international strait, as it connects two parts of the high seas (the Arctic and Atlantic oceans) and is used for international shipping. From this point of view, the waterway is considered Canadian territory, but foreign ships have the right to transit through it.

A similar situation has developed around the Northern Sea Route (NSR). According to Russian legislation, the Northern Sea Route is a historically established national transport communication; the water area of the Northern Sea Route includes the water area, covering the internal sea waters and the territorial sea.

The same position was adhered to in the USSR, noting that the NSR is the internal waters of the state. In the late 1980s. M. Gorbachev proposed to open navigation for foreign ships along the Northern Sea Route with the support of Soviet icebreakers.

The Northern Sea Route includes a fairly wide area. "The water area of the Northern Sea Route is understood as the water area adjacent to the northern coast of the Russian Federation, covering the internal sea waters, the territorial sea, the contiguous zone and the exclusive economic zone of the Russian Federation and bounded from the east by the line of demarcation of sea spaces with the United States of America and the parallel of Cape Dezhnev in Beringovo strait, from the west by the meridian of Cape Zhelaniya to the Novaya Zemlya archipelago, the eastern coastline of the Novaya Zemlya archipelago and the western borders of the Matochkin Shar, Karskiye Vorota Yugorsky Shar straits." (Gavrilov, 2015).

Such a broad definition of the boundaries of the water area of the NSR is explained by the fact that this route does not have a single and fixed route. Nevertheless, under any circumstances, in its significant part, this route is located within the exclusive economic zone of Russia, its territorial sea, or even in Russian internal waters, that is, it passes in areas falling under the sovereignty or jurisdiction of Russia.

However, according to the USA, the Northern Sea Route (as well as the Northwest Passage) includes straits used for international shipping. The creation of the Administration of the Northern Sea Route and the adoption of a federal law regulating icebreaker escort of ships and the procedure for navigation helps to strengthen Russian jurisdiction and increase the competitiveness of the NSR (Khan et al., 2018).

It is obvious that the closure of internal national waters to foreign ships is completely contrary to the interests of Canada and Russia: on the contrary, both countries are striving to expand the volume of shipping in order to extract maximum economic benefits. However, the establishment of national jurisdiction over the straits makes it possible to ensure the sovereignty of states, protect their interests and protect security (including environmental).

Among the risks of polar states due to a conflict of interests on the regulation of Arctic shipping are:

- Military confrontation over shipping regulation.
- Loss of the Russian Federation of control over shipping along the Northern Sea Route due to changes in the legal and regulatory nature.
- Geo-economic confrontation on the regulation of shipping (Manifested in the form of refusal to implement joint projects, suspension of scientific and technical cooperation, acceptance of tariffs and non-tariff barriers unfavorable for other parties, pressure in the media).

1.2.4 Risks of the Polar Regions Due to the Increase in Anthropogenic and Technogenic Impacts in the Arctic

The identified risks of increased human activity in the Arctic are quite similar in some of their manifestations to the risks of climate change. Nevertheless, if the ability of mankind to influence the processes of global warming is rather limited, then the risks of increasing anthropogenic and technogenic impact directly depend on the position of states on the development of the Arctic (Efremova et al., 2017).

Nevertheless, the idea of conserving the Arctic and leaving its nature almost intact is not supported by even the most active fighters for the preservation of the polar ecosystem.

What could be the consequences of increased human activity in the Arctic? According to a group of researchers (many of whom work for the World Wildlife

Fund), active development of the Arctic increases the risks of environmental problems (in particular, the reduction of biodiversity due to active resource extraction and shipping).

The authors (Moore & Reeves, 2018) analyze the habitats of populations of rare cetaceans (beluga whales, narwhal and bowhead whales) and argue that the development of oil production and the laying of new sea routes can cause irreparable harm to the fauna of the Arctic seas and, thus, undermine the well-being of indigenous peoples, whose occupation is associated with sea hunting.

In the joint work of scientists from Germany, Russia, and the USA (Kuemmerle et al., 2014), it is shown what harm can be caused to the wildlife of the Russian tundra (namely, the population of reindeer) the development of Arctic oil and gas fields.

Scientists of the Murmansk Marine Biological Institute of the Kola Scientific Center of the Russian Academy of Sciences, after conducting a sea expedition, came to the conclusion that at present, the seas of the Russian Arctic as a whole retain a relatively low level of anthropogenic pollution, with the exception of a few areas. These areas fall within the zones of local activity and are mainly associated with the areas of the port infrastructure. In other words, the long-term anthropogenic impact on the Arctic marine environment has a focal character with the formation of centers of anthropogenic pollution in the estuarine areas of large rivers and zones of port infrastructure. The scientific team within the framework of the project “Russian Federation—Support to the National Action Plan for the Protection of the Arctic Marine Environment” of the United Nations Environment Program (UNEP) and the Global Environment Facility (GEF) carried out a diagnostic analysis of the state of the environment in the Arctic zone of the Russian Federation. According to this analysis, scientists have come to conclusions that support the research of their Murmansk colleagues. Strong and moderate negative impacts of anthropogenic impacts on coastal marine ecosystems in the Arctic are most often limited to a local or local scale. And although pollution accompanies most types of activities on the coast and at sea, the maximum possible fishery damage from modern pollution of the Arctic does not exceed the loss of 0.01% of the biomass of commercial species inhabiting the waters of the Arctic shelf of Russia.

At the same time, there is currently a “greening of the Arctic competition”—increased pressure from environmental organizations and an increase in environmental standards and requirements, which may complicate activities in the region, but is an objective direction for the development of international relations. Anthropogenic and technogenic activities—aspects that can be directly controlled by states through the establishment of environmental standards; however, there is currently no single international environmental standard. But there are examples when individual countries are trying to rectify the situation. Thus, Finland, during its chairmanship of the Arctic Council, created a database on the sources of air pollution in the Arctic with soot (black carbon) and methane emissions. The main sources of soot emissions in the Arctic are transport and households, where wood and coal are used for heating, as well as forest fires, power plants and gas flares in oil fields.

Linda Nowlan (2001), published with the support of the International Union for Conservation of Nature (IUCN), notes the need to develop a unified regulatory framework aimed at preserving the Arctic ecosystem and achieving sustainable development. Indeed, the national Arctic territories have their own environmental standards: for example, Denmark, Finland, and Sweden are subject to European environmental legislation, and the USA and Canada are members of the North American Agreement on Environmental Cooperation (NAAEC). Linda Knowlan considers the Arctic Environmental Protection Strategy adopted in 1991 (Strategy, 1991) by all polar states as a basis for the emergence of such uniform standards. The Strategy declares that the Arctic countries are committed to the idea of international cooperation in the field of protecting the Arctic environment and its sustainable and equitable development and, thereby, protecting the culture of indigenous peoples.

The countries that signed the Strategy commit themselves to cooperate in the field of scientific research on environmental pollution processes, assess the potential environmental impact of development activities, implement measures and consider further measures to control pollutants and mitigate their negative impact on the environment. Environment of the Arctic. At the moment, Russia is developing a standard for the environmental safety of the Arctic—a kind of polar environmental code, the adoption of which is aimed at generalizing the environmental problems of the region and ensuring environmental safety.

Thus, among the risks of an increase in anthropogenic and technogenic impact (increased human activity in the Arctic), one can single out:

- Increase in environmental pollution (including an increase in the likelihood of an environmental disaster due to an oil spill).
- Changing the traditional living environment of the indigenous population.
- Negative impact on the population of Arctic animals (change and decline).
- Increased pollution of sea waters.
- Reduction of biological marine resources due to their intensive fishing.
- Negative impact on biological marine resources (both due to pollution and due to increased noise and intersection of sea routes with the trajectory of movement of fish and marine animals).
- Poaching of biological marine resources.
- Negative impact on traditional crafts of the indigenous population.

1.2.5 Risks of the Polar Regions Due to the Low Level of Socio-Economic Development of the Arctic Territories

The next group of risks is associated with the low level of socio-economic development of the Arctic territories. Undoubtedly, the degree of exploration and development of the Arctic space depends on the level of socio-economic development of the nation states to which the Arctic territories belong.

In other words, national social and economic problems in many ways give rise to the risks of a low level of socio-economic development of the Arctic territories associated with the opportunities that states have for the development and development of these regions (Romashkina et al., 2017). Despite the importance of geopolitical, environmental, and research issues, the resource potential of the Arctic contributes to the socio-economic development of the Arctic territories.

We have identified the risks that appear under the condition of a low level of socio-economic development for Russia (Since it is the geo-economic Arctic strategy of Russia that is a priority for us). Let us present the highlighted risks:

- Lack of labor (especially qualified).
- Low production potential (insufficient number of production facilities).
- Low labor productivity.
- Lack or insufficient development of transport and logistics, energy and information and communication infrastructure.
- Poor provision of education and health services.
- Absence or insufficient number of objects of housing and civil construction, trade, household, medical, cultural, educational purposes.
- Lack of investment for the renewal of fixed assets and the implementation of large-scale projects.
- Lack of government funding.
- Deterioration of the icebreaker fleet.
- Low standard of living of the indigenous population.
- Negative demographic processes and population outflow.
- Lack of funds for monitoring the Arctic territories and water areas.

To understand the existence of similar problems of socio-economic development in other countries, let us consider the features of the socio-economic development of Alaska, Yukon, Nunavut in comparison with the patterns of development of the Russian Arctic territories.

About 85% of Alaska's budget is replenished from oil revenues. It is the oil and gas industry (as well as the mining of gold, zinc, silver, molybdenum, and other mineral resources) that is the driving force behind the development of this region. Other sectors of the economy are associated with fishing, tourism, and logging.

The predominance of the oil and gas industry in the economy and the decline in oil prices in 2015 lead to an increase in unemployment in the region (according to specialists from the Alaska Department of Labor and Workforce Development) (Fried, 2018).

According to experts from the Department of Labor and Employment of the State of Alaska, the region has the highest degree of "turnover" of the population (In other words, the composition of the population of Alaska changes frequently: some people come to temporary work and then leave the state). This is also due to the presence of large American military bases in Alaska (In 2014, there were about 22,000 people at the military bases of Alaska out of 735,000 of the total population of the state).

The state's remoteness from the main territory creates a number of additional difficulties. In particular, according to some experts, food prices in Alaska are higher than the national average, precisely for this reason (Note that in Alaska, per capita incomes exceed the national average and amount to about 32,000 and 28,000 dollars, respectively, the average income of families is 69,000 and 52,000 dollars. Development problems of Alaska are also associated with the mono-directionality of the economy; experts note the subsidization of the region.

To protect the interests of the indigenous peoples of Alaska, the Alaska Native Claims Settlement Act was passed in 1971 on the granting of land ownership rights and resolving a number of issues related to the use of natural resources in the territory of traditional residence of the indigenous population. The indigenous people were allocated land holdings in the territories of their traditional residence, which provided them with the opportunity to maintain livelihoods through the use of surface and underground resources. Moreover, this law also determined the creation of the Alaska Native Regional Corporations. Local corporations and their shareholders receive financial support from the federal government through regional corporations. Interestingly, ethnic requirements were imposed on the shareholders of corporations: they had to possess at least a quarter of the blood of one of the indigenous peoples of Alaska. Thus, the state's land and natural resources were privatized, and a private-collective popular form of ownership was formed (Berman, 2018).

State aid to its Arctic regions is also provided by Canada: Yukon, Northwest Territories and Nunavut. The Territory budget, including grants, is maintained by the Federal Department of Aboriginal Affairs. The specificity of socio-economic development is illustrated by the following statistics: according to 2011 data, Canada ranked 6th in the world's HDI ranking, while its northern territories (Yukon, Northwest Territories, Nunavut) were, respectively, 17th, 3rd, and 38th. In terms of life expectancy of the population, the country was in 13th place in the world, the northern territories occupied the last three places in the country and, respectively, 40th, 38th, and 100th in the world. In terms of the average length of study, Canada was in sixth place in the world, the Yukon—in fourth; The Northwest Territories are in tenth place, Nunavut is in the last, 13th place in the country, and, respectively, 9th, 12th, and 30th in the world. In terms of income, Canada is in 16th place in the world ranking; the northern territories are leaders in this indicator and are ranked 1, 3, and 6 in the country, 5, 3, and 11 in the world. Yukon is an extremely sparsely populated region; as of 2012, only 0.1% of the total population of Canada lived in it; at the same time, the population density was lower than in the Chukotka and Nenets Autonomous Okrug, the two most "deserted" regions of the Russian Federation.

Experts from the Department of Economic Development of the Government of the Yukon note that in 2018 the rate of GRP growth in the region was the lowest in the country. The reason for this was the reduction in the extraction of mineral resources. The specificity of the region, which lies in the low population density and, at the same time, the desire to develop the extractive industries, positively affects the value of the unemployment rate, which in the Yukon is the lowest in the country. Nunavut is the most sparsely populated region in Canada. The region is also very rich in minerals (gold, hydrocarbons, zinc, silver, etc.). Nunavut is also a special region in terms of legal and regulatory aspects: it was created in the early 1990s by separating a separate Inuit area from the Northwest Lands.

So, the main problem of the socio-economic development of the Arctic territories of Canada is the demographic sphere and the associated lack of labor resources. To improve the skills of the local workforce and develop education in Nunavut, the Arctic College was established, which functions by distributing educational centers in aboriginal communities and developing priority educational programs for the indigenous population. Nunavut also has Aboriginal corporations similar in purpose to the regional corporations of Alaska Natives. Aboriginal corporations play a role in creating their own industries that operate on the principle of "dualism," ensuring the preservation of traditional economic activities while actively participating in the development of natural resources in northern Canada. Indigenous corporations serve to create jobs for Aboriginal people.

Nunavut, Yukon, Alaska, and the Arctic regions of Russia are united by a number of common problems associated, first of all, with the poorly populated territories, and, consequently, with the lack of personnel.

So, for example, the Nenets Autonomous Okrug ranks last in the list of subjects of the Russian Federation in terms of population (43,373 people as of January 1, 2015, of which 23,939 people, i.e., 55% of the population are in Naryan-Mar—the administrative center of the region). Chukotka Autonomous Okrug ranks last in the list of subjects of the Russian Federation in terms of density (and the penultimate in terms of population): 0.1 people per 1 km^2 and 50,000 people, respectively).

The economic mono-orientation of the Arctic regions of Russia, Canada, and the USA is also similar. The Arctic territory of the Republic of Yakutia is rich in deposits of gold, tin, lead, tungsten, mercury, and semiprecious stones. The basis of the economy of the Yamal-Nenets Autonomous Okrug is the oil and gas complex (Subsidiaries of OJSC Gazprom and OJSC NK Rosneft operate in the Yamal-Nenets Autonomous Okrug). The Nenets Autonomous Okrug possesses large reserves of oil and gas, as it is located in the northern part of the Timan-Pechora oil and gas province, which is ranked fourth in terms of oil reserves in Russia. The region is rich in natural resources (Deposits of iron, apatite-nepheline, copper-nickel ores, raw materials for building materials, semiprecious stones, etc., as well as the most famous hydrocarbon deposits—the Shtokman and Prirazlomnoye deposits should be highlighted).

Thus, the Arctic territories of the countries of the world have similar problems of socio-economic development.

1.2.6 Risks of the Polar Regions Due to the Insufficient Level of Development of Life Safety Protection Systems

Among the risks of polar states due to the insufficient level of development of life safety protection systems, the following were highlighted:

- Insufficient effectiveness of search and rescue operations.
- The risk of terrorist attacks.

The life safety protection system in the Arctic includes the appropriate security infrastructure (It includes reconnaissance and monitoring tools, attack prevention, various military bases, systems for organizing search and rescue operations, etc.), as well as measures taken by the state in this area.

The Arctic is a sparsely populated region and, probably, therefore, not the most attractive for large-scale demonstration terrorist attacks. Nevertheless, for example, an attack on the infrastructure facilities of the Northern Sea Route will significantly undermine the prestige of this transport corridor and reduce the volume of shipping, which is extremely disadvantageous for Russia. Graça Ermida (2014) wrote about the threat of terrorism in the Arctic.

Almost all polar states are deploying military formations to the north, creating special bases and developing monitoring systems. Perhaps this is due not only to the desire to ensure the security of these territories but also to an ordinary demonstration of military power.

For example, Canada has developed the Polar Epsilon military program, designed to create a unified system of all-weather control of vast water areas with a radius of up to 1000 nautical miles from the coast of Canada and the Arctic sector of Canada (Canada, 2009). Further, in Canada there is a coast guard system NORDREG, in which all ships entering the country's maritime territory are required to register.

Canada and the USA envisage the further development of aerospace tracking and control systems within the joint NORAD system (North American Aerospace Defense Command).

Norway in its Arctic strategy also states the need to increase the country's military presence in the region. Note that Norway is a training ground for the annual NATO Cold Response exercises. Also in the press you can find reports of additional large-scale NATO exercises codenamed Joint Viking. The Norwegian government plans to increase the participation of allies in military exercises and maneuvers in the north and will make efforts to maintain interest in them from allied countries and partners (Affairs, 2006).

Denmark draws attention to the need for cooperation between countries on maritime safety issues (For example, for a ship in distress to receive timely assistance from other states). To ensure the safety of navigation, Denmark introduces special rules for the inspection of ships and recommends that other countries have recourse to the same, having adopted the Polar Code in the near future.

In addition to inspections, it is necessary to promote the modernization of infrastructure, for which in 2009 Denmark created a special Transport Commission. The emphasis is on the use of satellite navigation technologies. In particular, ships entering Greenland waters must regularly report their position to the GREENPOS system.

Also in Denmark, it is proposed to create a special unit—Arctic Response Force (Arctic unit of rapid response).

Denmark has long and actively cooperated with the USA on military issues. In 1951, the USA and Denmark entered into an agreement on the joint defense of the island, as a result of which the largest American base in the Arctic region appeared in the town of Thule (Denmark, 2011).

Denmark signed an agreement of understanding with Canada aimed at strengthening military cooperation in the Arctic, including conducting joint exercises and cooperation in search and rescue operations.

Note that Roskosmos plans to implement a project to launch the Arktika-M1 and Arktika-M3 satellites. These satellites will provide Roshydromet with meteorological information, control emergencies, monitor the passage of ships along the Northern Sea Route, and carry out environmental monitoring of the environment. The constellation will also include the Arktika-R radar control satellite, which will carry out measurements related to the exploration of mineral deposits, and the Arktika-MS communications and communications satellite. The devices will contribute to the development of the information and communication system of the Russian Arctic.

Further, one of the elements of ensuring security in the Arctic zone of the Russian Federation is the federal system of search and rescue support for maritime activities of the Russian Federation, which is planned to be created (according to the Concept for the development of the search and rescue support system of the Navy for the period up to 2025) for the search and rescue of people and objects of maritime activities in the water space.

Thus, it seems that the main polar states are striving to build up forces in the Arctic space, and this is not associated with possible terrorist risks.

With regard to the risk of insufficient effectiveness of search and rescue operations, the polar countries seek to cooperate in this matter. For example, on May 12, 2011, in Nuuk, an Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, or in an abbreviated version—Arctic Search and Rescue Agreement (SAR) developed at the initiative of the Russian Federation and the USA. This document was the first legally binding instrument created within the framework of the Arctic Council.

By agreement, each state is assigned an area of responsibility for conducting search and rescue operations in Artik. In 2012, the first operational SAREX 2012 search and rescue exercises of eight Arctic states took place.

Among the most recent activities in the field of joint search and rescue, the joint exercises between Russia and Norway, completed on June 4, 2015, should be noted. In addition to practicing the rescue of the crew of a ship in distress, oil spill response drills were held.

For Russia, the effectiveness of search and rescue operations is associated with the implementation of the provisions of the Concept for the development of the search and rescue support system of the Navy for the period up to 2025. As an example of the implementation of measures to support search and rescue operations, one can single out the opening in Arkhangelsk of the third of ten search and rescue centers that are planned to be located on the Northern Sea Route. The first centers were opened in Naryan-Mar and Dudinka; In 2009, 910 million rubles were allocated for the construction of a complex of search and rescue centers.

1.2.7 Risks of the Polar Regions Due to the Insufficient Level of Development of the Arctic Science and Technology

The Arctic is a territory of harsh climatic conditions, a fragile ecosystem and a place where the interests of various countries of the world collide due to the richness of resources and the strategic position of sea transport corridors; that is why, in almost any area of the Arctic life, the development and application of special technologies is required.

The development of science and technology is the basis that will make it possible to carry out effective development and achieve sustainable development of the Arctic territories. It is the level of scientific and technological development that largely determines the state's ability to minimize the other risks highlighted above.

For example, the warming of the Arctic climate is causing the permafrost to melt, which contributes to the destruction of the foundations of buildings. The development of technologies for Arctic construction will help to minimize the consequences of the risks of soil failure and will allow the construction of buildings that do not require subsequent repair and reconstruction after the frozen ground thaws.

If the state possesses technologies to eliminate the consequences of an oil spill, then the environmental damage of such disasters will be reduced.

An important area requiring the use of new scientific and technical developments is the electric power industry. There are a number of problems here that are the same for all polar states: the need to develop energy conservation, difficult climatic conditions and the high cost of importing energy resources. Obviously, the latter problem should be solved through the use of local resources, but this requires the construction of oil refineries (and not just production platforms), which is a very long process, and after all, the implementation of energy conservation needs to be established at the very first stage of the development of new remote Arctic territories . In this case, the use of small-scale energy technologies seems to be optimal (in particular, wind energy, because the Arctic is the land of severe winds).

Finally, to carry out exploration of the Arctic shelf and submit applications to the UN to designate an exclusive zone, a number of studies and development of technologies for determining the shelf boundary are required.

The development of Arctic science and technology, of course, is determined by the general state of this area in each polar state, as well as the ability to implement joint research projects. Of course, the state influences the directions of fundamental and applied research by allocating funds and identifying priority areas.

Scientists from Canada and the USA made a great contribution to Arctic research (The analysis was carried out by the number of publications registered in the WoS system; some of the research work was carried out by joint teams of scientists (Didenko et al., 2020)).

On June 1, 2015, Canada adopted the Canadian High Arctic Research Act, which announced the formation of the Polar Knowledge Canada organization (can be translated as the Canadian Polar Research Organization). The goal of this organization is to "strengthen Canada's leadership in Arctic technology and conduct world-class breakthrough research." This organization will be responsible for the operation of the new research station, The Canadian High Arctic Research Station (CHARS).

The experience of Canada's creation of a network of research centers ArcticNet, which serves to facilitate interaction between scientists and indigenous organizations, municipalities, federal and local agencies and the private sector for Arctic research, is extremely interesting for Russia. More than 145 researchers from 30 Canadian universities, 8 federal, and 11 local agencies carry out joint research activities with scientists from Denmark, Finland, France, Japan, Norway, Poland, Russia, Spain, Sweden, Great Britain, and the USA; at the moment the network is implementing 41 research projects in various fields. The main goal of ArcticNet's work is to promote the development and dissemination of scientific knowledge for the development of national policies and adaptive strategies to minimize the impact of Arctic climate change and modernize the Canadian Arctic.

In 2013, the trilateral Transatlantic Ocean Research Alliance (The Transatlantic Ocean Research Alliance) was formed between the USA, Canada and the European Union, one of the activities of which is cooperation in Arctic research.

Interestingly, back in 1998, experts from the Canadian scientific community noted the existence of a deep scientific crisis in the field of Arctic scientific research, which was caused by the lack of formal scientific policy and government funding.

Interest in the Arctic, accompanied by an increase in polar research programs, occurred, most likely, in all countries, in 2004–2006, when the world started talking about the rapid melting of ice and about the prospects and problems that such climatic changes open and provoke.

In the USA, there is an independent agency that advises the Congress and the President of the country on polar research—USARC (United States Arctic Research Commission), created back in 1984. The objectives of the Commission are:

- Carry out the development of national policy, priorities, and goals necessary for the formation of a federal target program for the development of Arctic fundamental and applied scientific research.
- Promote the implementation of research projects and develop recommendations for the President and Congress in this area.
- Collaborate with the National Science and Technology Council and the National Science Foundation.
- Lead the Interagency Arctic Research Policy Committee to develop national Arctic research projects and a five-year implementation plan.
- To interact with local and international research organizations and programs.

To coordinate Arctic research activities in the USA and implement a five-year development plan for this area, the Interagency Arctic Research Policy Committee (IARPC) created a special structure, IARPC Collaborations, consisting of 12 thematic groups of scientists.

IARPC Collaborations serves for the cooperation of research initiatives of scientists from various federal and non-governmental organizations, industrial enterprises, representatives of indigenous peoples, etc. The main areas of activity (and areas of work of 12 thematic groups, respectively) are related to environmental, meteorological research, work in the field of health and systems development collection of information and monitoring.

Alaska also has a large International Arctic Research Center (IARC), founded in 1999 with the support of the American and Japanese governments.

Since 2001, the international network of Arctic research stations SCANNET has been developing. Initially, it included the stations of the polar states. The network was founded at the initiative of the European Union and initially included nine stations, and then expanded to 33 [70]. At the initiative of SCANNET, on the basis of the Royal Academy of Sciences of Sweden, the INTERACT network was launched, uniting research stations and organizations of both eight polar states and non-Arctic countries. In total, the INTERACT network includes 73 stations in 18 countries of the world (Only 33 stations included in the SCANNET system are located in the Arctic zone; the southernmost of the stations is located in Kyrgyzstan on the slopes of the Tien Shan mountain range).

Russia is represented by 18 INTERACT stations (for example, in the village of Chokurdakh, on the White Island in the Kara Sea). Also, since 2005, a joint Russian-German station has been operating on Samoilov Island in the Lena River delta. For comparison: Canada has 17 stations, Alaska—2, Svalbard (Spitsbergen)—5, Finland—8, Sweden—3.

The partners of the project are such organizations as the Institute for Biological Problems of the Cryolithic Zone of the Siberian Branch of the Russian Academy of Sciences, the Yugorsk State University and the Faculty of Geography of Moscow State University.

In Russia, the situation with Arctic science has recently begun to improve. In 2015, the program of drifting stations was restored, which was suspended in the summer of 2013. The opened station was named “North Pole—2015.” Previously, all stations after the words “North Pole” had a serial number; the last one, evacuated in 2013, bore number 40. Note that the world’s first drifting station “North Pole—1” was founded in 1937 in the USSR on the initiative of O.Yu. Schmidt. It is interesting that it was over this station that Valery Chkalov’s famous flight took place. In 2012, an article containing a review of N. Marchenko’s book “Seas of the Russian Arctic: Navigation Conditions and Accidents” mentioned that out of 67 Soviet polar stations located along the NSR route, only 16 remained operational.

Among the latest projects in the development of Arctic science and education, the creation of the Northern (Arctic) Federal University named after M.V. Lomonosov in Arkhangelsk (NArFU). On the basis of the university, cooperation with the international consortium “University of the Arctic” is carried out. The University of the Arctic is an international network of universities, colleges, institutions, and organizations working in the field of higher education and research activities in the North (a total of 150 educational institutions and about one million students of circumpolar countries). Russia is represented by 32 educational institutions, with NArFU occupying one of the leading positions.

Thus, at present, Russia is striving to develop cooperation in the field of Arctic science with the countries of the world. For example, according to the Russian Academy of Sciences, in 2014, certain successes were achieved in the development of scientific cooperation with Japan in the Arctic. Also, for quite a long time, cooperation with Norwegian institutions has been carried out.

The need for scientific cooperation in the study of the Arctic is proved, among other things, by the duration of international relations in this area. For example, since 1982, a global research event, the International Polar Year, has been taking place. As part of the first International Polar Year, which was attended by representatives of 12 countries of the world, for example, the first Russian polar station was founded in the Malye Karmakuly camp in the Novaya Zemlya archipelago.

Nevertheless, in the current geopolitical situation, there are risks of a possible rupture of scientific research relations for reasons outwardly in no way connected with the Arctic. There are reports in the press that Canada may refuse scientific cooperation with Russia for political reasons (with an eye on the opinion of the USA).

Undoubtedly, scientific exchange is mutually beneficial for all countries of the world and is extremely necessary for overcoming the scientific and technological backwardness of Russia that arose in the 1990s. It seems that any limitation of the circulation of knowledge and the rupture of scientific research relations with Russia will be dangerous for the development of international science as a whole (Although it will probably be more painful for our state in the short and medium term).

Thus, the following risks of an insufficient level of development of science and technology were identified:

- Lack of technologies for the Arctic infrastructure and housing construction.
- Lack of technologies in the field of exploration and production of minerals (as a result—the impossibility of realizing the raw material potential).
- Lack of technologies to ensure environmental safety (technologies for removing pollution, oil spill response, etc.).
- Lack of energy-saving technologies.
- Lack of icebreaking shipbuilding technologies.
- Lack of technologies in the field of defining the boundaries of the Arctic shelf.
- Lack of technologies in the field of life safety.
- Reducing joint international research.

Risks that are common to countries can be identified. For the polar countries, the common risks are provoked by global warming, the impact on the manifestations of which is rather limited. The danger is also posed by the risks of geo-economic and military confrontation in connection with the collision of interests of countries on the basis of control over Arctic resources.

Identifying the conditions (sources) and risks of the formation of the Russian Federation geo-economic strategy in the Arctic includes identifying the sources and identifying the risks they provoke. Identifying sources allows you to establish a causal relationship with the totality of risks generated by them. In other words, for each source, it is necessary to identify a number of associated risks. Assessment of risks and sources of their occurrence (conditions, the fulfillment of which leads to the formation of risks) makes it possible to highlight the priority directions of the state’s activity in the emerging geo-economic strategy.

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Transport and Logistic Support of Oil-and-Gas Offshore Production in the Arctic Zone

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Abstract The rich resource potential of the Arctic shelf zone of Russia requires the relevant development of the transport and logistics infrastructure for its fullest implementation. Working conditions in the region are characterized by difficult climatic conditions, a fragile ecosystem, dependence on supplies from the "mainland" zone, limited labor, natural, material and financial resources, a high level of wear and tear of fixed assets of transport hubs and logistics enterprises, and the presence of other risks. The required development of the transport and logistics infrastructure of the Arctic shelf zone assumes an increase in the density of railways and highways, the emergence of new logistics centers and transport hubs. Among other things, it is promising to develop a system of international transport corridors passing through the territory and water area under the jurisdiction of the Russian Federation, as well as a capillary transport infrastructure linking hard-to-reach Arctic settlements. These measures are designed to remove infrastructure restrictions on the growth of hydrocarbon production on the Arctic shelf.

1 Introduction

The Arctic is the region with the highest undiscovered hydrocarbon potential in the world at the moment. According to the Oxford Institute for Energy Studies and estimates by national energy agencies, 22% of the world's undiscovered oil and gas reserves are in the Arctic (Henderson & Loe, 2016). Sixty-one large hydrocarbon

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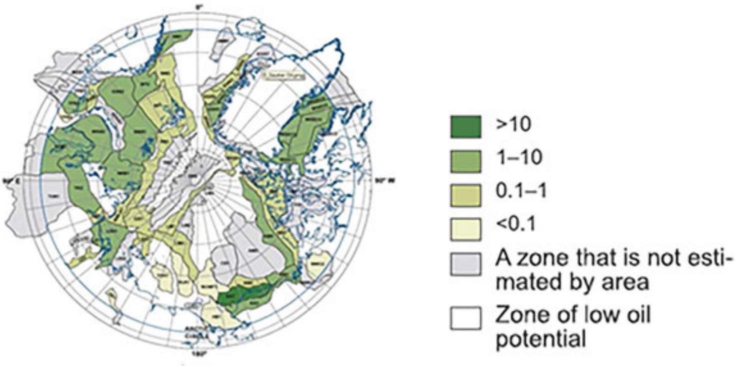

Fig. 1 Unexplored oil in the Arctic, billion barrels

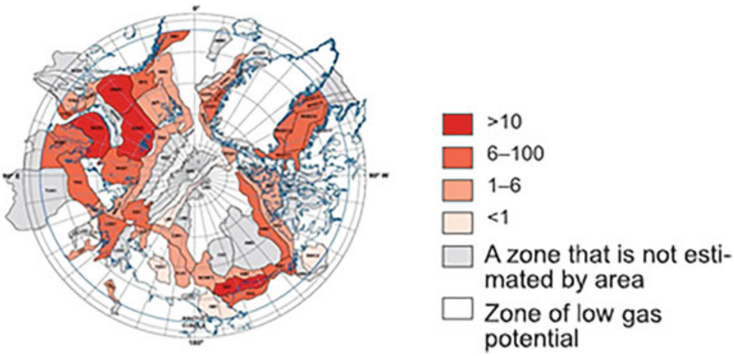

Fig. 2 Unexplored gas in the Arctic, trillion cubic feet

fields have been discovered in the Arctic, of which 43 are in the Russian sector. At the same time, according to estimates, in 2035, 60% of the planned oil and gas production will be carried out from fields that have not yet been discovered (Figs. 1 and 2). About 84% of all hydrocarbons on the Arctic shelf are primarily gas, gas condensate (Fadeev & Tsukerman, 2020).

Fifty-two percent of all Arctic hydrocarbon reserves are located in the Russian Federation. In terms of distribution over the water areas of Russia, two-third of the total resources fall on the so-called Barents-Kara province, which together possesses more than 70% of all hydrocarbon reserves that are located on the entire continental shelf of Russia. On the Arctic shelf, 44% of the resources are in the Kara Sea, 26% in the Barents Sea, 9% in the Sea of Okhotsk, 6% in the East Siberian Sea, 5% in the Pechora Sea, and 10% in other seas of Russia (Fadeev et al., 2020; Tsukerman et al., 2019).

Deposits in the Barents-Kara region are characterized by varying degrees of distance from the coastline, different ice conditions, different content (oil, gas fields, gas condensate structures). A number of deposits can be classified as unique, for example, the Shtokman, Leningradskoye, Rusanovskoye fields. The Shtokman gas condensate field is capable of providing energy to the planet Earth for 1 year and 3 months.

One of the main testing grounds in terms of developing technically and technologically unique solutions on the Russian shelf is the Sakhalin water area, the Sea of Okhotsk, where today Russian companies are successfully producing and exploring hydrocarbon deposits (Fadeev, 2013).

So far, there are not many projects in the Arctic beyond the Arctic Circle. This is due, among other things, to harsh natural and climatic conditions, complex technological challenges facing project operators, as well as the need to ensure environmental safety (Chanysheva & Ilinova, 2021).

Gazpromneft is today the first and so far the only company engaged in commercial oil production at the Prirazlomnoye field. It is also a unique experience in both hydrocarbon production and oil transportation in harsh ice conditions. The two largest fields on the Sakhalin shelf were discovered—the Neptune and Triton fields, which, in aggregate, make up Russia's annual production. The climatic conditions in which the operator of the Prirazlomnoye project operates are very low temperatures (the temperature minimum can reach minus 50°), these are more than 20 storms per year with a wind force of 8–9 points, this is significant sea disturbance with wave heights up to 7–9 m, changing the speed of current around the platform up to 7–12 km/h, hummocks up to 2 m, drifting ice 7 months a year. Oil is loaded onto tankers without rigid mooring, that is, tankers are held along the platform using a dynamic positioning system and oil bunkering takes place using a flexible hose. At the same time, the high qualifications of the platform and tanker crews ensure the absence of incidents related to environmental pollution. That is, it is possible to work in the Arctic not only efficiently, but also safely.

2 Basic Solutions for the Implementation of Offshore Projects

At the moment, there are the following technical and technological solutions for the development of shelf projects: artificial islands, stationary platforms, floating semi-submersible platforms, drilling and technological vessels, platforms such as SPAR, BUOY, TLP, submersible platforms, overpasses with landing platforms, other solutions, unique and very complex in terms of technological content. These are, for example, projects such as floating liquefied natural gas (LNG) projects. Such a plant does not require any special infrastructure; it can move from field to field, connect to gas sources, liquefy gas, and ship gas to gas carriers. This is a very high-tech cryogenic production that requires maximum safety measures. Such a project is unique from the point of view of the absence of the need to lay gas pipelines, the possibility of a quick reorientation of sales markets. On the buyer's side, only a regasification plant is needed, with the help of which gas will come to standard parameters, after which it can be pumped into the gas storage or directly supplied to the consumer.

In the field of subsea production complexes, it is currently possible to drill in depths of more than 3 km of the water column, and then underwater wells have different depths. It is important that the wells have so-called horizontal deviations that penetrate into the most productive formations.

In general, it is possible to say that projects on the Arctic shelf require science and technology to create fundamentally new technical and technological solutions, which are comparable in complexity to technologies for space exploration. This solves the problem of preserving the ecosystem, eliminating environmental pollution. Therefore, the development of the Arctic shelf is a driver of economic and technological development.

3 The Main Risks in the Development of the Shelf

The development of the Arctic shelf is directly associated with a number of key challenges and risks. First, these are harsh climatic conditions, polar night, pack ice, and so on. The second is a tough schedule for the project, since, with the exception of the fields in the Barents Sea, where the Gulf Stream exists and where the sea is non-freezing, the seas have an inter-ice window, that is, the period when the water area opens from ice and there is an opportunity to explore for hydrocarbons or to produce them. The open period can reach as little as 2 months, for example, in Chukotka. It is also necessary to clarify the current legislation in the direction of both the formal possibility of operators' work and the formation of a favorable investment climate in the Arctic. There is a need to open checkpoints across the state customs border. It is very important to have a transport and logistics infrastructure in the form of developed supply bases in the Arctic zone. It is a modern seaport capable of receiving, processing, and dispatching cargoes required for the development of the shelf 24 h a day (Ilin et al., 2020).

Another challenge is the remoteness from the coastline, as well as the lack of an adequate level of technology for the development of the shelf. Today, only the Russian Federation conducts industrial production in such volumes and in such conditions (Carayannis et al., 2017).

Economic risks are also important, since offshore projects are high-cost projects characterized by high capital intensity, duration of implementation and a significant increase in payback periods, and a decrease in return on invested capital. It is also important to take into account that the Arctic is very heterogeneous in terms of the characteristics of the fields, production costs, and logistics costs for transport. There are projects that are relatively close to the coastline and that are technologically and logistically affordable. There are techniques that make it possible to rank deposits according to the degree of favorableness of their development (Baydukova et al., 2019; Romashkina et al., 2017).

The following types of risks are transport and technological risks. Carrying hydrocarbons in ice requires special expertise. At the moment, Russia has already accumulated significant experience, but nevertheless, it has yet to be scaled up to other projects that are being implemented in Russia. Complex technologies are needed in the face of an increased likelihood of equipment failure in arctic conditions. There is a shortage of tankers, icebreakers, and support vessels with the required ice class for high Arctic latitudes. The use of such vehicles leads to a significant increase in the cost of the project, the complexity of making investment decisions (Radushinsky et al., 2017).

From the point of view of environmental risks, project operators need to take the maximum unprecedented measures in the field of industrial environmental safety in order to avoid such risks. The Arctic is a unique region with an ecosystem that is very sensitive to anthropogenic interference and takes a very long time to recover from the unreasonable impact; therefore, environmental principles are absolute priorities when deciding on the development of hydrocarbons. Environmental risks also include a significant distance from the coastline, the difficulty of eliminating potential accidents in the water area, and difficult meteorological and ice conditions.

4 Logistics in the Arctic

When implementing projects for the development of the shelf in the Arctic, special attention should be paid to the issues of ensuring production at the stage of exploitation and drilling. There is a need for the formation of so-called sourcing strategies, namely the identification of sources to attract highly effective technical means that are capable of working in very harsh extreme conditions of the Arctic. In addition to drilling rigs, these are icebreakers, platform carriers, cable-laying vessels, pipe-layers, rescue vessels, oil tankers and cargo ships, oil spill response vessels, and special helicopters used for offshore aviation. All of them must have a certain ice class, possess a number of characteristics that allow them to work effectively in high Arctic latitudes. The coastal infrastructure, shipyards for the construction of ships and platforms, etc. are also being considered (Devezas, 2020; Weigell et al., 2020).

The logistics network in the Arctic includes production complexes, support bases, supply vessels, tankers, helicopters, floating oil storage facilities, points of delivery of products, sources of personnel and material and technical costs, points of accumulation of personnel. Attracting qualified personnel who are able to work on offshore projects is also one of the most important tasks facing operators and the state (Belyy, 2014).

In general, logistics in the Arctic can be divided into two main groups—personnel logistics and cargo logistics (equipment, necessary materials).

For the transportation and rotation of personnel, air transport is the main one. Personnel are transported to offshore production facilities by helicopter. A certain small segment may be occupied by land transport. In addition, an important direction is the meeting, escort, accommodation of personnel, in the process of which safety issues are of paramount importance.

For the delivery of goods, equipment, and materials, sea transport takes the first place. Often in the Arctic, the so-called modular principle is used, when the assembly from modules delivered by sea is carried out on site. Nevertheless, some of the equipment can be started up by land transport, railway transport (Inozemzev, 2013). Emergency shipments can be delivered by air transport. It is also necessary to provide for the transportation of non-standard and bulky goods, temporary storage areas, customs clearance, handling and loading of goods.

5 Transport Support of Oil-and-Gas Offshore Production in the Arctic Zone

5.1 Northern Sea Route

The basis of shipping in the Arctic is the Northern Sea Route (NSR). Now, in the western section of the NSR, year-round navigation is carried out along the Murmansk—Dudinka route to ensure the operation of the Norilsk Mining and Metallurgical Combine, and oil transportation has begun from the regions of the Gulf of Ob, Varandey and Kolguev (Zhura et al., 2019). From the ports of the NSR, Sabetta (through which NOVATEK also began shipping liquefied natural gas and ships products to Gazpromneft-Yamal) and Dudinka, through which MMC Norilsk Nickel ships products, are distinguished by the volume of cargo turnover. In other ports, cargo is mainly handled via the "northern delivery." With the growth of production in the Arctic fields, there is an increase in cargo turnover. Thus, shipments from the Prirazlomnaya platform are increasing. The products of the Yamal LNG plant are exported from Sabetta along the NSR by special ice-class LNG carriers with a length of 300 m and a draft of 11 m (in winter with icebreaker assistance). The offshore transshipment complex of the Kola Oil Terminal LLC (the Umba heavy tanker) was put into operation. The Gates of the Arctic oil loading terminal (Cape Kamenny, Novy Port) ships products to Arctic tankers with a carrying capacity of about 35,000 tons and a draft of 9 m, operating in winter with icebreaker support; in Murmansk, oil is pumped to larger tankers. The seaport in Kharasavey (the western coast of the Yamal Peninsula) is being built for the export of oil and gas condensate through the NSR in the amount of up to 11–12 million tons per year, it is planned to accept tankers with a draft of 11.5 m both in summer and in winter. In the future, the use of Yamburg (the right bank of the Gulf of Ob) as a port is being considered—the only place in the Arctic zone of Russia (AZR) where the railway went directly to the Arctic Ocean (Veretennikov et al., 2018). The formation of the NSR as a year-round route requires the modernization of the icebreaking fleet of Russia, primarily the nuclear one (Didenko & Cherenkov, 2018; Victoria Babaeva, 2020).

The main problems of the NSR to be solved:

- Insufficient development of port, logistics, rescue, hydrometeorological, and navigation infrastructure
- Insufficiently transparent tariffs for icebreaking operations, pilotage
- High cost of transportation along the NSR, taking into account cargo insurance, icebreaker escort, and other expenses
- The lack of the status of the NSR as an independent Eurasian transport corridor
- Lack of a fixed route
- Failure of the eastern section of construction and installation work to reach the level of profitability, lack of its year-round operation (Skripnuk et al., 2020)

5.2 Sea Transport

In connection with the development of Arctic deposits, the largest Russian oil and gas and shipping companies have organized intensive construction of the Arctic transport fleet. To ensure year-round transportation of oil and gas condensate, Arc7 class tankers, ice-breaking supply vessels and diesel icebreakers are used. A number of universal nuclear icebreakers have been built to ensure year-round operation of the eastern section of the NSR. Taking into account the estimated prospects for increasing cargo traffic, it is necessary to build a linear nuclear icebreaker leader, new nuclear vessels with a capacity of at least 2000 TEU of cargo. In November 2020, at the request of Rosmorport, the non-nuclear icebreaker Viktor Chernomyrdin was launched to operate in the Arctic. To solve the problems of search and rescue support in the Arctic and Far Eastern regions, modern multifunctional rescue vessels of ice classes Icebreaker6 and Arc5 have been built. In 2020, the Decree of the President of the Russian Federation of October 26, 2020, No. 645 (On the Strategy for the Development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period up to 2035, 2020) entered into force, which provides for the phased construction of universal nuclear icebreakers, icebreakers of the Leader project, rescue tugs, hydrographic and pilot ships in order to ensure year-round navigation in the entire water area of the NSR. Vessels must comply with the Arctic characteristics in terms of ice class (Arc7), deadweight (from 15,000 tons), be able to independently navigate in ice up to 1.5 m thick. These issues have already been considered by the authors (Fadeev et al., 2021). Nuclear and diesel-electric icebreakers should be multifunctional, performing, in addition to icebreaker assistance, tasks to ensure rescue operations and liquidation of emergency oil spills. The mentioned Decree also provides for the construction of cargo ships for merchant shipping in order to carry out cargo and passenger traffic between sea and river ports in the AZR. At the moment, a serious problem is that the functioning of the inland waterway transport network is of a pronounced seasonal nature (Pegin, 2016; Tsyganov, 2019).

For the functioning of maritime transport, the problems are:

- Shallow depths of a number of ports in the Kara Sea and the Laptev Sea and in river estuaries and an insufficient number of dredging equipment
- Insufficient number of ships in the northern version, insufficient transportation capacity or their characteristics
- Long-term construction of icebreakers

A number of requirements are also imposed on the support base, since the efficiency of well construction on the shelf depends on the successful operation of this element. The depth of the berthing line of the approach channel at the quay wall should be at least 8.5–9 m, since heavy loaded supply vessels have a sufficiently high draft. The berthing line must withstand a high load, as additional equipment is installed on it. All infrastructure must be in good service condition. The support base must have a railway entrance, must be provided with a crane facility, transshipment complexes with various crane mechanization with different lifting capacity, and have containers for receiving, storing, and disposing of drill cuttings (Verny & Grigentin, 2009). Base owners must have licenses for the right to transship explosives and radioactive substances used in well testing, sometimes for waste disposal.

The next very important element is supply vessels, which account for more than 30% of the costs for the construction of an offshore exploration well. They are involved at all stages, from seismic exploration to well construction, field operation, oil spill response, and are often used as a logistics solution for delivering personnel to an offshore production complex when high fog and strong wind load do not allow the use of a helicopter. Supply vessels for the Arctic should have a dynamic positioning system, but there is practically no such fleet in Russia.

5.3 Air Transport

In the field of offshore aviation, a special kind of helicopter is used for the shelf. They have a special rectangular porthole design. This is due to the need to provide an emergency escape from the helicopter in the event of a splashdown. It must be a lightweight and at the same time very durable helicopter; it must have high reliability and engine power. It should have a special anti-icing system, a special explosion-proof fuel system and tanks, emergency equipment, and an increased number of emergency exits. Important characteristics of a modern multifunctional helicopter for work in the Arctic are increased load and flight range, shock-resistant structure, modern flight and navigation system, shock-absorbing seats for pilots and passengers, adaptability for night flights, and compliance with the carrying capacity of the platform's helicopter deck.

In general, the development of air transport is an integral part of the development of the Arctic zone. The Decree plans to modernize the airports of Murmansk, Arkhangelsk, Vorkuta, Naryan-Mar, Amderma, Khatanga. It is planned to put into operation a mechanism for subsidizing mainline, interregional and local (intraregional) air transportation in the AZR.

For passenger traffic, light multipurpose aircraft with a capacity of 9–19 passenger seats and regional turboprop aircraft with a capacity of 50 passenger seats are offered.

The main problems for the development of air transport in the shelf zone are:

- Insufficient number of airports, including those with runways for passenger aviation
- Insufficient amount of equipment in the Arctic performance

5.4 Railway Transport

The existing sections of railways in the AZR are outdated and have an undeveloped infrastructure. Their modernization, further construction, and general development of railway transport in the region are required. The planned railway lines of the Barentskomur and Belkomur projects will make it possible to shorten the length of the route for the transportation of goods from the Komi Republic through the ports of Murmansk and Arkhangelsk. A number of planned railway lines will connect the areas of the AZR fields with the industrial regions of the Urals. The meridional railways going to the ports of the White, Barents, Kara, and Laptev Seas will increase the cargo potential of the Northern Sea Transport Corridor. At the same time, in each specific case, the possible competition between rail and sea transport should be assessed in terms of tariffs, speed and reliability of cargo delivery (Petrov et al., 2019). The prospects for the development of railway lines in the AZR were discussed in detail by the authors earlier (Fadeev et al., 2021).

The submeridional railway line from Tyumen to Yamburg made it possible to start delivering natural gas from the Urengoyskoye and Yamburgskoye fields, and the 525 km line from the Obskaya station of the Severnaya (Pechora) railway to Bovanenkovo made it possible to use the reserves of the Bovanenkovskoye field on the Yamal Peninsula.

The main problem in the field of rail transport is the underdeveloped infrastructure in many areas.

5.5 Automobile Transport

A number of regions of the Russian Arctic do not have year-round access to the road network of Russia; they operate temporary winter roads. The road network is unevenly developed and has a seasonal character of functioning. To ensure transport accessibility of such territories, it is recommended to operate multi-purpose all-terrain vehicles. Automobile transport is necessary for the primary supply of equipment and cargo, for organizing communication between fields and for communication with settlements, oil refineries and transport hubs for further transportation.

Standard cargo can be delivered by conventional commercial trucks. For heavy cargoes, multi-axle platforms “trawls” are usually used.

The Decree provides for the construction of a number of highways, including highways connecting the seaport of Arkhangelsk with other regions of Russia. The year-round roads Surgut—Muravlenko—Urengoy—Nadym, Novy Urengoy—Yamburg, Urengoy—Tazovsky, Nadym—Priozerny operate. In the same technological corridor with the Northern Latitudinal Railway, the construction of the Nadym-Salekhard highway, 344 km long, is underway. The straightening road Muravlenko-Nadym is also under construction.

The main problems for road transport in the region:

- The need for year-round all-terrain vehicles
- Poor road condition and quality
- Pronounced seasonality

5.6 *Pipeline Transport*

In the area of pipeline transportation, a system of gas trunklines was put into operation in the direction of Bovanenkovo-Ukhta (northern corridor of the Unified Gas Supply System of Russia, OJSC Gazprom). The Zapolyarye—Purpe—Samotlor oil trunk pipeline was built, which is part of the general oil pipeline system in Russia (OJSC Transneft). As a result of the development of the Vankor field, a pipeline was laid up to the Vankor—Purpe oil trunk pipeline, which connected Vankor to the general system of Russian oil pipelines, and the Vankor—Khalmerpayuta gas pipeline was built and included in the Unified gas supply system of the country.

Gas and gas condensate projects, which require storage of gas pipelines, deserve special attention. The area for their placement must be at least 40 hectares. The search for similar sites in the Arctic, with the required depth of the passage channel, with crane mechanization is also a challenge.

The main problems of pipeline transport are associated with:

- The need for new trunk pipelines to sea terminals
- The need to develop new technical means for the detection, localization, and elimination of accidents

5.7 *Alternative Transport*

It is also necessary to develop alternative modes of transport, including gas planes, airships, airplanes, ekranoplanes, etc. Strict requirements are imposed on the preservation of the ecological purity of the region in conditions of high sensitivity of ecological systems to external influences. It is necessary to develop off-road vehicles on low-pressure pneumatic rollers (0.05–0.07 kg/cm^2) and wide tracks, the operation of which is possible in the summer; non-traditional aircraft, in particular, aerostatic (airships). In the conditions of Siberia and northeastern Russia, the cost of transporting goods by airship is significantly lower than by plane, and is comparable to the cost of transportation by barge (Gruzinov et al., 2019).

Also, an important element is a temporary camp for the shift personnel. They need to lay a road network, organize power supply, delivery of water, food, garbage collection, and a medical center. But this is also an impetus for the development of the region.

6 Logistic Support of Oil-and-Gas Offshore Production in the Arctic Zone

One of the promising areas can be the full-scale implementation of the transport and transit potential due to the formation of a system of international transport corridors passing through the territory and water area under the jurisdiction of the Russian Federation, as well as a capillary transport infrastructure connecting hard-to-reach Arctic settlements. The NSR with adjoining rail and river routes, aviation, highways, and coastal infrastructure is considered as the backbone of the Arctic transport system (Akimova & others, 2018). It should be borne in mind that inland waterways in the Arctic zone of Russia (AZR) are used on average from May 10 to October 10, and ice roads and most of the roads operate on average from December 20 to April 20. The capabilities of the Yenisei River are unique here: sea vessels with a carrying capacity of up to 15,000 tons can go up the Yenisei to Dudinka (423 km from the mouth), with a carrying capacity of up to 10,000 tons—to Igarka (685 km from the mouth).

The main links of the transport and infrastructure framework of the AZR are the latitudinally oriented Trans-Siberian Railway (Transsib) in the south and the NSR in the north. At the same time, the Transsib and the railway network growing from it carry out the integral functioning of the southern part of the macroregion, while the NSR and river meridional arteries (Ob, Nadym, Pur, Taz, Yenisei, Khatanga, Lena, etc.) provide economic consolidation of the territory from north to south. An important drawback of such a transport system is the weak connection between the main latitudinal communications (Transsib—NSR): within the entire Siberia, only the Ob and Yenisei navigable routes rely on the Transsib and at the same time on the NSR, and from the Transsib to the Arctic Ocean (Ob Bay) it reaches only one submeridional railway Tyumen—Tobolsk—Surgut—Novy Urengoy—Yamburg.

The development of the concept of the Northern Maritime Transit Corridor (NMTC) is promising. The cargo will be delivered by a feeder fleet of cargo carriers from the ports of Asia and Europe to the western and eastern transport and logistics hub (TLH), then transported along the NMTC route by the NMTC's own Arctic container fleet with the support of nuclear icebreakers.

The location of the TLH outside the NSR in a year-round ice-free zone makes it possible not to impose special and ice requirements for feeder carriers. One of the advantages of the NMTC route is that it is the shortest route.

The creation of a unified logistics system in all regions of the Russian Arctic can be based on the key projects of the transport infrastructure of the mainland part of the AZR: Belkomur, the Northern latitudinal route (NLR), which will connect the Northern and Sverdlovsk railways, i.e., station Obskaya (Labytnangi) and Nadym, Bovanenkovo—Sabetta, Barentskomur, Karskomur, Murmansk transport hub, deep-water port of Arkhangelsk, port of Indiga, Northern Sea Route (NSR). The involvement of the High Latitude Sea Route is also being considered. As a result of the global warming trend, the central part of the Arctic Ocean is increasingly free of ice in the summer. High-latitude and polar routes run outside the internal and territorial waters of Russia. The advantages of these routes: first, they are shorter than traditional coastal routes (the length of coastal routes from Murmansk to the Bering Strait is 3.5 thousand miles, high-latitude—2.9–3.3 thousand miles, polar—2.7 thousand miles); secondly, high-latitude and polar routes do not have restrictions on depths, which makes it possible to use economical vessels of large carrying capacity.

7 Clustering

From the point of view of shelf development, clustering is of particular importance. In a number of territories of the Russian Federation, geographic clusters can be created to support offshore projects—seaports, supply bases. For example, Murmansk is the largest city in the Arctic Circle in the world. It has accumulated a huge industrial and organizational potential that can be reoriented toward the operation of the oil and gas complex. Shipyards, an ice-free port, developed science and education in the region, and others give the Murmansk region the right to be considered a natural center for the development of offshore fields, at least in the Western Arctic. Arkhangelsk is a promising transport hub for transshipment of goods in the development of the Arctic. During the development of offshore fields, new jobs are created, the region is gasified, an influx of highly qualified personnel, an increase in employment and in the level and quality of life. The offshore projects support cluster includes pipelines, sea transport, seaports, supply bases, rail and pipeline transport, oil transshipment, metallurgical and machine-building enterprises, centers of science and education.

8 International Projects on the Arctic Shelf

Examples of large international projects aimed at the development of transport communications in the Arctic may also be of interest, for example, the project of the European Union "Northern Dimension," covering the countries of Northern Europe, the Baltic states, as well as Russia. The main goal of the Northern Dimension in the transport sector is to increase the volume of sea traffic between European ports and ports in northern Russia, in particular, Murmansk and Arkhangelsk.

There was also a project in the field of logistics and transport "Development of logistics in the Barents transport corridor," dedicated to the development of transport and regional logistics in the Murmansk region. The project involved the development of a transport route from the port of Kem through Salla to Murmansk, as the development of the Barents transport corridor is one of the most important areas for improving logistics in the Barents region. This project was implemented in 2006–2008 and was funded by the European Union under the Kolarctic Neighborhood Program.

Within the framework of the Logistics in the Barents Region project, a pilot container was transported along a new route. At the same time, using satellite communications, the parameters of time costs, speed, etc. were monitored.

A continuation of this work was the Barents Logistics-2 project, aimed at increasing professional competence in the field of logistics, developing logistics know-how, and expanding the supply chain in the Barents Region. The project started in 2011 and is funded by the Kolarctic ENPI-CBC program of the European Union. Enterprises and organizations from Russia, Finland, and Sweden became partners of the project.

Another effective example of international cooperation in the field of transport is the joint Russian-Norwegian oil and gas project "Ru-No Barents," within the framework of which a special direction "Logistics and Transport" was created. The overall objective of this project is to assess the "gap" between the current level of technology (including in the field of logistics and transport) required for oil and gas production in the Barents, Pechora, and Kara Seas in the most environmentally safe and reliable way.

There is still a promising project "Northern Air Bridge," which provides for the organization of air routes from Asia to North America through the Arctic. The Krasnoyarsk Territory should become the key link between the continents. According to experts, such routes will be needed, first of all, for the countries of Southeast Asia, for which it is more convenient to fly to North America through the Arctic. In this case, the flight time is reduced by 2–5 h, depending on the route.

A practical example of international cooperation in the development of the Arctic and in the organization of transport and logistics services of unprecedented complexity can be the project for the development of the Shtokman gas condensate field, which is being developed by Gazprom jointly with foreign partners. As part of the project, a huge logistics complex is being created, the tasks of which are to organize the delivery of personnel to the work areas, loading and unloading operations, transportation, and storage of heavy equipment. At the same time, the project implementation area is located at a significant distance from the coast, the work will be carried out in severe weather conditions with a tight schedule.

9 Results

As conclusions from the results summarized above, it is possible to formulate the requirements (Fig. 3) for the transport and logistics infrastructure of oil-and-gas offshore production in the Arctic zone to solve the above problems:

- Connecting mainland and port infrastructure into a single logistics system
- Ensuring uninterrupted year-round operation of the NSR
- Construction of the western and eastern transport and logistics hub of the NSR
- Modernization and creation of port infrastructure along the entire route of ships
- Creation of transit infrastructure of the Northern Sea Transit Corridor, a logistics platform
- The use of digital services based on digital platform solutions: a digital route model, geo-information services for scenario, and predictive modeling to control the movement of a vessel on the route
- Integration of space systems services with ship complexes using artificial intelligence technologies to provide digital services for the development of the NSR

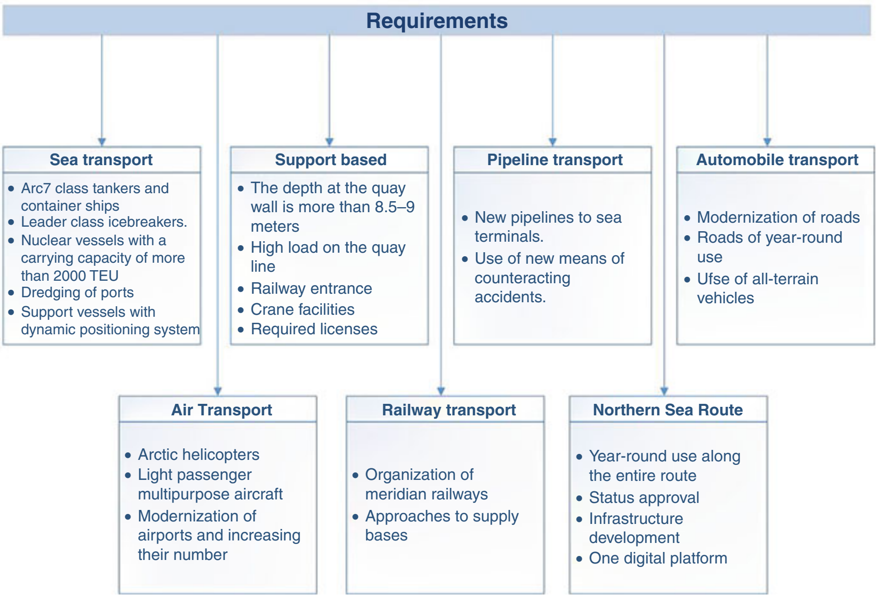

Fig. 3 The requirements for the transport and logistics infrastructure of oil-and-gas offshore production in the Arctic zone

- Modernization of the Russian icebreaker fleet, primarily the nuclear one
- Modernization and expansion of the range of vehicles in the Arctic version, including sea and river vessels, off-road vehicles, aircraft for regional aviation
- Using the fact of ice melting to intensify transportation along the NSR
- A clear definition of the composition and structure of the boundaries of the Arctic zone of Russia
- Development of all types of transport
- Taking into account the results of monitoring the impact on the Arctic environment
- Creation of a technological fleet for geological exploration and maintenance of offshore structures
- Modernization of the airport network and development of small aircraft
- Clarification of the legal regime of the NSR
- Development of pipeline transport in terms of transition to resource-saving environmentally friendly technologies, construction of new trunk pipelines to sea terminals; the use of advanced means of detecting, localizing and eliminating pipeline accidents
- Modernization and new construction of railway sections with an emphasis on transport corridors, meridian railways, sections for connecting resource regions, and oil production zones with areas of the industrial Ural
- Creation of all-terrain vehicles
- Application of new technologies for road construction
- Resolving issues with departmental affiliation of roads

10 Conclusion

In general, oil and gas projects provide an opportunity to launch impulses, structural shifts in industrial production. This gives a multiplier effect that affects the development of territories. The development of the shelf is a driver of economic development, not only through direct sales of hydrocarbons but also as a source of development of high-tech industries. The development of hydrocarbon deposits on the shelf, at a considerable distance from the coast, in uniquely complex conditions, requires the attraction of huge funds and new technological solutions in the field of construction of production complexes, laying gas pipelines along the seabed, creating onshore infrastructure, including facilities for processing and liquefying gas. The implementation of projects requires significant supplies of equipment, materials, overalls, food, construction, exploration, transport, research, and other works.

The development of transport communications and infrastructure is of paramount importance for the successful implementation of oil and gas projects. The transport and logistics sector is developing as the most important service sector in the extraction of natural resources.

The implementation of projects for the development of the resource potential of the Arctic forms the preconditions for the creation of logistics complexes, within the framework of which the transportation and storage of heavy equipment, loading and unloading operations, and the organization of personnel delivery to the work areas are carried out. At the same time, most of the work is carried out in harsh weather conditions and with a tight schedule, and the areas of the project are located at a considerable distance from the industrialized centers of the Russian Federation.

It is obvious that transport and logistics services in the Arctic can become one of the largest income items to the budgets of all levels after the extraction of natural resources, provided that the transport and logistics potential of sea and land waters is effectively used. The development of transport and logistics services in the implementation of projects of the mineral and raw materials complex can help to smooth out the risks caused by a potential deterioration in the price situation on the world raw materials markets. All this requires an effective production support system, the development of a system of maritime services, the formation of a well-defined strategy for managing the oil and gas complex, and a sustainable positioning of the Russian Federation as a Eurasian maritime transport state.

The most important feature of the implementation of the transport and transit potential in the Arctic is the emergence of powerful economic multiplicative and complex-forming effects, sometimes exceeding the direct economic effect from the export of natural resources.

The main navigable artery in the Arctic is the Northern Sea Route, which runs along the seas of the Arctic Ocean and connects European and Far Eastern ports, the mouths of Siberian navigable rivers into a single Arctic transport system. The task is to make it a year-round operating highway. This will reduce the cost of transporting natural resources produced in the Arctic.

The Northern Sea Route with adjoining rail and river routes, highways, aviation, as well as coastal infrastructure is intended to become the backbone of the Arctic transport system.

To implement a truly effective operation of the NSR routes, it is necessary to solve a number of issues: this is the creation of a unified management system, control of ice escort of ships, as well as improving legislation in terms of state regulation and merchant shipping along the NSR routes. For the efficient operation of the Northern Sea Route, modern infrastructure is needed to ensure safe navigation conditions in the Arctic seas, hydrographic support, and icebreaker support. At the same time, support from the state is the most important factor in resolving these issues. It should be noted that the effective development of the Arctic does not deny the possibility of active international cooperation, which, however, should be carried out exclusively in the interests of the Russian Federation.

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Architecture of the Maritime Logistics Ecosystem of the Northern Sea Route: Vision and Gap

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Abstract Nowadays, the Arctic zone is a major topic of interest of Russian and foreign experts and the media. Long-term interests of many countries of the world, primarily Russia, are connected with the development of the Arctic region. However, the development of the Arctic region cannot be considered complete without the proper level of development of the Northern Sea Route (NSR). One of the most important elements of the development of the Northern Sea Route is its digitalization. The purpose of this article is to form a general vision of the future target architecture of the Northern Sea Route, as well as to conduct a gap analysis that allows to identify the discrepancy between the existing architecture and its target state.

1 Introduction

In order to better understand the economy, we should dig deeper into political, cultural, and social spheres. Decision-making process is a good way to determine economical beleifs (North, 2005). The main inputs were associated with direct expenditures incurred to develop the inputs (Bessette, 2003; Goldstein, 1990) and total factor productivity (Martin, 1998; Siegel et al., 2004). Only a few studies related the economic impact to the change in the gross domestic product (GDP) (Roessner et al., 2003).

At present, interest in the Arctic region from many states is gradually increasing. This is primarily due to the fact that the Arctic contains significant reserves of various natural resources. Interest in the Arctic territories from Russia is also growing. This is clearly manifested in the fact that the number of various initiatives aimed at the development of the Arctic is increasing: the network of meteorological stations is being restored, mineral deposits on the Arctic shelf are being actively developed, and new Arctic bases are being built (Fadeev et al., 2021). However, the

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development of the Arctic region cannot be considered complete without the proper level of development of the Northern Sea Route (NSR).

The importance of the Northern Sea Route for the Russian Federation has been repeatedly emphasized at the state level. This is confirmed by the fact that the state has developed a plan according to which, by 2035, the Northern Sea Route should become a full-fledged transport route for the implementation of transit shipping (Lukin & Yakunin, 2018). To implement the goals of this plan, several projects were initiated to develop various aspects of the Northern Sea Route: infrastructure, fleet, ports. One of these projects was the Northern Maritime Transit Corridor (SMTC) project initiated by the State Atomic Energy Corporation Rosatom in 2019, within which the need to use advanced digital technologies and platform services for the development of the Northern Sea Route was directly indicated. In this regard, the relevance of the research topic is due to increased attention to the Northern Sea Route and the launch of an initiative for its digitalization.

The purpose of this article is to form a general vision of the future target architecture of the Northern Sea Route, as well as to conduct a gap analysis that allows us to identify the discrepancy between the existing architecture and its target state.

2 Materials and Methods

Due to the transit through the NSR, the loyalty of the user countries to Russia can be maintained (Vylegzhanin et al., 2020). The political factor also matters. The cargo traffic on the Trans-Siberian Railway was very significant due to the specialization of cooperation between the European part of Russia and the Far East, but the increase in tariffs adversely affected transportation. In accordance with this, the NSR can replace the Trans-Siberian Railway as a unifying factor. Finally, there is the economic factor because the NSR can also be a factor in increasing cooperation between the European and eastern parts of the country (Didenko & Cherenkov, 2018).

Despite the fact that the Northern Sea Route has great potential for development, its active use is currently restrained by a number of serious problems. They hinder the development of the highway, thereby making minimal or zero from its usage.

The American side still insists on opening the NSR for free transit passage. Russia cannot allow this because a free NSR is a threat to its geopolitical interests in the Arctic. The non-recognition of the current legal status of the NSR by the USA is a problem that may affect the functioning and development of the NSR as an international transport corridor in the future (Blunden, 2012).

At the moment, there is no emergency service network along the NSR, and the risk of collisions due to the unpredictability of the ice environment and the lack of marked fairways is still high. For normal safety, it is necessary to have a base of the emergency rescue service every 500–800 km along the entire route.

The state of the icebreaker fleet is also extremely unsatisfactory. Navigation on the NSR without icebreaking is impossible even in the long term. Only during the summer navigation period, some transport vessels of a certain ice class can independently move along this route. There are nine icebreakers operating on the NSR: four diesel-electric and five nuclear-powered (And only four nuclear-powered icebreakers carry out the wiring of transport vessels). The aging of the icebreaker fleet is also a very important problem. Currently, three of the four available nuclear icebreakers, which carry out the largest number of ship transports, will soon exhaust their resource. “Vaigach” will run out in 2022, “Taimyr”—in 2024 and “Yamal”—in 2026. Only “50 years of Victory” will remain in service after 2030. If the icebreaker fleet is not modernized in the coming years, there are no thoughts about turning into international passage (Kiiski et al., 2018).

An equally serious problem is the underdeveloped infrastructure of the Arctic ports. The Arctic seaports are the weakest link of the NSR due to the lack of funds from the owners for modernization. Most ports have a number of serious drawbacks (Sergeev et al., 2021):

- Berthing facilities require major repairs and reconstruction (The berthing wall and reloading port cranes are severely worn out; the gantry and crawler cranes used for reloading have worked for more than 30 years in the conditions of the difference between day and night temperatures and are depleted by more than 90%).
- Necessity to deepen the bottom to receive modern large-capacity vessels.
- No services for bunkering ships, receiving wastewater and solid waste.
- No emergency oil spill response facilities, as well as facilities for receiving and disposing of ship waste, or they are in critical condition.
- Due to the lack of proper control, the barrage structures, alarm, and warning systems have become unusable, and the security service for inspection and access to special facilities is poorly developed.

Ports are anchor points for shipping in the Arctic. They equally play an important role in the successful functioning of the NSR, which is why all of them should be modernized and developed without exception.

The perfect conditions for participation in international projects will allow Russia as a state to receive an important source of income. Despite the fact that South-East Asian countries are the main potential investors in the NSR, the sanctions regime can significantly affect their preferences for investing in the Northern Sea Route (Verny & Grigentin, 2009).

In general, the Northern Sea Route has enough prerequisites for development. Various foreign carriers and shipping companies are showing significant interest in the possibilities of the Northern Sea Route as a transport route, which is due to two main factors. Firstly, transportation along the Northern Sea Route can become a more profitable alternative from an economic point of view in comparison with the currently carried out transportation between the ports of Europe, the Far East and North America (Liu & Kronbak, 2010).

Nowadays, the interest in using as an alternative transit route on the part of international carriers is rather episodic and rather resembles testing the route for the possibility of its future use. And although large transport companies of the world

(Cosco, Maersk) assure that the transit volume is planned to be increased to 12 million tons by 2028 with a subsequent increase to 28 million tons, this is absolutely incomparable with the volume of national transportation (the predicted value is 80 million tons per 2025), nor with the scale of transit through the Suez Canal (more than 1 billion tons annually) (Milaković et al., 2018).

The need for digitalization is driven by several key factors. First of all, it is the strategic importance of the Northern Sea Route for the Russian Federation. In addition, the desire for full-fledged international integration of the Northern Sea Route into the global transport system is also a significant prerequisite for digitalization. In order to attract foreign carriers and ship owners, it is necessary to demonstrate to them a high level of safety and navigational reliability of the Northern Sea Route. This can be ensured only with the use of modern information and digital technologies. A logical continuation of the previous premise is that recently there has been an objective need to significantly improve the quality, efficiency, and safety of transportation carried out along the Northern Sea Route, and significantly—due to the widespread use of modern digital technologies and info-communication resources. Also, the need for digitalization is due to the natural process of technology development, which leads to the fact that many industries and objects are significantly transformed. For example, modern ships differ in many respects from ships created several decades ago and already from the very beginning have a need for digital services.

It is obvious that all of these prerequisites are multifaceted and interrelated. Their combination forms a kind of "motivational field" for the digital transformation of the Northern Sea Route. That is why digitalization of the NSR in the context of its development is an urgent task. At the same time, several main targets for the digitalization of the Northern Sea Route are singled out, such as ensuring the safety and security of people and assets when transporting through the NSR, ensuring the rhythm and planning of logistics operations and minimizing the costs of logistics operations.

However, it should be noted that at the moment, the digitalization of the Northern Sea Route is associated with a number of certain difficulties that will need to be taken into account and overcome as the digital transformation is implemented. Mostly, these difficulties are associated with the problems of informatization of the entire Arctic region as a whole, but they will inevitably appear during the implementation of the digitalization project of the Northern Sea Route, since it is part of this region. The main problems are informational disunity and closedness of the participants in the development of the Arctic, the absence of a single information space in the Arctic zone, the absence of a target architecture and a program for the implementation of a complex of interconnected digital services in the Arctic zone.

Taking into account the existing prerequisites, goals, as well as the current difficulties in the digitalization of the Arctic region, it seems expedient to develop an architectural vision of the future digital ecosystem of the Northern Sea Route, as well as to analyze the gap between the existing state and the target. All this will be based on an architectural approach. The architectural approach, due to its consistency, allows researchers to create a holistic view of the activity in question, in order to take into account all the relationships and interactions of the elements (Ilin et al., 2021). There are several basic standards and methods for building enterprise architecture, but this study is based on the TOGAF framework. TOGAF (Open Group Architecture Framework) is the most widely accepted and recognized framework in the world. It is flexible and can be adapted for various modeling purposes (Levina et al., 2020). The architecture visualization was performed using the open and independent enterprise architecture modeling language ArchiMate.

3 Results

To form a common vision of the concept of digitalization of the Northern Sea Route, it is necessary to determine what the final target state is, as well as what steps should be taken to achieve this.

To indicate the target state, an architecture "to be" was built, which reflects the main stakeholders, key business processes, applications, physical server infrastructure, as well as the relationships between these domains. The whole architecture "to be" is presented in the Fig. 1.

The architecture "to be" gives a general vision of what the target architecture of the Northern Sea Route should be. This architectural vision sets the stage for developing a real ecosystem.

As it was mentioned before, the NSR should be an international transit corridor. That is why the necessity of the instrument, that will help to connect all parties involved—Business Digital Ecosystem or the Single Window concept is

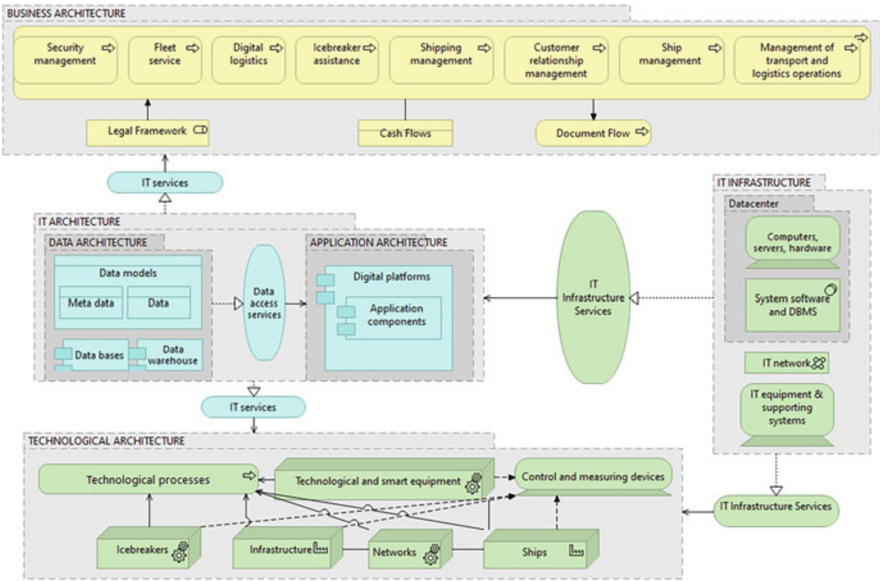

Fig. 1 Architecture "to be" of the Northern Sea Route

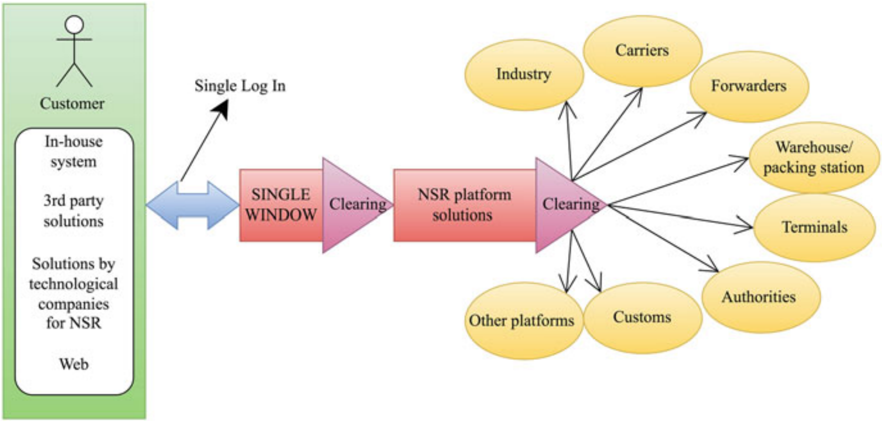

Fig. 2 Business digital ecosystem for the Northern Sea Route (UN Recommendation No 33, 2005)

implementing worldwide and helps to make communication and documents exchange easier. The definition is "a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfil all import, export and transit-related regulatory requirements. If information is electronic, then individual data elements should only be submitted once" (UN Recommendation No 33, 2005) (Fig. 2).

The implementation of such idea will help governments avoid paper routine. It is an approach of information exchange with state regulatory authorities, which assumes the presence of an authorized agent (authority) who receives information when the cargo crosses the border. The information is recorded only once, and its valid for all further movements. It should be noticed that each actor involved has to access not for the whole information about the cargo, but only for a small required amount. So, the greatest problem is to achieve mutual agreement about sharing and communication.

When forming a common vision, it is also useful to analyze what advanced digital technologies can be applied to achieve the goals of digitalization of the Northern Sea Route. Since the digital technology market is extremely vast today, the container shipping industry was preliminarily studied, and the most popular technologies and tools were selected.

Data collection and processing is an important first step. The leading technology in data collection today is the Internet of Things (IoT). The Internet of Things is a computing network consisting of physical objects, which includes technology for collecting and transmitting information, devices and technologies for storing and intelligent processing of information, and devices that generate control actions in various parts, and the algorithm is combined system and the whole system. Internet of Things technology connects various devices to computer networks, allowing them to collect and analyze data and send it to other devices using applications, software, and technology equipment. The device can operate without human intervention, but the user can interact with the device. That is, it gives instructions, configures, and accesses data. Such systems often work in real time (Aslam et al., 2020).

An IoT system consists of a set of smart devices connected to a network and a cloud platform to which they are connected. Smart devices are various sensors, controllers, smart cameras and RFID readers. Such devices first collect the necessary data and then send the data to the cloud. You can connect to the cloud in a variety of ways, including Wi-Fi, satellite, or cellular, Bluetooth, and communication types. After the data is uploaded to the cloud, the software processes the data.

Regarding the digitization of NSR, IoT technologies can be used to collect all kinds of data. The sensor will collect information about the various system and equipment operations on board, the ship's speed and direction, and its current position. Gauges and controllers also monitor the use of resources such as fuel usage. Also, this technology can be used to collect information about the collection of goods. Modern sensors can collect information about the condition and location of goods, as well as the conditions (temperature, humidity, light) in which goods are stored or transported. Ports, terminals and warehouses can also be equipped with sensors to collect data on infrastructure status, available capacity, traffic flow, and the like. In addition, IoT technology makes it possible to collect data on climatic conditions critical to controlling severe arctic conditions (Aslam et al., 2020).

Data processing can also be done using various digital technologies. Artificial intelligence technologies stand out in this regard. Artificial intelligence (AI) is the science and technology of intelligent intelligent machines, especially intelligent computer programs. Artificial Intelligence is linked to the challenge of understanding the human intelligence of using a computer (Suvetha et al., 2019).

Among the methods of artificial intelligence for the purpose of processing data on various aspects of the Northern Sea Route, computer vision is most applicable. Computer vision (CV) is a field of artificial intelligence associated with the analysis of visual information (images and video). As a result of computer vision technology, a modified image or a list of values of certain image parameters (object size, color, speed, etc.) can be obtained (Liu et al., 2019).

In the context of digitalization of the NSR, the use of computer vision is most promising for processing data on hydrometeorological and ice conditions in the water area of the NSR. Recognition of images will allow you to analyze the real ice situation on the routes, as well as assess the weather conditions. In addition, computer vision can be used to process information about the congestion of ports and terminals (video monitoring of ship calls, video counting of containers), as well as to ensure security on their territory (identification of unauthorized persons). Also, computer vision technologies may be needed in the event of an emergency—for example, when sensors and ship systems have failed on a ship and there is no other way to determine its location.

Another area of artificial intelligence that can prove extremely useful is Data Mining technology. Data Mining is a kind of collective name used to denote a set of methods for detecting previously unknown, non-trivial, practically useful and accessible interpretation of knowledge necessary for decision-making in various spheres of human activity in data. To date, this technology has found application in a wide variety of industries and fields of activity (Fu, 1997).

Table 1 Tasks solved using Data Mining technology (authors' creation)

Task type	Tasks in the context of digitalization of the Northern Sea Route
The task of classification	Determination of the minimum required ice class of a vessel for passage along a certain route of the NSR, taking into account ice conditions
Forecasting task	Forecasting weather and ice conditions; forecasting the delivery time of the cargo; forecasting the time of arrival of the vessel at the port; forecasting the need for icebreaker escort
The task of clustering/ segmentation	Drawing up a plan for the placement of goods, taking into account the conditions of their transportation or storage
The task of determining relationships	Determination of the most dangerous sections of the routes; determination of the most loaded ports and terminals
The task of analyzing sequences	Analysis of the causes of emergencies
The task of analyzing deviations	Analysis of deviations in equipment operation; identification of deviations of actual indicators from planned ones; identification of dangerous and emergency situations; identification of fraudulent transactions
Visualization	Drawing up ice maps; visualization of traffic flows

It should be noted that this technology can perform tasks of the following type (Gheware et al., 2014):

- The task of classification (definition of a category for each object of research).
- Forecasting task.
- The task of clustering/segmentation (dividing a set of objects into groups according to some criteria).
- The task of determining relationships (identifying the frequency of occurrences of sets of objects among the set of sets).
- The task of analyzing sequences (identifying patterns in sequences of events).
- The task of analyzing deviations.
- Visualization.

Table 1 shows examples of which of these tasks can be solved by Data Mining technology in the context of digitalization of the Northern Sea Route.

These technologies allow the collection and processing of data, and this, in turn, makes it possible to create virtual models on their basis. Such modeling can be realized using digital twin technology.

A digital twin is a digital representation of a physical object, associated processes, systems, and information. Digital twins combine advanced engineering models and analytics with asset-specific operational data to create digital simulations and information models that update and change throughout the lifecycle of their physical counterparts. The digital twin is constantly learning and updating itself using sensor data that measure various operational aspects, as well as information from experts with relevant industry knowledge and data on similar objects and their interactions with the environment (Fuller et al., 2020).

Table 2 Types of digital twins in the context of digitalization of the Northern Sea Route (authors' creation)

View of the digital twin	A brief description of the main features of the digital twin
Digital twin of the ship	• Ship design at the stage of creation; • Conducting virtual tests and crash tests of ships; • Forecasting the possibility of failure of ship equipment and systems; • Remote monitoring of the vessel in real time.
Port and terminal digital twin	• Testing of various scenarios of the port operation, including the occurrence of accidents; • Forecasting the possibility of failure of the port infrastructure; • Assessment and forecasting of the workload and throughput of the port/terminal; • Forecasting of emergencies on the port territory.
Warehouse digital twin	• Support and coordination of all warehouse operations in real time; • Modeling the movement of goods, personnel, and handling equipment in the warehouse; • Assessment and forecasting of warehouse throughput; • Checking the effectiveness of changes in technology, topology, rules of commodity circulation, arrangement of goods; • Checking any conditions in relation to the current topology (for example, whether there is enough equipment, personnel, zones, etc.).
Digital twin of the Northern Sea route	• Modeling and analysis of traffic flows in various conditions; • Forecasting and assessing the carrying capacity of various routes; • Forecasting and calculating the needs for icebreaker assistance; • Forecasting the need for ongoing repairs of the coastal infrastructure; • Forecasting the occurrence of possible emergency situations on the routes of the Northern Sea route.

It should be noted that an important distinguishing feature of digital twins from any other types of models is that they have the ability to predict the future states of an object based on current data. This allows you to prevent unwanted conditions or reduce the damage from their occurrence.

As part of the digitalization of the Northern Sea Route, several types of digital twins can be created. They are presented in Table 2.

Expect for digital twins, digital shadows should be modeled. They are able to predict the behavior of a real object only in the conditions in which the data was collected. It does not allow simulating situations in which the real object was not used. Figure 3 illustrates digital twins and digital shadows.

All modeling will be proceeded using the digital platform for the development of digital twins CML-Bench, awarded in 2017 the National Industrial Award of the Russian Federation "Industry." It allows to manage the processes of digital design, multidisciplinary mathematical modeling and optimization, the processes of generation, storage, processing, transmission, and protection of big data (primarily "smart"—Smart Big Data), resources of high-performance computing systems (HPC-Hardware), dozens of best-in-class computer technologies (CAE-Software)

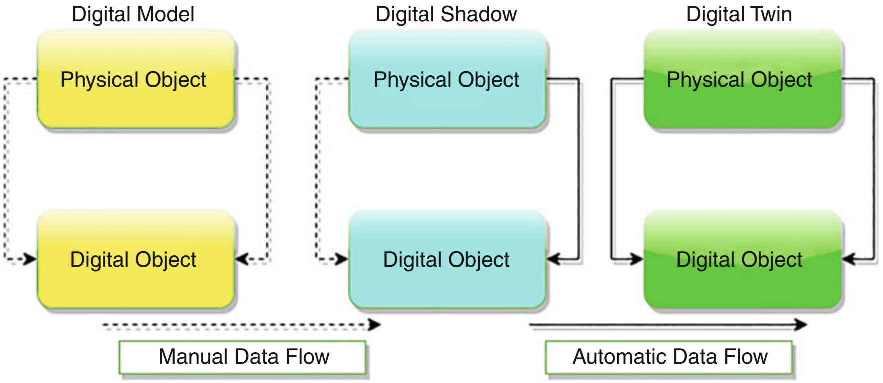

Fig. 3 Digital twin and digital shadow model

and, of course, Digital Brainware (the digital platform CML-Bench contains more than 175,000 design solutions from many high-tech industries formed during the implementation of real projects).

For example, the digital counterparts of container ships developed during the implementation of the SMTC project will allow performing all the necessary tests of static, cyclic, and dynamic strength, thermal resistance, hydrodynamics, as well as many others in the virtual space. It is this specially organized process of "digital certification" that will significantly reduce the volume of physical and field tests, respectively, reduce the time and cost of development (Borovkov & Ryabov, 2019).

It is important to note that there is a relationship between the mentioned technologies—the Internet of Things, artificial intelligence and digital twins: IoT technologies collect information using various sensors, artificial intelligence implements the processing of this data, and all this information goes to the digital twin to model objects.

An important component is the study of the conditions and conditions in which logistics will be carried out. Nikolay Shabalin, Executive Director of the Marine Research Center of Moscow State University, told about remote monitoring of the ice situation, hydrometeorological and environmental parameters when forming a digital logistics model to ensure reliability, safety, and cost optimization during cargo transit along the NSR route. Figure 4 is adapted from Iceberg company conference (2019).

Navigation and control systems can maintain stable telecommunication, escort, on-ship communication and broadcasting. The comparison of the monitoring results with the developed standards of the "state of materials" and processes stored in specialized databases is used for "advanced virtual control," which, using specially developed mathematical procedures for processing and transmitting information, forms control commands to adjust the modes of subsequent technological processes and/or the product itself, taking into account the actual parameters of the "state of the material."

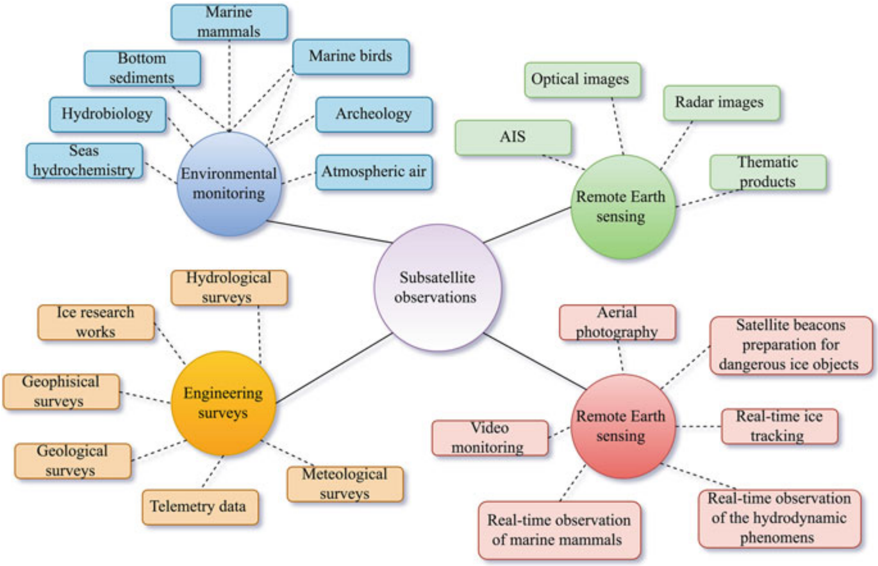

Fig. 4 Used satellite technologies for the NSR

Still it is a big gap for the NSR, and all monitoring satellite technologies should be improved. This will make the route safer and the cargo movements faster. All the required information should be available for the main parties involved.

In addition to the listed technologies, blockchain technology is also very popular in the field of sea transportation. Blockchain is a decentralized ledger of all peer-to-peer transactions. Using this technology, participants can confirm various transactions without the need for a central clearing authority. Blockchain technology can be used in a wide variety of activities: funds transfers, settlement of transactions, voting, and more (Yang, 2019).

Blockchain technology has some key features and characteristics that distinguish this technology from many others and make it applicable in various fields. First of all, the blockchain ensures the transparency and reliability of the data. Blockchain technology includes several mechanisms that allow you to ensure the accuracy of stored records, ensure that third parties do not interfere with them, and ensure that data is received from trusted reliable sources. Thus, instead of a situation where each stakeholder solely on their own maintained (and modified) copies of their own dataset, all stakeholders have controlled access to a common dataset, thereby forming a single common source of true data. This ensures that everyone who works with this data is using the most recent, accurate, and reliable data set. Also, blockchain technology provides a high level of data security. In a blockchain-based system, security mechanisms implement cryptographic encryption of individual transactions and messages. This ensures the required level of security and prevents the risks of hacking, data manipulation and compromise. In addition, blockchain technology allows the implementation of a smart contract algorithm. A smart

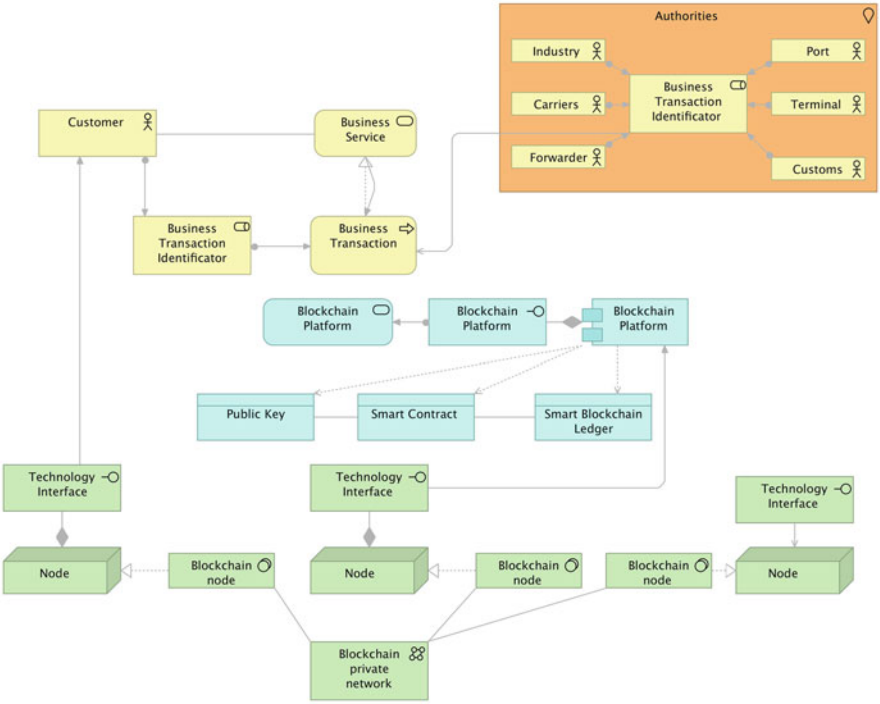

Fig. 5 Blockchain for NSR

contract is a blockchain-based system component that can automatically enforce rules, and process steps agreed with stakeholders (Wang et al., 2019).

The specified features of the technology largely predetermine the areas of its possible use. In the context of the digitalization of the Northern Sea Route, blockchain can be used for different purposes. Blockchain can be used to organize payments, as well as information and document exchange. Using this technology, all actors involved can store and exchange information with each other, transmit messages, give instructions, or make payments in a secure and transparent manner. In addition, blockchain technology can be applied in the field of ship and cargo insurance (issuance of insurance policies and settlement of claims for marine insurance). Blockchain can also be used to monitor the movement of goods and check their compliance with certain parameters and requirements. If all the data about the cargo is entered into the blockchain, it is possible to control everything that happens to the goods, including during transportation. One of the possible use cases for blockchain technology is visualized in Fig. 5.

Currently, the level of development of digital technologies and tools makes it possible to radically change and improve any kind of activity at various levels—both within individual companies and in the context of entire industries. Thus, today there are many different digital technologies and tools, the use of which should be considered in order to digitize the Northern Sea Route.

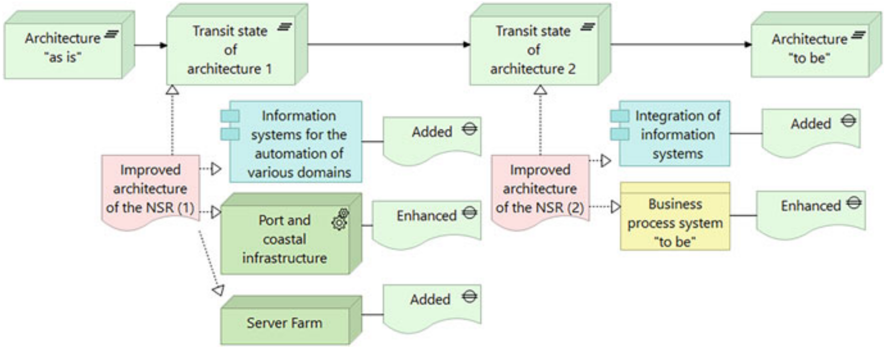

Fig. 6 Stages of transition to the target architecture of the Northern Sea Route

The target architecture and an overview of possible technologies constitute a common vision of the future ecosystem of the NSR. In addition to creating a vision of the future architecture, an important step is to conduct a gap analysis, which allows you to identify and analyze the discrepancies between the existing and the desired state of the architecture, as well as its individual domains. This analysis makes it possible to identify the key steps and necessary changes in the direction of the target architecture. A visualization of the results of this analysis for the NSR architecture is shown in Fig. 6.

In accordance with this analysis, it is proposed to divide the process of transition to the target architecture of the Northern Sea Route into several enlarged stages, while these stages can be divided into smaller sub-stages and separate works. To move from the existing architecture to one transit state of the architecture, it is necessary, first of all, to modernize the entire physical infrastructure of the NSR in order to comply with modern standards and ensure the collection of the necessary data for further processing. After that, a server farm can be built, which will ensure the operation of information systems, the implementation of which is also planned to be implemented at this stage.

After that, the architecture is prepared for the transition to its transit state 2. At this stage, it is necessary to ensure the integration of all information systems to create a single information space of the Northern Sea Route. In addition, it is important to re-engineer business processes in order to meet the new digital realities.

After this complex of works is implemented, the architecture of the Northern Sea Route will come to its target state.

In accordance with the proposed ecosystem architecture, it is extremely important to consider which benefits from digitalization are most likely for each group of stakeholders, as well as for all stakeholders in general (Table 3).

The digitalization of the Northern Sea Route is expected to be associated with the emergence of a number of different effects and benefits at various levels—from individual companies to the country and the international community as a whole. It should be noted that due to the scale of the digitalization project, as well as its dependence on the implementation of other initiatives for the development of the

Table 3 Direct qualitative effects of the digitalization of the Northern Sea Route for stakeholders (authors' creation)

Stakeholder	Key effects
Administration of the Northern Sea route	• Increasing the transparency of the formation of tariffs for transportation along the routes of the NSR; • Increasing the predictability of malfunctions and accidents and, as a consequence, reducing the accident rate; • Increasing the service life of coastal and other infrastructure by increasing the accuracy and timeliness of maintenance and repair; • Raising the level of awareness of the transport participants; • Increasing the speed of processing applications for the issuance of permits for transportation along the NSR; • Increasing the uniformity of capacity utilization and route loading; • Increasing the rhythm and planning of transportation operations; • Improving the level of manageability through the use of the media.
Government and state bodies	• Reducing the negative impact on the environment through monitoring and prompt prevention of accidents; • Improvement of the general level of safety in the water area of the NSR due to continuous monitoring; • Improving the collection of payments (taxes, duties, etc.); • Simplification of control over the activities of the NSR and compliance with legislative norms; • Reducing the opportunities for fraud and getting when receiving government services; • Increasing the speed and quality of the provision of public services.
Ship owners	• Increasing the service life of ships due to automatic adjustment of operating modes of equipment and ship systems, • Improving the accuracy and timeliness of maintenance and repair of ship equipment and networks due to the transition to a service model "according to the actual state;" • Simplification of the procedure for insurance parameters of automatic data collection as needed for the insurance parameter assessment; • An increase in the number of clients during the period of implementation of a more flexible mechanism for planning the operation of the vessel.

(continued)

Table 3 (continued)

Stakeholder	Key effects
Carriers	• Simplification of procedures for interaction with consignors and consignees; • Increasing the speed of delivery of goods, through the introduction of mechanisms for flexible planning of transportation; • Increasing the level of traffic control; • Reducing the number of disputes on liability for damage or loss of cargo, due to constant monitoring of the condition of the cargo; • Improvement of customer experience (increase in the reliability and quality of supplies, transparency in the formation of tariffs, etc.); • Simplification of the cargo insurance procedure; • Reduction of losses due to detection and timely suppression of damage and theft of goods.
Crews of ships	• Increasing the level of personnel and vessel safety; • Reduction in the number of errors, due to the reduction of the factor of human participation in ship management; • Simplification of ship management, due to the automation of most ship systems; • Increasing control over the actions of personnel; • Reducing the level of uncertainty about the conditions in which the ship should move; • Reduction in the number of crews forced to work in the harsh arctic conditions; • Increasing the speed of decision-making, due to information support.
Transport intermediaries (port authorities, terminal operators, stevedores, and warehouse operators)	• Increasing the speed and quality of service of ships; • An increase in the speed and volume of shipment; • An increase in throughput, by improving the coordination of vehicle traffic; • Increasing the service life of the port infrastructure by increasing the accuracy and timeliness of maintenance and repair; • Increasing the manageability of warehouse operations; • Improving the security of the port, through the control of personnel and vehicles.
Financial institutions	• Improving the user experience (quick and easy access to financial services, increasing the speed of service); • Reducing the time spent on individual banking operations; • Reduction of losses due to detection and suppression of cases of fraud.

(continued)

Table 3 (continued)

Stakeholder	Key effects
All parties involved as a whole	• Formation of a unified secure environment for transmission, storage, and processing of data, available to all stakeholders in accordance with their rights; • Reducing the number of routine operations and errors, due to the maximum automation of processes; • Increasing the level of completeness and reliability of data; • Elimination of cases of duplication of data and documents; • Reduction of cases of loss of data and documents; • Elimination of manual preparation and maintenance of documents; • Reduction in the number of operational errors; • Standardization of documentation in accordance with uniform rules and government regulations; • Simplification of the settlement procedure using various payment systems and financial instruments; • Increasing the level of process control through the use of decision support information.

NSR (for example, modernization of infrastructure), it is not possible at the moment to make an accurate quantitative assessment of future effects.

4 Conclusion

Nowadays, the Arctic zone is a major topic of interest of Russian and foreign experts and the media. Long-term interests of many countries of the world, primarily Russia, are connected with the development of the Arctic region. The Northern Sea Route (NSR) lays a major part in the development of the national Arctic transport system and is a main transport route in Northern Artic.

A stable development of the Northern Sea Route is a guarantee of the unity of the country's economic space, free movement of goods and services, competition and freedom of economic activity and ensuring the integrity of the state. Moreover, the route provides intercontinental transport links between Russia and the countries of the Asia-Pacific region.

One of the most important elements of the development of the Northern Sea Route is its digitalization. In this article, the most pressing problems typical for the NSR have been studied, which must be overcome or taken into account in the process of digitalization; the target architecture is proposed, as well as a list of those works that need to be reproduced to achieve the desired results. Thus, the architectural vision of the ecosystem of the Northern Sea Route was formed and the gap between the current and target state was fixed.

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Smart Port Concept: Strategic Development, Best Practices, Perspectives of Development

Carlos Jahn and Nicole Nellen

Abstract Seaports play an important role in the maritime supply chain. In recent years, the need for process optimization and automation solutions has increased, not least due to growing challenges regarding the complexity of processes. This is due to the growth in ship size and space restrictions in ports. The use of new technologies offers opportunities to meet these challenges. Large ports are increasingly implementing automated process solutions to meet these challenges. Science is also developing new approaches to optimize processes and to better connect the maritime supply chain. In the context of the chapter, solution approaches from science and practice are presented to give an insight into the current developments in ports to become smart ports. Different aspects such as the networking of logistics partners, automation and artificial intelligence, processes and environmental aspects are addressed.

1 Introduction

Increasing global trade and megatrends such as Industry 4.0 and the increasing demand for individualized products in combination with shorter product life cycles are leading to a change in logistics chains. This results in a global division of labor, decreasing logistics costs and the opening of new markets. These trends also have an impact on seaports (Philipp, 2020).

Seaports play an important role as interfaces in global maritime supply chains. In addition to transshipment between the different modes of transport, storage, as well as pre- and post-processing of goods, ports offer various types of value-added logistics services. However, seaports have to deal with different challenges in order to stay competitive or to maximize the efficiency of the maritime supply chain. Especially increasing ship sizes, geographically limited growth opportunities and increasing pressure on the productivity of seaports are current challenges. At the

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same time, the demands to reduce emissions along the entire supply chain are becoming more important. These structural changes and challenges in the logistics chain need to be addressed. One possibility is digitization along the entire maritime supply chain, for example by integrating new information technologies and global networking. Seaports can benefit from the development of traditional ports into smart ports, increasing connectivity among the individual actors and improving their performance (Karas, 2020).

The chapter "Smart Port concept: strategic development, best practices, perspectives of development" is intended to provide an overview of what smart ports are and which innovative digital technologies are already being used both in science and in practice around seaports. First, a brief definition of a smart port is given in section 2 "Definition", followed by a presentation of the development stages of ports from simple loading and unloading ports to smart ports. In the following section, theoretical as well as practical innovative solutions from science and industry for reducing complexity in ports are presented. Finally, the chapter ends with a summary of all important findings and an outlook.

2 Definition

During the last decades, the function of a port has changed significantly, as can be seen in Fig. 1. In the first generation, ports were only loading and unloading nodes between waterside and landside modes of transportation. In the beginning, the ports' function was limited to services related to ships and the goods they handled. However, more and more manufacturing industries settled around the ports. Therefore, the second generation of ports is called "industrial port." After the 1980s, it can be seen that ports have become more than simple transshipment hubs. They also offering value-added services related to the distribution of goods, as well as data

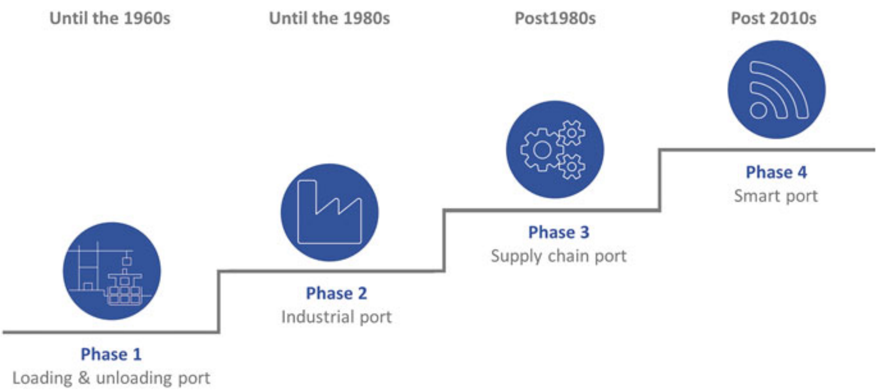

Fig. 1 Port development (based on Berns et al. 2017)

Fig. 2 A smart port uses innovative digital technologies to improve its performance (Saxe & Jahn, 2017)

processing and the use of telecommunications systems. Thus, they also called "logistics/supply chain ports" (Berns et al., 2017).

Nowadays, ports must become more and more service providers. New services are increasingly replacing traditional services. Regarding the changing requirements of the world trade, the need that the ports become more and more "intelligent" is getting a higher importance. Thus, currently the fourth generation of ports, the so-called smart ports, is born. A smart port uses automation and innovative technologies such as artificial intelligence, Big Data, Internet of Things (IoT), and blockchain to improve its performance. Thereby, innovative digital technologies can be used in different parts of the port and turn a conventional port into a smart port. Figure 2 shows some exemplary applications of smart technologies in the port environment, which can be used both on the water and on land (Saxe & Jahn, 2017).

In summary, the smart port concept is based on digitalization, automation of port and terminal processes and also on the interconnectivity of all actors in the maritime supply chain through the automated transmission of mobile data in real time. As a result, this concept aims to increase the overall competitiveness of ports and also contributes to the integration of the maritime supply chain (Douaioui et al., 2018).

By integrating different data sources and improving the use of data, added value can be generated. This creates many opportunities for the new generation of ports. For example, the integration of innovative new technologies into ports enables logistics actors to network safely and securely. In addition, the use of artificial intelligence makes it possible to automate tasks. Opportunities for synchronizing processes also arise from the transformation of ports into smart ports. There are opportunities for the emergence of new business models. The tasks of people in smart ports will shift. They will increasingly take on a supervisory role. And finally, solutions will be found to make processes more environmentally friendly. Many research and development projects in the academic or practical world are concerned with the development of innovative solutions to reduce complexity in ports with regard to the aspects mentioned above (Saxe & Jahn, 2017).

3 Interlink Logistics Partner

In addition to the planning, design, and control of material flows of sea-bound transports, the acquisition, storage, transformation, and transmission of information play a central role in the maritime supply chain. Thus, computer-based operational and inter-operational information systems are becoming increasingly important for the planning and control of cross-border flows of goods. For this purpose, it is necessary that the actors in maritime transport are comprehensively and cyber-securely networked in and between the ports. This networking is already taking place in many cases via commercial platforms, which are often developed and operated by companies in the port industry (Gimenez & Llop, 2020).

The widespread use of sensor and communication technology (Internet of Things) provides permanent real-time information about the location, condition of equipment, vehicles and cargo carriers (intelligent containers). Challenges in the design of information networks in the maritime transport chain arise, among other things, from many different peer-to-peer interfaces, the question of data sovereignty, data security issues, and lack of data exchange standards, among others (Saxe & Jahn, 2017).

Port community systems are an example of the successful networking of logistics partners along the maritime supply chain. They enable better and more transparency in planning and faster handling and reduce the frequency of errors. A global pioneer in port community systems is DAKOSY Datenkommunikationssystem GmbH, an operating company of a communication network for the storage, transmission, conversion, and distribution of logistics-relevant data. Among other things, DAKOSY operates the Port Community System for the Port of Hamburg. Via data interfaces, transport companies can link up with the loading and receiving industries as well as with the authorities relevant to the transport process (e.g., water police, customs). Intermodal hinterland processing is also integrated into the system (DAKOSY Datenkommunikationssystem AG, 2021).

Furthermore, there are current efforts in research to address the increase in the need for information to improve the coordination of the transport chain based on open IT platforms. One example is the research project "MISSION—Manage Information Seamlessly in Ports and Hinterlands" initiated by the Fraunhofer Center for Maritime Logistics and Services (Fraunhofer—Center for Maritime Logistics and Services CML, 2017).

MISSION aims to create a prototype for a non-discriminatory information network. The open infrastructure, in which as little data as possible is held centrally and data sovereignty remains with the provider, is very important part of the project. A key aspect of MISSION is the possibility for all participants to integrate their own services, such as truck routing and tracking services. The data is not held centrally, but remains with the owners of the data. To make this possible, an identification service is used to provide login information for the entire network. In addition to the possibility of single sign-on (one login for many connected services), this relieves the service providers in the network of user administration and enables secure data exchange. In addition, modules are being developed to support truck routing and tracking (Fraunhofer—Center for Maritime Logistics and Services CML, 2018).

4 Automate Tasks with Artificial Intelligence

In recent years, Big Data and artificial intelligence have increasingly become the focus of science and industry. In several areas of logistics, artificial intelligence and data analytics have enabled the introduction of automation, such as driverless transport systems. A higher degree of automation has a significant impact on operational efficiency and productivity. The use of artificial intelligence has the potential to reduce human error, speed up operations, and reduce emissions by analyzing the large number of available data in a specific way to optimize existing processes. In addition, big data analyses provide deep insights into logistical, economic, and technical correlations and forecasts (Schwerdtfeger, 2021).

Especially the larger ports, for example Singapore, Rotterdam, and Hamburg, are using artificial intelligence to improve their business processes. One example of the use of artificial intelligence in ports is the project "KIK Lee—Using artificial intelligence to reduce truck congestion." The aim of the project is to use artificial intelligence to provide utilization forecasts of track arrival rates and truck waiting times for an empty container depot. As part of the project, information will be generated and made available. The information will be used to enable container depot customers to avoid peak times. Furthermore, facility operators should be able to adjust to the expected workload. This will help depot operators to manage their resources more efficiently, support trucking companies in optimizing their routes, and reduce traffic congestion in the port. Based on an analysis of the information requirements, data collected by the container depot on incoming trucks and publicly available data (e.g., traffic data, data on ship arrivals) are combined. These are integrated into a real-time and AI-based forecast in order to be able to make predictions about capacity utilization during truck dispatch. The open data access is published on the data platform mCLOUD, which is operated by the German federal ministry of transportation and enables the generated information to be accessible and always updated for all actors involved in the empty container depot (Fraunhofer—Center for Maritime Logistics and Services CML, 2020).

Another example of the use of artificial intelligence in ports is the research project "Cookie—Container Services Optimized by Artificial Intelligence." At up to 40%, empty containers account for a significant share of the total number of containers transported on land. This underlines the relevance of reducing the workload in empty container logistics as well as the fastest, most efficient, and resource-saving temporary storage, repair, cleaning and finally delivery to the place of loading. The repair of empty containers is an essential service to support the performance of seaports. In the process flow at the empty container depot, manual activities and a lack of digitization result in delays that reduce the plannability of the processes for associated actors in the maritime supply chain. With Cookie, the use of artificial intelligence in the context of services of an empty container depot is being researched. The goal is to help make the processes in the depot more efficient by making reliable forecasts about container availability, optimizing the cleaning process in a way that conserves resources, and implementing automated identification and assessment of damage cases. In this way, intelligent systems using AI methods will help to eliminate inefficiencies in container service processes and to achieve optimized control of empty container processes across all actors, which in turn will facilitate optimized planning of empty container transports in the port (Fraunhofer—Center for Maritime Logistics and Services CML, 2019).

5 Synchronize Processes

Along the maritime supply chain, uncertainties in the arrival times of ships complicate the planning reliability of the actors involved. These can be caused by various influences, such as unfavorable weather conditions, high traffic volumes, or bottleneck situations. The same applies, for example, to landside delays of external trucks in terminals or fluctuations in handling times at logistics nodes. These factors can have a strong impact on the resource and capacity utilization of the various actors. A better networking of the actors in international trade processes, e.g. importers and exporters, transport companies, port authorities, terminal operators, customs, freight forwarders, etc. allows a better coordination of material and information flows. Thus, logistic processes can be organized more efficiently and long waiting times at the various nodes of the maritime supply chain can be reduced (Ascencio et al., 2014). This is where IT networks and IoT create end-to-end transparency in the logistics chain, so that the relevant actors are familiar with the location, condition, handling of the goods, as well as other upcoming processes and their options. This enables synchronized logistics chains and more efficient use of existing logistics resources and infrastructures.

One example of successful coordination of different actors and efficient process design is the Port of Hamburg. It is one of the most efficient universal ports in the world. Spread over 43 km of quay walls for vessels and 300 berths, the port has almost 7500 ship calls per year. On land, more than 1300 freight trains and countless trucks are handled every week. In 2020, around 126.3 million tons were handled across the quayside in Hamburg, with a large proportion of the goods reaching the port in containerized form. This makes Hamburg the third largest container port in Europe. Hamburg ranks 18th on the list of the world’s largest container ports (Port of Hamburg, 2021).

One of the most important factors for efficient operations is seaward accessibility. High accessibility results in shipping companies deciding to use a port. Likewise, poor accessibility and inefficient processes ensure that a port loses its attractiveness for shipowners, thus worsening its competitive position. In order to coordinate the inflow, flow between terminals if necessary and outflow to and from the Port of Hamburg, the Port of Hamburg has created a central, inter-company coordination office for large ship, feeder and inland waterway vessel traffic, the Hamburg Vessel Coordination Center (HVCC). In addition, the HVCC acts as the central communication interface to the Hamburg Nautical Center and to the pilotage fraternities. In this way, the HVCC links different partners and their data. All actors involved benefit from this, because the Elbe River area and the Port of Hamburg can be used efficiently. In addition, the resulting reduction in emissions and lower energy consumption protect the environment (HVCC Hamburg Vessel Coordination Center GmbH, 2021).

6 Enable New Business Models

The need for sustainable and efficient supply chain processes means major challenges in terms of developing new business models. The current demands on maritime supply chains are great. The aim is to protect natural resources, avoid environmental pollution, and increase safety requirements. At the same time, the supply chain must be competitive. This requires development of new intelligent business models to meet all the requirements. AI-based data generation, analysis, and use, as well as automation, will help to support the development of new business models and new operating concepts for technical systems (Zijm et al., 2016).

One possibility to open up new business sectors for (maritime) logistics is the use of drones or unmanned aerial vehicles. Although the drone industry is still rather young, it offers great potential. Thus, the use of drones is also becoming increasingly important in logistics and industry, and new applications are added every day. Drones help to reduce the time spent by inspectors and minimize the risk of accidents. At the same time, they can be deployed quickly and flexibly. In the maritime environment, they can monitor the conditions of bridges, locks, and various buildings in the port and thus support their maintenance. Figure 3 shows a drone during a bridge inspection in the area around the port (Saxe & Jahn, 2017).

Drones are already being used in ports today. For example, the drones are used for inspection tasks on the facilities in ports. One field of application is the regular inspection of ship-to-shore gantry cranes. In particular, the inspection involves checking the weld seams for signs of fatigue. In this way, the time during which the ship-to-shore gantry cranes are out of service can be reduced to a minimum. Another area of application for drones in ports is checking the transponder surfaces of AGVs on the terminal. In addition, the use for automated control flights to monitor track systems and gantry cranes is being investigated (Saxe & Jahn, 2017).

Further potential can be seen in the automation of ships. Concepts for unmanned or autonomous ships have been developed since the early 1980s. However, most (partial) automation projects before 2010 focused on functions such as asset monitoring and predictive maintenance rather than the vision of an unmanned, autonomously deciding and acting ship (Saarni et al., 2018).

Although there are more and more small remote-controlled or autonomous ships that have been used for various purposes in ocean research since 2017, there are still

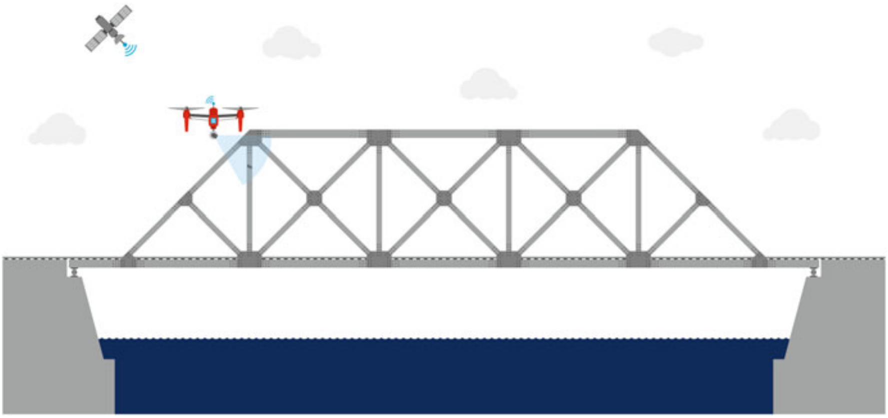

Fig. 3 Flight drones (Saxe & Jahn, 2017)

no large autonomous ships in daily operation (Lloyd's Register, 2017). Despite major technological advances, for example in data processing and networking as well as in the operational concepts of autonomous ships, there are so far only field trials or individual construction projects for autonomous ships, but no regularly deployed solutions. This is mainly due to the fact that there are still obstacles to the introduction of autonomy in maritime shipping, both due to unresolved safety issues and in the area of legal foundations (Levander, 2017). Nevertheless, automation of shipping opens up new opportunities to address existing as well as future challenges in the areas of competitiveness, safety, and sustainability (MUNIN, 2016a). For example, autonomous ships can operate even in conditions where manned ships cannot. On the other hand, autonomous systems allow for a more frequent cycle and in this respect ensure a competitiveness of shipping compared to land transport (Bruhn, 2017). Furthermore, a changed cost structure, for example due to personnel savings, can be counted among the motivations (Willumsen & Simonsen, 2018). In conventional shipping, liner services for small transport units are often uneconomical due to disproportionate transport costs. For such trips, autonomously operating ships could be an economical alternative (Bruhn, 2017).

Regular inspection of ships and port infrastructure is an unavoidable responsibility. This is the only way to ensure safety at sea and in coastal areas. Such responsibilities are traditionally assumed by professional divers. The turbidity of the water in harbor basins in particular poses a risk for divers that should not be underestimated. The use of underwater drones is one way of making such tasks safer and more efficient in the future. The international research project "RoboVaaS—Robotic Vessels as a Service" is attempting to implement this. The idea behind the research and development project is to implement maritime, coastal services such as depth measurements, quay wall and ship hull inspections with the help of underwater drones (Fraunhofer—Center for Maritime Logistics and Services CML, 2021).

7 Human Center

Due to increased digitalization and automation of processes in the port, the job profile for the employees in this area is also changing. Routine physical activities are replaced by automation solutions or supported by cooperative robots. Human work focuses on complex maintenance tasks. Instead, human labor is increasingly focused on complex maintenance tasks. Thus, the need for qualified employees with IT-related profiles is growing. One example of the support of human tasks through the use of modern technologies is the implementation of visual appliances. These can provide additional information for employees. For this, employees working in the ports need to be trained and educated with regard to new tasks and work profiles (Saxe & Jahn, 2017).

New job profiles in the port are, for example, data scientist, multimodal traffic controller, shore-control-center operator, land-based crew, port energy manager, officer in the Port Authority's nautical command center, and port infrastructure manager.

At the port, large data sets are generated each day. On this basis it is not possible to forecast and make decisions. In order to make the data useful, data scientists analyze it using Big Data analytics, as shown in Fig. 4. Only this way the data can be used to increase the efficiency of a port by identifying complex causal chains and also uncovering data correlations that are not obvious. The analyzed data can then be used, for example, to optimize the management of transport and handling resources.

The multimodal traffic controllers work closely together with the data scientists. Their task is to optimize the entire transportation system. To do this, they use deep learning and big data analytics with the help of historical and real-time data. This enables them to organize the entire traffic system and not just individual traffic flows.

Fig. 4 New job profile—Data scientist in the port's data lab (Saxe & Jahn, 2017)

Fig. 5 New job profile—Energy Manager (Saxe & Jahn, 2017)

Fully autonomous ships usually run without a crew on board. Instead, the captain of an autonomous ship is located on land in a so-called Port Traffic Center. From here, he monitors the ship. Telemetry is used to display relevant information about the ship's condition and the current situation on board. For this, the shore control center monitors nautical information, the traffic situation at sea, weather and wave conditions as well as the operating status of the engines and aggregates on board. In case of a fault or a critical situation, a Port Traffic Center can take over control and navigate the ship safely.

In controlling and guarding such autonomously operating ships, the captain is supported by a specialized crew that is also based ashore. In many ways, land-based controlling and monitoring of ships is more attractive than on-board operations. This means that there are no long shifts with non-stop working hours and less difficult or dangerous working conditions (MUNIN, 2016b).

Another new job profile created by increased digitalization and automation of processes in ports is the energy manager, which can be seen in Fig. 5. The energy manager's task consists of collecting and analyzing information regarding electricity generation and consumption around the port. It is the manager's responsibility to match the energy available in the port with the electricity demand of the different stakeholders (e.g., terminal operators). For this, analyses of traffic peaks, ship arrivals, and operational shifts at the terminals must be taken into account. If necessary, additional energy required has to be purchased on the forward market.

Finally, there is the job as a port infrastructure manager, who is responsible for monitoring both mobile and stationary port infrastructures. In this job field, employees can use the latest technologies, such as flying drones, to fulfill their tasks.

8 Green Logistics

The logistics sector has a significant impact on global greenhouse gas emissions. In addition to greenhouse gases, the mobility and logistics sector also produces other emissions that are important parameters for making transportation more eco-friendly. These include noise, air pollutants, and particulate emissions. Thus, Green Logistics stands for environmental compatibility and resource efficiency along the entire logistics chain, i.e., for transport, intralogistics, and logistics buildings. Opportunities to reduce emissions can be realized, for example, by increasing transport efficiency, reducing transport volumes, optimizing routes, shifting transport to more environmentally friendly modes of transport, or using more energy-efficient vehicles. Overall, existing approaches to reducing emissions can be divided into technological approaches, operational approaches, and political approaches. An example of a technological approach is the development of new driving technologies. Personnel training is one of the operational approaches, and the introduction of speed limits is an example of a political approach (Fraunhofer-Institut für Materialfluss und Logistik IML, 2011).

Also, in the maritime sector, more and more technical systems are being used both on land and at sea that are designed to avoid emissions. The Hamburg Container Terminal Altenwerder uses a fleet of 90 so-called automated guided vehicles (AGV) to transport containers between the quay side and the yard. Until now, these automated container transporters were largely diesel-hydraulically and diesel-electrically driven. Since 2017, the AGVs at the terminal have been switched to lithium-ion batteries step by step. This should not only reduce CO_2 emissions at the terminal, but also reduce noise, particulate matter, soot and nitrogen emissions. The AGVs will be refueled during off-peak hours in order to withdraw excess energy from the power grid. At the same time, it is planned that AGVs can also feed energy back into the power grid as so-called primary control power. This is intended to smooth load peaks in the power grid and keep the network frequency stable. For the realization of this project, a sufficient number of charging stations have to be installed on the CTA. Therefore, a control software has to be developed that continuously determines the transport performance of the vehicles required for container handling and optimizes the charging strategies of the AGVs based on this (HHLA Hamburger Hafen und Logistik AG, 2021). At the beginning of 2019, the project "FRESH—Flexibility Management and Control Energy Provision for Heavy Goods Vehicles in the Port" started its research and development of the necessary control software. By the end of 2022, the terminal plans to complete the changeover to purely electrically powered AGVs (OFFIS e.V., 2021).

9 Conclusion and Outlook

The chapter has shown how ports have developed over time from simply being ports of loading and unloading to becoming increasingly automated and digitized. Approaches from science and practice were presented on how ports are trying to integrate the trend of digitalization into their daily processes. The aim is to make port processes more flexible, robust, and efficient. This enables better handling of complexity in terms of structural complexity, data complexity, product complexity, and complexity due to networking and e-commerce.

In summary, the concept of the smart port is the key to facing the upcoming challenges of ship size growth, space constraints, and the increasing pressure to increase productivity in ports. A wide range of digital technologies is now available to optimize processes and systems in ports. In this context, topics such as digitalization, automation, and emissions avoidance are having a significant impact on technology, infrastructure, and human labor in ports. A critical success factor on this journey will be bridging the gap between science and industry for the implementation of innovative digital solutions in the coming years. Implementation on the path to the smart port will only be successful if cooperative research projects can be launched. The overriding goal should not be to create individual smart ports, but to create a chain of smart ports. A success factor will thus be the global cooperation of port-relevant players to promote co-innovation and to lead the market-oriented digital transformation process in the maritime supply chain from the customer's front door to the customer's front door.

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Digitalization of Maritime Logistics Systems

Ann-Kathrin Lange and Michaela Grafelmann

Abstract Due to the increasing demands on participants of maritime supply chains for short turnaround times, low costs and high quality with a simultaneously growing number of disruptions, for example due to the COVID-19 pandemic or shipping accidents, digitalization is of elementary importance for companies in maritime logistics systems. Nevertheless, the level of digitalization is very heterogeneous due to various factors, such as the size of the company or the field of activity. The aim of this publication is therefore to provide an overview of the state of research in the field of digitalization of maritime logistics systems in order to support the alignment of the level of digitalization.

To achieve this, a structured literature review was conducted and evaluated, particularly with respect to the dependencies of the selected parameters. The analysis shows that increasingly broad-based publications prevail, which provide an overview of the topic without going into detail about the requirements of the individual stakeholders. Furthermore, only rarely are methods explicitly used or technologies investigated that could drive digitalization.

1 Introduction

Heilig et al. (2017a) state that "digitalization is pushing the maritime industry beyond its traditional limits and provides many new opportunities to enhance the productivity, efficiency, and sustainability of logistics."

This applies in particular to maritime supply chains and their nodes, the seaports, and inland ports. For a long time, these were characterized by traditional structures and a high proportion of manual work. However, increased pressure from customers and other stakeholders, for example to reduce costs and comply with stricter emissions regulations, and the challenges posed to logistics by the COVID-19 pandemic have resulted in extensive changes in the structures, processes and,

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above all, the views of logistics companies in recent years, many of which also relate to digitalization. The pandemic has enabled first movers in digitalization to remain ahead of the competition by, among other things, using information technology, blockchain solutions, digital platforms, and electronic trade documentation. In the next years it will be the mission to adapt to these challenges for all players in the maritime supply chain. This is especially challenging as maritime transport involves a wide variety of stakeholders with different fields of activity and company sizes and the associated opportunities to implement methods and technologies for digitalization. In some cases, this makes cross-company digitization approaches significantly more difficult and leads to large differences in the levels of implementation and, accordingly, to disadvantages for individual companies.

The aim of this publication is to show the current state of research in relation to the digitalization of maritime systems with the existing research gaps and, building on this, to identify new research opportunities. This should somewhat smooth out the differences in knowledge levels and thus enable increased transparency along the maritime supply chain. In order to achieve this, an extensive, structured literature search and evaluation will be carried out, in particular to determine the interdependencies of the parameters under investigation. In Sect. 2, the relevant terms are defined and distinguished from each other. Based on this, Sect. 3 describes the current challenges for maritime logistics systems. In Sect. 4, the methodology of the literature analysis is explained, followed by the evaluation. The summary and an outlook are presented in Sect. 5.

2 Terms and Delimitations

The possibilities and challenges of digitalization are among the most discussed topics in maritime industry and research. Technological development and the increasing willingness of companies to network are continuously opening up new opportunities for the use of digital technologies. Due to the many different application areas, involved parties and technological and organizational approaches, it is necessary to specify the focus of the study to get detailed results on current trends and promising research and development areas. In the following sections, the term "maritime system" is defined and delimited for the purposes of this study. The terms "digitization" and "digitalization" are then distinguished from one another.

2.1 Definition and Delimitation of Maritime Systems

In industry and science, there is a wide variety of views concerning maritime systems. This is partly due to the involvement of many different scientific fields and partly due to the historical growth of the concepts and fields of activity. They range from maritime systems for the extraction of raw materials and generation of renewable energies, to transport vehicles on the water, transshipment facilities on the coasts and the associated hinterland traffic. Therefore, there is no overall definition for the term *maritime system*. It is broadly used for many different applications on and at the sea and their related technologies. The term *maritime domain*, which is used similarly, has a stronger focus on safety-related issues (e.g. Tetreault, 2005).

For the specific subsystem, which is highly relevant for this study, there are more detailed definitions. This subsystem is named *maritime transportation system* or more rarely *marine transportation system*. Mansouri et al. (2009) define maritime transportation systems as "critical infrastructure systems that enable economic activity through transferring goods between national and international destinations." Helmick (2008) details this definition with focus on the application as "ports, waterways, and their intermodal connectors" and names it "the backbone of world trade." Sánchez and Wilmsmeier (2010) highlights that the maritime transportation system "encompasses both shipping and port subsystems." They state that "one basis for distinguishing between the shipping and port subsystems remains the fact that the constituent elements of the latter are composed of physical characteristics in space, while the former comprises mobile elements" (Sánchez & Wilmsmeier, 2010). Notteboom (2010) uses the term port system to describe all ports and their associated transport links in a particular geographic region, such as Europe. In this chapter, the focus is on ports and *port systems*, limited to one or several cities in close proximity to each other. Both seaports and inland ports, including combined transport terminals without a direct water access, are considered. These port systems are made up of many different companies, institutions, and public institutions with various functions, ranging from the provision of infrastructure and handling services to value-added services. The *shipping subsystem* will be analyzed in the following chapter.

2.2 Definition and Delimitation of Digitalization

Digitalization is one of the current key drivers in process innovation around the world. Its manifestations vary widely depending on the application area. As a result, there have been many different definitions of *digitalization* throughout the years. Furthermore, the term *digitization* was partly used synonymously and partly distinct. Therefore, the understanding of the two terms needs to be set for this chapter.

Ritter and Pedersen (2020) refer to Brennen and Kreiss (2016) and state that "digitization, i.e. the increased availability of digital data enabled by advances in creating, transferring, storing, and analyzing digital data, has the potential to 'structure, shape, and influence the contemporary world' (Brennen & Kreiss, 2016)." They proceed by defining digitalization "as the application of digital technologies [. . .] related to the application in businesses [and broader] [. . .] in relation to digital communication." Reis et al. (2020) go a step further and define digitalization as "the phenomenon of transforming analogue data into digital language (i.e., digitization), which, in turn, can improve business relationships between customer and companies, bringing added value to the whole economy and society." For this chapter, the definition by Reis is used and thus the focus lies on the possibilities and challenges for port systems induced by the digitalization process. For a more general view on digitalization in general, please be referred to the publication of a. o. Reis et al. (2020), Ritter and Pedersen (2020), and Brennen and Kreiss (2016).

3 Status Quo and Current Challenges

Over the past decades, port systems have continued to develop towards a high degree of digitalization and automation. For a very long time, particular focus was placed on seaport container terminals (Heilig et al., 2017a). In the meantime, however, other, and also smaller, players along the maritime transport chain are also making significant efforts to drive digitalization forward. The goal is usually to increase the company's own efficiency in order to keep up with the continuously increasing demands of the market environment. Frequent areas of application are: increasing the degree of automation of the company's equipment, improving transparency and data exchange with other players in the transport chain, and improving operational processes through the use of new data processing and control methods. The current level of digitalization and its impact vary not only greatly among the different players in the maritime supply chain but also between the different types of maritime transport chains. This is mainly dependent on various factors, which are briefly presented below.

The location of a port has a major impact on the requirements for the resident companies, on their structures and processes. First of all, a distinction can be made as to whether the port is a seaport, an inland port, or a combined transport terminal. Seaport terminals, especially in the area of container handling, are subject to increasing pressure for optimization due to the progressive growth in ship sizes while the handling time windows for the ships remain the same. For this reason, seaport terminals are characterized in principle by a high degree of automation. Furthermore, many seaports, especially in Europe, are located in or near cities. Accordingly, the expansion areas for the ports are small. As a result, capacity expansions are only possible through higher stacking of containers, which in turn leads to more complex processes and higher inefficiencies. To counter this, many terminals are using novel concepts and technologies from the field of digitalization, which in particular take advantage of increasing data availability and support employees in planning and operational work processes or take them over completely. Examples include automated container storage cranes, OCR gates for trucks and trains at terminal entrances, or programs for stowage planning for ships.

Inland ports or combined transport terminals are often characterized by a lower level of automation and digitalization. This may be due, among other things, to somewhat less time pressure from the respective customers, but also to smaller company sizes and the associated lower investment opportunities. Furthermore, smaller transshipment facilities often have less market power, which means that they are dependent on the cooperation of the other companies involved when implementing digitization measures. Larger companies can in principle implement changes more easily, even if the cooperation of some of the parties involved is limited. However, it must be considered that the cooperation of all participants in a supply chain always leads to better results. In principle, it can be assumed that ports with lower handling volumes are under less pressure to digitalize. The port's hinterland connections have a major influence on handling volumes. Ports and terminals with trimodal connections have the option of transferring traffic to other modes of transport, depending on the prevailing conditions, and thus ensuring a stable supply. At the same time, more connected modes of transport also mean greater complexity in operational processes. The available equipment must be flexibly and appropriately allocated to the modes of transport and the tasks at hand must be handled as efficiently as possible. The terminals and logistics nodes can choose from a variety of objectives. For example, orders can be processed as quickly as possible, as cost-effectively as possible or with the lowest possible emissions. Here, too, digitalization concepts and technologies are increasingly being used.

The investment funds available for the digitalization of companies also continue to depend on the ownership structure of the ports and the companies located there. In the area of digitalization, large corporate groups often have standardized solutions that can be rolled out to many associated companies with comparatively little effort and correspondingly low costs. Since these solutions were not created specifically for individual companies and their structures and processes, there can be efficiency losses when they are used. In contrast, small or medium-sized individual companies invest large sums as a percentage of their revenue to create and implement customized solutions. However, due to the generally low margins of these companies and the resulting limited investment volume, this rarely happens. Another influencing factor here is government subsidies for new buildings and expansions. In many countries, combined transport in particular is considered to be especially economic and ecological, and corresponding transport and handling companies are subsidized. Nevertheless, these subsidies are currently aimed more at the infrastructure and less at the supporting information technology.

The current challenges of digitization in ports vary widely. Some important examples are briefly presented below. On the one hand, there is still a very strong reluctance to share data with other companies, even along a supply chain. The fear of many companies here is that by sharing their data, they will lose advantages over their competitors and thus have a worse market position in the future. The opportunities offered by this data transparency are seen, but their feasibility is strongly doubted. Nevertheless, a cautious change of views can be registered here in recent years. On the other hand, many media discontinuities within and between companies complicate operational and administrative processes. This can be, for example, that equipment control is carried out in a different system than warehousing or access control. Manual data entry using paper lists or simple tables is also increasingly used. This leads to redundancies in data entry and storage and thus increases the susceptibility to errors. New, comprehensive systems that would avoid these redundancies are difficult to implement, especially for smaller companies. One way to improve this would be to expand subsidies for IT infrastructure. Furthermore, there are very different levels of knowledge among employees in the companies, especially with regard to IT systems and data processing. Persistent problems to find junior staff and a lack of funds or capacity for further training mean that there are still high hurdles to getting involved with new technologies. Furthermore, many small or medium-sized companies tend to be operationally oriented and have hardly any employees who can deal with the acquisition, adaptation, or further development of IT systems. Here, too, a change is slowly taking place. Further support is being provided by industry associations and increasing networking.

As a means to illustrate current developments, the next Section examines the approaches to digitalization in relation to port systems that have been investigated in research since 2010 in the form of an extensive literature search and literature classification based on this, and then classifies them into relevant fields of research. Among other things, this allows current trends to be presented and existing research gaps to be identified.

4 Development Trends of Digitalization in Maritime Logistics

In order to describe development trends in the digitalization of maritime logistics, an extensive literature review is conducted. This is structured as follows: First, a structured literature search is carried out and described in Sect. 4.1. The identified publications are then classified in Sect. 4.2 based on various criteria concerning the content and the selected approach. Finally, the literature classification serves as the basis for deriving current trends, research gaps, and promising future research areas in Sect. 4.3.

4.1 Literature Review

For the literature review, the Scopus Citation Database was selected as a comprehensive and peer-reviewed publication database. Scopus is among the most used and largest curated abstract and citation databases to explore relevant research activities, claiming to ensure the highest quality data are indexed (Singh et al., 2021). Baas et al. (2020) found that Scopus has a larger number of exclusive journals than, for example, Web of Science. Based on the definitions and delimitations explained in Secs. 2.1 and 2.2, the following search terms were selected:

digitali*ation AND maritime OR port

The search terms were chosen to identify as many publications as possible that either have a direct connection to ports or are in maritime context. Therefore, subsequent filtering was taken into account. In addition, more specific search terms (such as applications) have been omitted in order to draw a comprehensive picture rather than

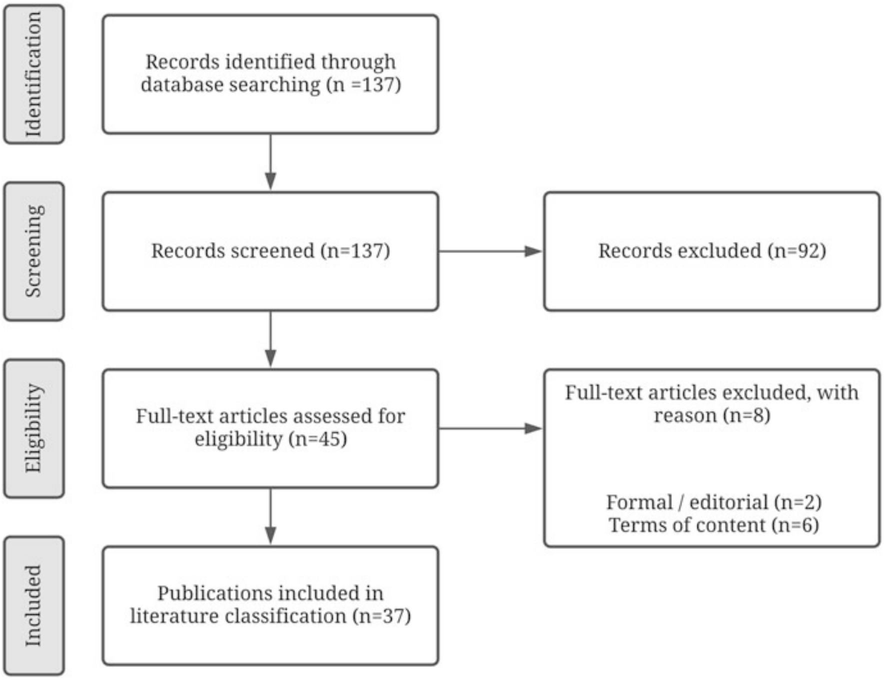


Fig. 1 Framework of the literature review process (based on Moher et al., 2009)

influencing the results in certain areas. Truncation allows to include different spellings of the search term "digitalization", since it is spelled differently in British English than in American English. The search was carried out for documents where these terms appear in the title, abstract, or keywords. Using this search strategy, 148 publications were initially identified (status June 6th, 2021).

Subsequently, the search was limited to publications between 2010 and 2021, with reference to Heilig et al. (2017a), which illustrate that the digital transformation in ports can be divided in three generations. The first generation includes in principle the transformation to paperless procedures in the 1980s. The focus of the second generation (1990s–2000s) was on the transformation to automated procedures. The third generation, from 2010s until today, covers the transformation to smart procedures. An analysis of the latter digital transformation in ports is the focus of this contribution, hence the time restriction of the search, which results in 137 publications.

In Fig. 1, the different phases of a systematic review based on Moher et al. (2009) are depicted. After the identification phase, the 137 records were screened to exclude publications that either did not fall within the thematic focus or were not available for full-text review in the English language. As described in Sect. 2, the focus of this work is on the digitalization of ports and logistics nodes in the maritime sector and

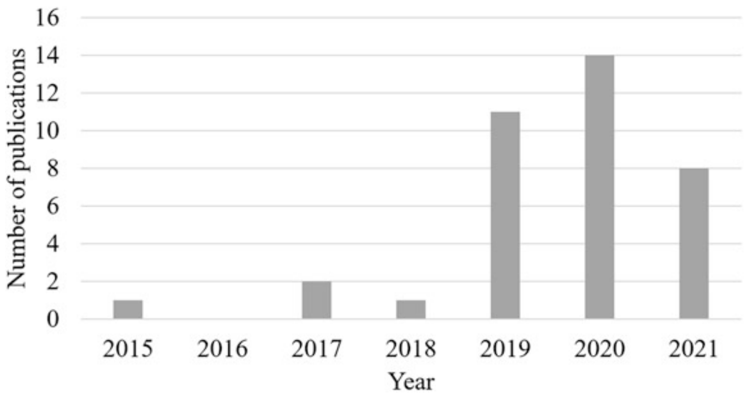


Fig. 2 Number of publications per year

their interfaces to connected (transport) sectors. To achieve this, the filtering of unrelated publications is inevitable since, as for example, "port" may also refer to computer soft- or hardware. Therefore, filtering was initially based on title- and abstract reading. In addition to the exclusion of publications without maritime relevance, publications dealing solely with shipbuilding, (autonomous) shipping and e-navigation, or the development of coastal areas/ecosystems, including fisheries, were also excluded. This filtering was based on the delimitations explained in Sect. 2.1. Thus, 45 publications could be identified for full-text assessment.

In the next phase, the eligibility of this subset of publications is checked, whereby the reasons for exclusion were either that the publication does not meet the formal or editorial requirements, or in terms of content. The latter included publications that focus solely on maritime transport, shipping or shipbuilding (four times) or security for cruise services (one time) or that digitalization is not in the main focus (one time). As a result, 37 publications were identified to be included in the literature classification. Figure 2 shows the number of publications per year.

Despite the inclusion of publications from 2010 onwards, the figure shows that the oldest publication identified is from 2015. It is also apparent that there is a significant increase in publications from 2019 onwards. This trend is likely to continue with additional publications in the second half of 2021. Digitalization is pushing the maritime sector beyond its traditional limitations and presents numerous innovative opportunities to improve the productivity, efficiency, and sustainability of logistics (Heilig et al., 2017a). It can be assumed that the increase in publications over the last few years is due to the increased pressure for optimization due to more current issues, i.e. the growth in vessel sizes, as well as due to the further development of new approaches, such as blockchain, whose application in the maritime sector is lately being discussed in literature. The pressure for digitalization and a change in thinking among some actors in the maritime environment, who are required to be more open/forward-looking, have influence on research.

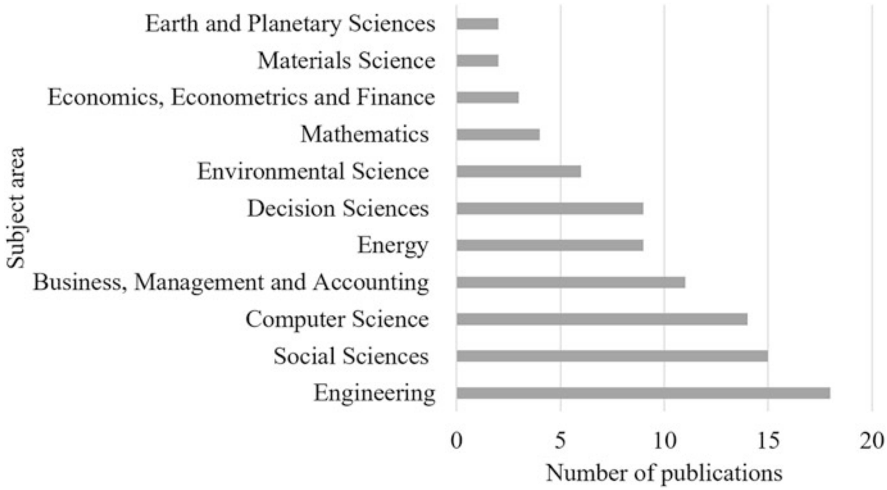


Fig. 3 Subject area (multiple selection possible)

Six of these 37 publications have a citation count of ten or more. Two of them (Heilig et al., 2017a, b) deal with land-based transport in ports, also known as inter-terminal transport. The focus here is on increasing the efficiency of processes, e.g. by using cloud-based platform. Sanchez-Gonzalez et al. (2019) and Inkinen et al. (2019) rather give an overview of various applications. Fedi et al. (2019) discuss to what extent port community systems can influence the implementation of new legal constraints in port operations. Yang (2019) focuses on maritime shipping supply chain and particularly explores the most significant applications of blockchain technology and expected improvements. Basically, it can be concluded that a lot of papers are published, but at the same time few other papers with similar topics are cited. It remains to be observed to what extent this will change in the next few years, especially since most of the publications are recent, and therefore it may not yet have been possible to access other papers prior to publication. In addition, the emphasis on these most cited six publications already indicates that the thematic focus varies greatly.

Figure 3 shows the subject area classifications assigned to the identified publications in Scopus. Multiple selections per publication are possible.

It is evident that a wide variety of subject areas are covered by the 11 categories, mostly regarding Physical Sciences (Computer Science, Earth and Planetary Sciences, Energy, Engineering, Environmental Science, Material Science, Mathematics) but also Social Sciences (Business, Management and Accounting, Decision Sciences, Economics, Econometrics and Finance, Social Sciences). As digitalization is a technology driven topic with a high impact on social and business life, the high number of publications in engineering and computer science as well as in social sciences and business, management and accounting can be expected. The publications in the other subject areas show the broad impact of digitalization on various industries and issues.

4.2 Classification

The classification scheme is a central element for the analysis of the 37 relevant publications. In addition to the bibliographic data (authors, year), the scheme includes five content-related categories (see Table 1). These are categories that go beyond the evaluation of the characteristics of the publications available in Scopus. They were mostly defined prior to the analysis of the papers, but some were added during the elaboration. They serve to more clearly assign the procedures and

Table 1 Structure of the classification scheme

	Specification	Description/example
Research methodology		
1	Project review	Description of a research project
2	Case study	Analysis of existing systems
3	Empirical study	e.g., Surveys, interviews
4	Literature review	Structured analysis of literature
5	Scientific modeling	Heuristic algorithms, simulation
6	Other	Methods not previously mentioned
Application field		
1	Seaport	Several actors in one port
2	Terminal landside/transport	Focus on truck/train transport
3	Terminal seaside/shipping	Focus on ship transport
4	Overall supply chain	All actors on a supply chain
Continents considered		
1	Africa	e.g., Tanger Med, Port Said
2	Asia	e.g., Primorye, Singapore
3	Europe	e.g., Rauma, Gävle, Hamburg
4	North America	e.g., Long Beach/LA, NY
5	South America	e.g., Valparaiso, Buenos Aires
6	No mention	No reference to existing port
Objective		
1	Improve digital infrastructures	e.g., Update to 5G
2	Increase collaboration	e.g., Between trucking companies
3	Increase efficiency of landside processes	e.g., Truck appointment system
4	Increase efficiency of seaside processes	e.g., Berth allocation problem
5	Increase safety and security	e.g., Increase cyber security
6	Provide an overview	Show used tools/ instruments
Categories of technologies		
1	Decision support and decision-making	e.g., Big data, artificial intelligence
2	Identification and interconnectivity	e.g., Digital platforms, IoT
3	Seamless information flow	e.g., Port community systems, ICT
4	Automation, robots and new production technology	e.g., Blockchain, automation, robotics

decisions of the respective authors more clearly and to increase the comparability of the among each other.

In the first category, the applied research methodology was analyzed. A total of six approaches were identified. A *case study* analyzes the strengths and weaknesses of existing systems and, if necessary, transfers them to a system to be planned. *Empirical studies* use structured surveys and interviews to test the researchers' hypotheses. *Literature reviews* are conducted to provide a comprehensive overview of existing work on a topic. In *scientific modeling* simulation studies and heuristics algorithms are considered. In a simulation study, systems characterized by high stochasticity are examined and the influences of the various parameters are evaluated. Heuristic algorithms are used to find good solutions to mathematical problems when an exact solution is not possible. All other procedures were grouped under *other*.

In the next category, the application field to which the publications refer is recorded. Four use cases are distinguished based on their focus point. Publications were assigned to the *seaport* item if their focus is on cross-stakeholder systems in a seaport. These include, for example, systems to improve transport in the port through increased stakeholder exchange. The focus of the publications for *terminal landside/transport* can be, on the one hand, on the landside processes at the terminal and, on the other hand, on the transports to the hinterland connected to it. The same applies to *terminal seaside/shipping*, where publications are listed that focus on the handling of ships at the terminal or on seaborne transport. The last item is selected if the entire *supply chain* or larger parts of it are considered in the publication.

In the subsequent category, those continents whose digitization solutions have been more extensively analyzed or adapted are noted. Antarctica and Australia are not listed here because there were no publications relating to these continents in this search. The large number of different approaches suggests that they should also be classified according to their objectives. Six characteristics are assigned to the category goals. These objections are to improve the digital infrastructures in the port, to increase the collaboration between different port actors, to increase the efficiency of landside processes, to increase the efficiency of seaside processes, to increase safety and security in the port and in shipping, and to provide an overview.

Since these goals can be achieved in different ways, the last category focusses on the technologies used in the digitalization process. These have been arrayed into four groups, following Bastug et al. (2020) based on Strandhagen et al. (2017), to provide a simpler overview. While these groups have originally been designed for technologies in factories, they can also be applied to port systems. Digitalization can especially help with *decision support and decision-making* by automatically collecting and analyzing data from processes and products. The technologies used for *identification and interconnectivity* have the potential to increase the efficiency and service level in maritime logistics as well as in factories. A *seamless information flow* will increase the preciseness of planning processes and enable decisions based on real-time information. The group of *automation, robots, and new production technology* refers to enhanced application of highly automated tools and robots in the traditional work environment as well as for new task.

Table 2 Classified publications

	Research methodology						Applicat. field				Continents considered						Objective						Categor. of tech-nology			
Author, Year	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4
Ahokangas et al., 2021		■					■						■				■							■	■	
Zanne et al., 2021		■		■				■					■						■					■	■	■
Grivanova et al., 2021		■		■			■					■										■		■		■
Senarak, 2021		■	■				■	■	■			■									■				■	
Gonzalez et al., 2021		■								■			■				■	■					■		■	
Bour et al., 2021			■							■						■					■				■	
Bottalico, 2021				■						■			■									■			■	■
Inkinen et al., 2021		■	■			■	■						■									■	■	■	■	■
Bouklata and Bensfia., 2020			■				■			■	■								■	■		■		■	■	■
Tsiulin et al., 2020			■				■			■			■									■			■	■
Kapidani et al., 2020						■	■						■				■	■							■	
Torlak et al., 2020		■					■						■				■								■	
Guo et al., 2020					■		■			■			■						■	■				■		
Senarak, 2020			■	■			■					■						■							■	
Di Vaio and Varriale., 2020		■					■			■			■				■							■		
Marila et al., 2020	■								■				■							■				■		
Ahonen et al., 2020	■						■						■									■	■		■	■
Bastug et al., 2020				■			■									■						■	■	■	■	■
Henesey et al., 2020					■		■		■				■							■			■	■		■
Nellen et al., 2020				■			■									■						■				■
Jović et al., 2020				■			■									■						■		■		
Agatić and Kolanović., 2020				■			■					■	■	■	■							■	■	■	■	■
Koroleva et al., 2019		■					■					■							■	■				■	■	■
Vairetti et al., 2019			■				■								■		■	■						■	■	
Yang, 2019			■							■						■				■						■
Zerbino et al., 2019		■				■	■						■				■	■					■		■	
Inkinen et al., 2019			■				■						■				■						■	■	■	■
Jovic et al., 2019a		■					■						■									■			■	
Jovic et al., 2019b		■					■						■								■			■		
Sanchez-G. et al., 2019				■			■		■							■						■	■	■	■	■
Fedi et al., 2019			■	■			■									■					■				■	
Hafizon et al., 2019		■					■					■					■									■
Lesniewska et al., 2019		■					■					■	■								■				■	
Heuermann et al., 2018						■			■				■							■				■	■	
Heilig et al., 2017a				■				■		■			■					■	■					■		
Heilig et al., 2017b					■			■		■			■						■				■	■		
Karlsson et al., 2015	■									■			■				■	■								■

The specific items of each category were developed during the analysis and not beforehand. Therefore, it must be noted that possible values that do not occur in the papers examined must also be identified. Furthermore, this procedure means that each proficiency has occurred at least once in the relevant publications. The results of the classification are shown in Table 2. A box filled in with gray color indicates that the corresponding of a respective characteristic. Since there are several characteristics in each category and more than one characteristic may be selected, the sum of the number of publications may exceed the total number of mentions by a considerable margin. The detailed analysis of the results, their dependencies as well as promising future research and development trends will be presented in the next Section.

4.3 Analysis

The following section analyzes the classification scheme, focusing first on the individual aspects in order of their mentioning in Table 1 and afterwards their combined evaluation to determine dependencies.

Figure 4 shows that a large part of the used research methods is based on case studies, empirical approaches, or literature-based reviews. A few are reviews of projects. Less than 10% of the publications use scientific modeling.

It can be assumed that scientific modeling is not always easy to apply, since port-related data are often confidential and the necessary information and data basis for such comprehensive approaches is therefore often lacking. In order to circumvent the inadequate data situation, a wide range of assumptions must be made for scientific models, which require extensive knowledge of practical processes if a high degree of realism is desired. This is usually only possible through the participation of experts from the field, who often have little time or motivation for purely scientific

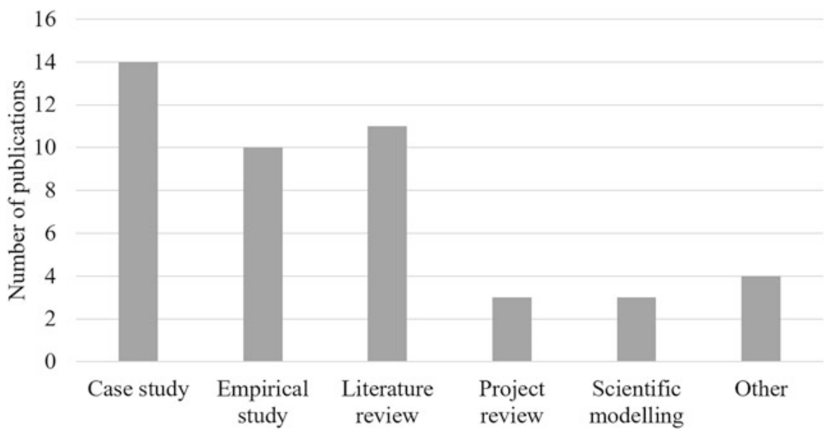


Fig. 4 Distribution of research methods

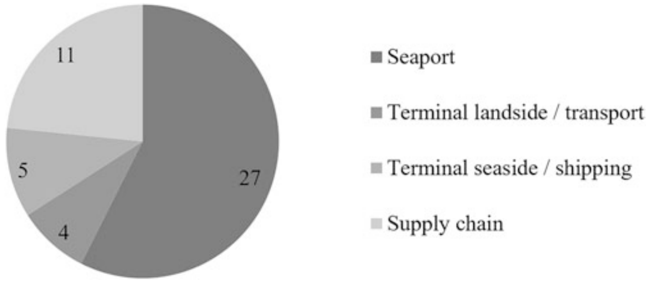
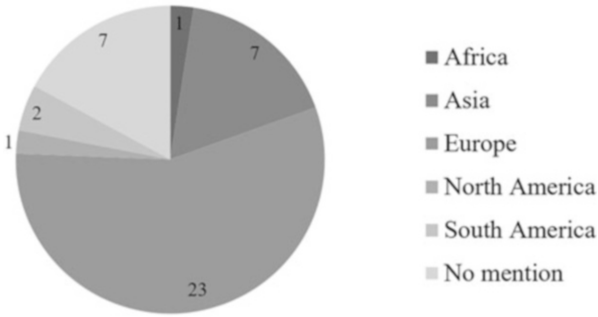


Fig. 5 Division of the application fields

Fig. 6 Continent of the port considered in the publication



investigations. Nevertheless, in recent years, there has been an increasing positive trend in practice regarding the disclosure of non-confidential or revenue-relevant data, which is likely to increase the number of scientific investigations in the future. Furthermore, it is to be expected that more studies will be based on the findings of previous studies in the future and that the data basis will thus also improve continuously.

As shown in Fig. 5, almost three quarters of the publications relate to the entire seaport (27 times). Direct reference to terminals can be found in about a quarter of the publications (nine times), whereby the focus on the landside (four times) is addressed about equally often as the waterside (five times). The maritime supply chain is considered in 11 publications.

This distribution of application fields could suggest that the focus is more on comprehensive, generalized approaches. This may be because the optimization of terminal processes is often driven by the terminal operators themselves, with the necessary (confidential) information base, rather than shared with the wider public. This result also depends on the defined search terms. By focusing on the term "port," publications that directly contain this term may have been clearly preferred in the search. Building on this study, further analyses would have to be carried out to examine the various players in the port and maritime transport chain and the frequency with which they are mentioned in scientific publications.

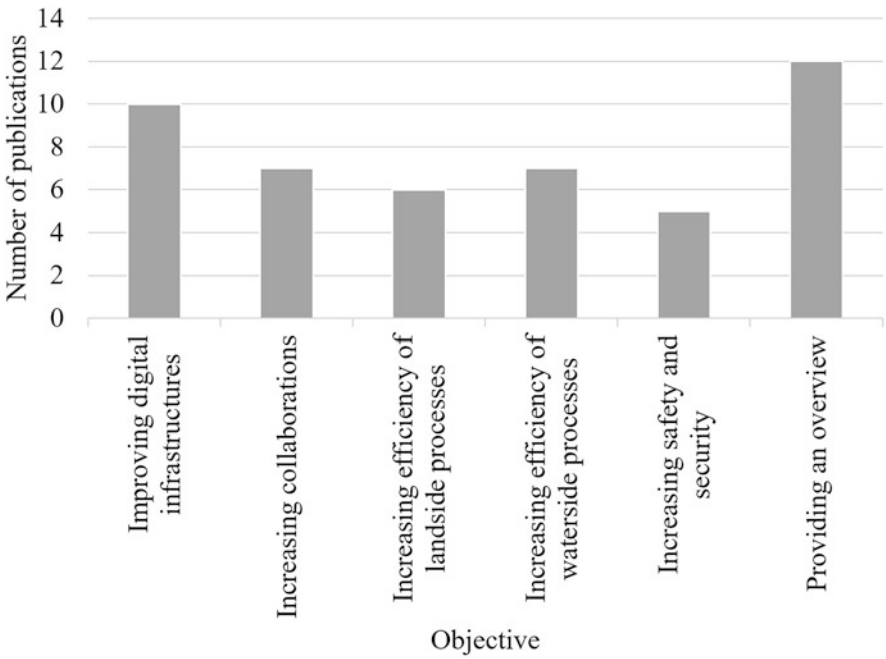


Fig. 7 Objectives (multiple selection possible)

European ports are considered in about three quarters of the publications (see Fig. 6). The focus is more often on Scandinavian ports and ports in the North Range than on other European ports. The figure also shows that only seven publications deal with ports in Asia, three in the Americas and one in Africa. Seven of the publications identified do not explicitly refer to a region.

This distribution can be partly explained by the pronounced competition between ports in Europe and in Asia. In addition to the costs of handling, in particular short berthing times, and the connection to the hinterland, a high quality of handling and additional services are also decisive. All these factors are known to be influenced by introducing and optimizing digitalization solutions and methods. Furthermore, in Europe, there is only very limited expansion space in ports, which significantly increases the need to enhance efficiency through digitalization methods. This can be done by reducing the dwell time of the transport goods at the terminals or other logistics companies by increasing the transparency throughout the supply chain, e.g. by introducing a truck appointment system or using digital platforms. This also has a positive impact on the efficiency of the processes at the companies and therefore reduces costs as well as emissions, which are highly important factors in maritime logistics. For future research, it would still be necessary to check whether other synonyms for digitalization are used outside of Europe and whether further publications can be found for the respective continents.

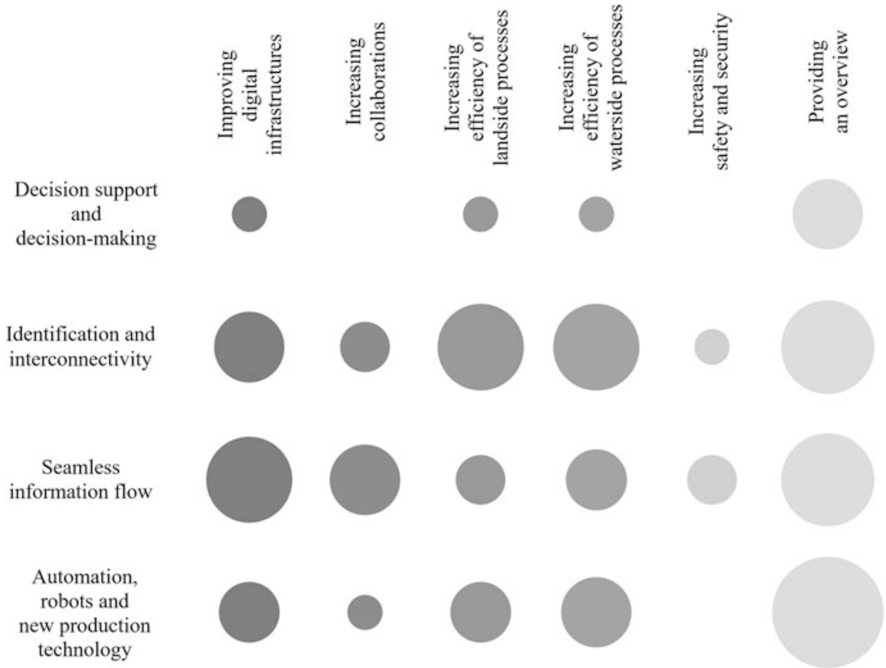


Fig. 8 Relationship between the categories of the approaches/technologies and the objectives

Figure 7 illustrates that about one third of the identified publications give an overview of different applications. With ten mentions, the general improvement of the digital infrastructure is also a frequent focus, whereby half of these publications naming the improvement of collaboration as a supplementary goal. Five publications are mainly aimed at increasing safety and security, whereby this is always selected as the sole research objective.

The fact that there are so many overview papers shows that there may still be a need for fundamental overviews before the beginning of works that look deeply into the subject. This might be due to the wide range of technologies and approaches that are far from being fully exploited in the maritime environment. An analysis of the distribution of other objectives shows that, on the one hand, the creation of a forward-looking digital environment is still the focus of many publications, often in connection with safety and security-related issues. On the other hand, more specific approaches to improving the process of the digital infrastructure in the port and along the maritime supply chain as well as at the terminals' interfaces are considered highly relevant.

The bubble grid graphic in Fig. 8 illustrates the relationship between the objectives of the publications and the overarching categories of the approaches/technologies under consideration. The size of the spheres shows the number of mentions of

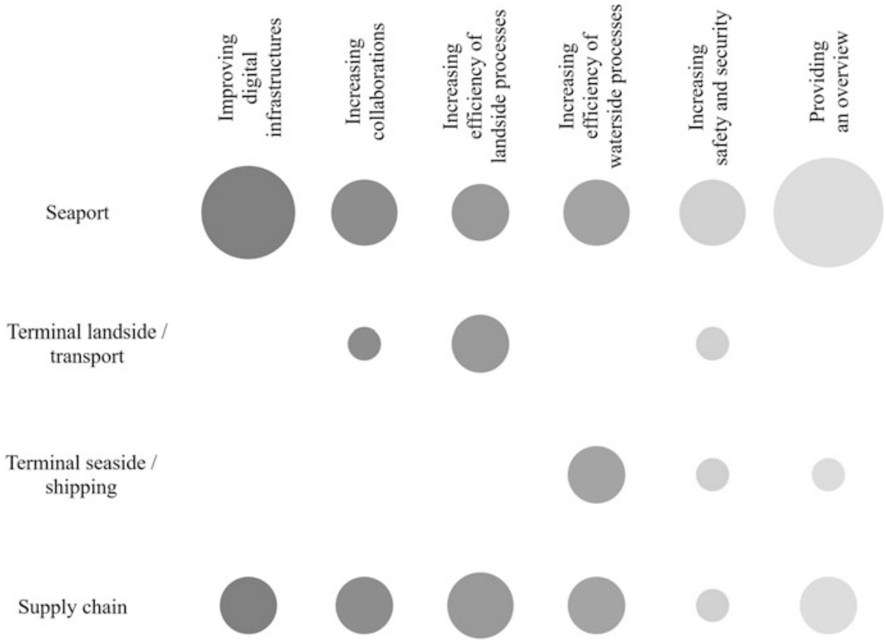


Fig. 9 Relationship between the application field and the objectives

technologies or approaches from the four categories in publications that have been assigned to the different objectives.

The number of publications providing an overview of the topic area is distributed fairly evenly across the four technology categories, with a somewhat smaller amount of publications dealing with decision support. The field of decision support is quite sparsely represented and publications dealing with cooperation along the maritime transport chain or with increasing safety could not be found at all. This can possibly be related to the already mentioned novelty of the topic field. This implies that especially the feasibility of possible approaches and technologies is investigated and the direct implementation in the companies is neglected so far. This assumption is supported by the fact that many publications deal with the improvement of the digital infrastructure for the creation of a continuous information flow and with the interconnectivity of land-based and water-based processes. Overall, very few publications deal with increasing cooperation and security along the maritime transport chain. Here, too, there is still potential to be seen in the area of decision support and automation.

Figure 9 compares the application fields of digitalization with the stated objectives of the publications.

In this figure, it becomes clear that all defined goals are considered relatively evenly by the publications examined, both when considering the overall port system and the supply chain. For the seaport, the goals of digital infrastructure and overview are somewhat more pronounced. For the supply chain, safety and security issues are examined slightly less frequently than the rest. For landside handling and related transportation, collaboration and safety and security are explored in addition to process improvement itself. Analyses of infrastructure and the presentation of an overview have been entirely lacking. In the case of waterside handling and shipping, in addition to the handling processes, especially issues of safety and security and the presentation of an overview are pursued in the publications. Here it is noticeable that neither the cooperation nor the improvement of the digital infrastructure is examined. From this work, there is a dedicated research need for the requirements, technologies and approaches and possibilities of digitalization for the individual application fields. Even though digitization is a topic that should link the different application areas, the individual challenges should not be neglected but overcome by integrated solutions. A generalization of the issue and a cross-industry and cross-stakeholder solution seems to make only limited sense at this early stage.

5 Conclusion and Outlook

The COVID-19 pandemic has shown the strength and necessity of digitalization in an increasingly connected world. The technologies and methods of digitalization can help companies in maritime logistics systems not only to stay operable in a crisis but also to become more competitive by reducing costs, increasing efficiency and meeting customer requirements, such as low emissions. Nevertheless, due to the diversity of different companies and company sizes, there are very large discrepancies in the industry when it comes to the state of digitalization. This results in challenges for the implementation of cross-company systems.

The state of research is also not very uniform with regard to several parameters. Many publications merely provide an overview of the technologies and developments currently in use. Only a few publications focus on individual actors or areas of the transport chain. By focusing on large areas, however, the studies lose depth, which in turn means that the situation and challenges of the smaller players are often neglected. The step-by-step linking of individual actors seems to be a good approach to avoid this. Furthermore, the effects of the different technologies and methods need to be investigated in more detail for the different actors and the overall system to work out the potentials and risks. To do this, scientific modeling, such as simulations or mathematical models, can be used in particular.

Due to the selection of the search string and the restriction to publications in English, the literature search was strongly limited. This is particularly evident when considering the continents to which the publications refer. In further investigations this should be avoided by including additional search terms. Furthermore, the results of digitization projects from other industries can be transferred to maritime logistics systems. Production, for example, but also the healthcare sector could be used for this purpose.

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Modern Liner Shipping: Opportunities and Risks of Using the Northern Sea Route

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Abstract This chapter gives a general idea of the state of liner shipping in the Russian Federation and the prospects for using the NSR for liner shipping. Based on various Russian and foreign publications, the factors influencing the possibility and success of liner shipping in the Arctic are evaluated. The outlook for the transit of goods is not so optimistic, taking into account the fact that the market of linear container transportation is monopolized by a narrow circle of economic entities closely related to global companies and financial and industrial groups. The authors believe that the state of the linear transportation market should be the subject of constant study and control by the proper authorities of the Russian Federation and the wider business community. Taking into account the scale of activities, the combination of new and traditional technologies, the importance of the development of the region, liner shipping in the Arctic region will either become the basis for the development of the maritime transport industry and mutually beneficial international cooperation, or turn out to be another "hot" point of collision of the different sides.

1 Introduction

Federal Law of the Russian Federation of July 28, 2012, No. 132-FZ determines that the Northern Sea Route is a historically established national transportation route of the Russian Federation. "The water area of the Northern Sea Route consists of the water area adjacent to the northern coast of the Russian Federation, covering the internal sea waters, the territorial sea, the adjoining zone and the exclusive economic zone of the Russian Federation. It is limited on the east by the maritime boundary between Russia and the United States of America and the parallel of Cape Dezhnev in Bering Strait, and on the west by the meridian of Cape Zhelaniya to the Novaya

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Zemlya archipelago, the eastern coastline of the Novaya Zemlya archipelago and the western borders of the Matochkin Shar, Kara Vorota, Yugorsky Shar straits."

Russia's sovereign right to navigation in the region was established in the sixteenth century, practically at the very beginning of Russian statehood. In the late XIX—early XX, more or less successful attempts to navigate the NSR were actively carried out by the Russian Empire, and then the Soviet Union. During the Soviet period, the transport infrastructure of the Arctic developed in accordance with the material and technical capabilities of the country, which had a clear idea of the significance of this territory for the present and future. At the same time, the Arctic has always been a place for testing the strength, maturity, and capacity of the state, society, and individuals.

On October 26, 2020, by the Decree of the President of the Russian Federation, the Strategy for the Development of the Arctic Zone and Ensuring National Security for the Period until 2035 was approved. In the document, among the peculiarities of the Arctic zone, the actual low level of transport infrastructure development is noted, as well as a high dependency of economic activity and life support of the population on the supply of fuel, food, and other necessary goods. At the same time, there is a stable geographical, historical, and economic connection of the territory with the Northern Sea Route, on which the development of the region depends (Kremlin.ru, 2020).

The Arctic zone holds utmost importance for the development of Russia and ensuring its national security. Thus, more than 80% of Russian natural gas and 17% of oil are produced in the Arctic. The continental shelf is a strategic reserve of the mineral resource base. The objects of the strategic containment forces are located in the Arctic zone as well (Kremlin.ru, 2020). All this determines the importance of regular and high-quality transport services.

Trade in the Arctic region is carried out via tramp shipping and is, in a significant part of the territory, seasonal. The composition of the fleet is extremely heterogeneous. The transport fleet used for the transportation of oil and gas is modern, complying with generally recognized operating standards and environmental requirements. General cargo ships are old and obsolete. Cellular container vessels, Ro-Ro ships, and other specialized vessels suitable for liner shipping are virtually absent.

The development strategy includes steps aimed at the construction of cargo ships for merchant shipping, and cargo-passenger ships for transportation between sea and river ports of the territory (Kremlin.ru, 2020).

One of the most important steps toward the development of this area is «the construction of hub ports and the creation of a Russian container operator in order to ensure international and coastal shipping in the water area of the Northern Sea Route» (Kremlin.ru, 2020).

The implementation of the Strategy involves three stages. In terms of merchant shipping, the first stage is about subsidizing local transport in the Arctic (Kremlin.ru, 2020); at the second stage (2025–2030), it is planned to "start the construction of port hubs for the transshipment of international container cargo"; at the third stage (2031–2035) it is planned to "form on the basis of the Northern Sea Route, a competitive national transport communication in the world market" and "to complete the construction of ports for transshipment of international container cargo" (Kremlin.ru, 2020).

The target indicators of the Strategy regulate the amount of cargo transportation along the water area of the Northern Sea Route in million tons: base value (2019)—31.5, including transit—0.7; 2030—90.0, including transit—2.0; 2035—130.0, including transit—10.0. The target value for the amount of transit traffic in 2024 is 1.0 million tons. Transit also occupies an insignificant share in transportation along the NSR (about 2% in 2019–2030, up to 7.7% by 2035) (Kremlin.ru, 2020).

If we assume that half of the goods in transit will be transported in containers, and the average container load is 9 tons for TEU (20′ foot equivalent), we are talking about 110,000 TEU in 2024, 220,000 TEU in 2030, and 1,100,000 TEU in 2035. For comparison, the total containerized trade on the Asia-Europe route in 2019 was 24.7 million TEU, in 2020—23.0 million TEU (UNCTAD, 2020). Thus, in terms of target indicators, we are talking about an insignificant number of transit containers—up to 0.5% in the short term, up to 5% in 2035, with the unlikely preservation of the existing amount of traffic on the Asia-Europe route. This is an insignificant amount, even for one of the trades.

Container shipping is associated with liner shipping. Regardless of the amount of transit cargo, the Strategy touches upon topics that are of fundamental importance for the development of the Russian merchant marine fleet. This is the creation of a national sea line container operator, the commissioning of a modern specialized port, the construction of container terminals in the Arctic region (as well as the connection of these terminals with other ports), the development of regular transport support in the water area of the Northern Sea Route.

In this chapter, we will focus on the problems of modern liner shipping, the possibilities, and risks of this form of navigation, including ones that may occur during the work required by the Strategy for the Development of the Arctic Zone.

2 The Modern Definition of Liner Shipping

The widespread prevalence of liner shipping gives the impression of the simplicity and availability of this form of shipping. But this simplicity is illusory. The very definition of a sea line or sea liner transportation contains more questions than answers. According to Federal Law No. 282-FZ ("On Amendments to the Merchant Shipping Code of the Russian Federation and Articles 17 and 19 of the Federal Law "On Seaports in the Russian Federation and on Amendments to Certain Legislative Acts of the Russian Federation" dated 03.07.2016 No. 282- FZ) "a sea line is a communication between seaports, through which the carriage of goods and (or) passengers and their luggage by ships is carried out on a regular basis according to a schedule."

Federal Law indicates that the only characteristic feature of liner shipping is transportation between the ports carried out on the schedule.

However, the UN Convention on a Code of Conduct for Liner Conferences (United Nations, 1975) and UNCTAD Recommendations on the Use of the Code (UNCTAD Secretariat, 1986) gave a broader definition of liner shipping. According to the convention, line carriers:

1. Provide service in a specific direction of transportation with a regularity and frequency of trips that are necessary for the clientele of sea transport for the normal implementation of their activities
2. Provide guaranteed services to shippers who send cargo frequently and in small batches and to shippers who cannot ensure the full load of the vessel
3. Ensure the availability of the necessary conditions for loading, transporting, and unloading goods of various assortments
4. Take over the duties of a public carrier in places where it is required by law or custom. Where such responsibilities do not exist, they meet the general expectation of the quality of service. It is assumed that, after the announcement of information on planned voyages from specific ports, all proposals for the carriage of goods will be accepted in the order of receipt of applications, regardless of the extent to which this cargo suits the carrier or is of interest to him.

Thus, the definition of the line given in the Federal Law only partially repeats the one in the convention. At the same time, the convention speaks of such important points as the needs of the clientele of sea lines, the provision of guaranteed services by the carrier to the customers, providing them with conditions for loading and unloading at ports, and finally, compliance with the principle of a "public" carrier.

The convention is not an empty declaration. It appeared in the early 1970s of the twentieth century as a result of the painstaking work of specialists in the field of maritime liner shipping, who summarized the experience of centuries of development of the industry and took into account the interests of different parties—carriers and clientele of maritime transport, major maritime powers and developing countries, which gained independence shortly before the start of work on the convention. The convention took into account the interests of the largest liner carriers and their associations, as well as outsiders, companies from socialist countries, and the young fleet of new states. The convention was initially seen as a practical document. Therefore, the points surrounding the definition of the sea line in the convention are not accidental.

In the convention, special attention is paid to the fulfillment of the duties of a public carrier by the line. A public carrier is a carrier that provides transport services to clients at affordable prices and without discrimination against individual cargo owners. The public carrier is obliged to provide services on equal terms to any shipper. The carrier does not have the right to choose the consignors and must accept for transportation, within the technical capabilities and cargo capacity of the vessel, any legal cargo from all consignors, without making a distinction between them (Rusinov et al., 2016a).

We drew attention to a significant difference in the definitions of the line given in the Federal Law and the UN Convention, which in itself is a risk. Any activity is based on a regulatory framework. Normative acts must be clear, unambiguous, and correspond to the occurring tasks. But there is a reason for this discrepancy. The "right" convention conflicts with the "wrong" reality. In fact, the public carrier principle is widely forgotten, customers do not have equal rights, tariffs do not work as before, and discrimination against individual shippers, cargo, or ports has become the norm. As a result, the movement according to the schedule remained the only obvious and effective manifestation of linearity, taken from the past, which is reflected in the Federal Law. At the same time, carriers in many cases are not responsible for observing the transit time, they can change the dates of shipment and arrival of goods.

In order for the regulatory and legal framework of liner shipping in the Russian Federation to become modern, all the fundamental changes that have taken place since 1991 must be taken into account, including the priority of individual agreements between carriers and clientele (service contracts) over tariffs, the termination of the activities of the majority conferences of line carriers and the emergence of alliances, an unprecedented level of market consolidation, fundamentally new technical and technological capabilities, etc.

2.1 Tramp and Liner Shipping

Sea trade does not imply a wide variety of forms of shipping. Back at the end of the nineteenth century, the Austrian scientist and theorist of transport science Emil Sax pointed out that "a shipping company either offers its services for voyages between certain ports at the declared duration of flights and usually with an exact timetable, or organizes the transportation of various goods according to different directions, concluding deals separately in each specific case." "The first system is called liner shipping, and the second is called free or tramp. The use of each of them is associated with special considerations, each of them has its own advantages and disadvantages, each presents an entrepreneur with different requirements" (Sax, 1925).

Unlike tramp shipping, in which the loading of a vessel is the result of not only professional knowledge and experience but also successful circumstances, liner shipping does not depend on chance. Therefore, "a kind of exploitation requires a perfect organization of management ... An enterprise cannot be content with a passive position in relation to the freight market, but must strive to influence it ... In its business considerations, it must reckon with the future in order to determine what value will be have separate lines over time. Business foresight and foresight are of particular importance and a wide field of application in liner shipping, and large companies are the most suitable form for such enterprises" (Sax, 1925).

Thus, Emil Sachs noted among the fundamental features of liner shipping the need for a perfect organization of large enterprises that actively influence the market.

There is no point in talking about which is more important or more difficult—tramp or liner shipping. The important thing is that they are different—from the equipment of the fleet to the routine work of specialists. The difference is already visible in the fact that for tramp shipping, the main form of the contract of carriage by sea is considered to be a charter, and for liner shipping, a bill of lading, although here, too, liner shipping once again misleads us with its seeming simplicity, because in reality things are more complicated and most of the goods are already transported under individual service contracts.

It is important to note that shipping in the Soviet and then in the Russian Arctic was and remains tramp shipping. Since tramp and liner shipping are not identical, liner shipping in the Arctic must be considered virtually from scratch in all aspects. This in itself is a significant risk. The third form of shipping can be called "industrial" shipping. Some large enterprises have constant transport needs, satisfying which requires using their own fleet, optimized for solving specific tasks. If we consider the movement of ships, then in many cases "industrial" shipping meets the linearity criteria specified in the Federal Law. However, such companies, as a rule, do not provide services to a wide range of customers and, moreover, do not perform the functions of a public carrier, which is quite natural. As an example for the Arctic, one can name the well-equipped and successfully operating Murmansk transport branch of PJSC MMC Norilsk Nickel.

The traditional liner shipping approach also allows ships to move between declared ports without strict adherence to timetables, with calls at optional ports. This form of liner shipping continues today in the multipurpose ship segment and, in some cases, versatile vessels equipped with heavy cranes.

In the Arctic, the movement of ships strictly on schedule is associated with obvious risks and unnecessary costs. Therefore, it is advisable to consider liner shipping not only and not so much as transportation on fixed dates (liner service), but as regular shipping from successive voyages with pre-announced expected start dates of the voyage (semi-liner service). Ultimately, "always on time or we will return the money" for any person dealing with sea and cargo is just an empty advertising slogan, as opposed to "safety first," which is an axiom. At the same time, many modern production cycles involve the movement of goods and raw materials on time, without creating stocks. For Russia, with its colossal distances, different climatic conditions, and the influence of administrative factors, for example, customs clearance, the just-in-time principle on delivery times is in some cases not feasible, in others, the impossibility of its implementation is explained by "philosophical" categories that hide various subjective problems.

2.2 Liner Shipping and the Needs of the State

Liner shipping cannot exist without a permanent cargo base. In the event that the cargo base is not defined or is not sufficiently predictable and controlled over a long period of time, liner shipping can only exist as an enterprise that generates regular losses.

Sometimes the activity of the lines are related to the needs of the state. For example, they provide communication with remote (overseas) territories, perform some social functions, are among the elements of an indirect action strategy, etc. In such cases, the commercial component is not a priority, and the government directs funds to support shipping companies, orders, and pays for their services.

The legal framework of western countries, primarily the United States, believes that such work should be performed by controlled companies, whose activities contradict "market" principles, and therefore should be limited by law (United States Congress, 1984).

However, initially, all liner shipping performed similar functions—it connected the metropolises and colonies, ensured the delivery of correspondence, transported emigrants leaving European countries, of which in the first century of liner shipping there were more than 50 million people. For them, sea transport was the only way to cross the ocean. Everywhere liner shipping was subsidized "per mile traveled," subject to the conditions—the frequency of voyages, transit time, compliance with the technical and cargo characteristics of ships, etc.

In addition to the above functions, the liner fleet has always been viewed as one of the key elements of the mobilization system, including the deployment of rapid reaction forces. So, during World War I, the total number of servicemen transported by the ships of the merchant fleet of the Entente countries amounted to about 23 million people (Makedon, 1940).

To illustrate the importance of this aspect of liner shipping, let us dwell on one not that well-known historical event. In March 1918, ten ships of the German liner companies Hamburg-Sued and Norddeutscher Lloyd (now Hapag-Lloyd) were used to deliver General von der Goltz's expeditionary force to Finland. The presence of German troops predetermined the quick victory of the bourgeois Finnish government in the civil war, and the German merchant fleet was a direct participant in the events that influenced the future of Russia and Finland (Makedon, 1940).

The strategy for the development of the Arctic zone of the Russian Federation and ensuring national security for the period of 2035 takes into account the importance of the merchant marine fleet in the implementation of mobilization measures and (or) transportation of military cargo in peacetime. In this aspect, the potential line fleet of the Russian Federation is no different from the existing line fleet of the maritime powers.

Thus, the tasks of the merchant marine fleet in the development of the economy of the Arctic region are in many respects similar to those that were originally solved by the liner ships of British, German, French, Dutch enterprises, as well as the Russian Steam Navigation and Trading Company (ROPiT) and the Voluntary Fleet in the "development" of new territories. But what used to be natural will now be assessed differently. It is likely that the national shipping company will become "controlled" and insufficiently marketable in the assessments of competitors. This will restrict the company's access to certain markets and to conventional financing methods. Considering the risks of liner shipping when working in the Arctic, it is necessary to remember the difficulties faced by the Chinese national carrier China Ocean Shipping Company, Limited (COSCO) and the Iranian national carrier Islamic Republic of Iran Shipping Lines (IRISL) especially.

2.3 Liner Shipping and the Global Economy

When embarking on the thorny path of liner shipping development, one must have an idea of the disposition of the parties. Seafaring has always been the "wings" of international trade. Liner shipping and, above all, liner container shipping, acquired particular importance at the end of the twentieth century. In today's world, "successfully operating and cost-effective maritime transport ensures the economic development and prosperity of countries. The competitiveness of trade largely depends on the availability of international shipping services and the port network." UNCTAD argues that "the country's ability to carry out its containerized foreign trade using sea lines is more important for trade costs than indicators of "logistics organization," "start-up costs for setting up a business enterprise," and "tariff reduction "combined" (UNCTAD, 2020).

American political scientist Samuel Huntington unexpectedly defines the place of liner shipping in the modern world: "There are two pictures that describe the relationship between the power of the West and other civilizations. The first is the overwhelming, triumphant, almost absolute power of the West . . . With the collapse of the Soviet Union, the only serious competitor of the West disappeared, and as a result, the appearance of this world is determined by the goals, priorities and interests of the main European nations . . . The West is the only civilization that has significant interests in all others civilizations or regions, as well as the ability to influence their politics, economy and security. Societies of other civilizations usually require Western help to achieve their goals and protect their interests. Western nations own and operate the international banking system, control all hard currencies, are the world's major consumers, play the role of moral leader for many societies, engage in cutting edge technical research, dominate the aerospace industry, dominate communications, dominate arms production, they are capable on a major military intervention and control the sea lines" (Huntington, 2011).

Probably, Samuel Huntington did not mean liner shipping, but sea trade in general, this does not change the core statement. The merchant marine fleet is one of the key elements in influencing the economy on a global scale.

For liner shipping, what matters is not an armada of container ships with a capacity of 20,000 TEU, but a system that is deployed differently in different countries due to "national" characteristics, but has common features and is called a modern management model.

For a better understanding of the essence and scale of the phenomenon, consider COSCO Shipping. The development of the Chinese merchant marine fleet can be divided into three stages, coinciding in time with the stages of development of the PRC—from 1949 to 1977 (from education to the end of the "cultural revolution"), from 1978 to 2001 (the period of the "open door" policy), from 2001 to the present (the period of development after accession to the WTO). The modernization of the system of operational activities of the maritime fleet took place in the period from 1991 to 1995. Since 1995, the activities of Chinese shipping enterprises have been carried out on the basis of a modern model. In 1998, the state formally renounced direct participation in the activities of COSCO. In 2016, the assets of the largest companies, COSCO and China Shipping, were merged.

As a result, an additional dominant has emerged in world maritime trade. Now COSCO Shipping is a high-tech industrial cluster that includes more than ten large companies, each of which is one of the world leaders in its market segment. When creating the cluster, the 6 + 1 scheme was implemented—navigation, sea transportation, shipbuilding, logistics, finance, real estate, IT-technologies. COSCO Shipping Lines are the core element of COSCO Shipping, while remaining one of several elements.

The following figures indicate the scale of the activity. In addition to COSCO Shipping Lines, by the beginning of 2019, when the program was mainly implemented, COSCO Shipping included: COSCO Shipping Bulk (the world's largest fleet for the transport of dry bulk and bulk cargo—more than 380 ships with a deadweight of about 35 million tons), COSCO Shipping Energy Transportation (about 120 tankers with a deadweight of 18 million tons), COSCO Shipping Specialized Carriers (more than 150 specialized dry cargo vessels, including vessels for the transportation of general, oversized, heavy cargo, Ro-Ro vessels, Ro-Flow vessels, etc.), COSCO Shipping Ports (46 container terminals in the PRC and other countries with a market share of over 11%), COSCO Shipping Heavy Industry (13 shipyards and more than 20 service firms capable of providing annual construction and repair of up to 1500 ships), as well as companies responsible for finance, insurance, education and industry science, logistics, real estate, and IT technology.

The assets, which were already of considerable value, were structured and modernized. The state spent about US $8.7 billion on activities related to the merger. At the same time, the consolidation of Chinese shipping assets was not a challenge to the existing model in the world but followed the logic of the development of the world fleet. This story is striking not only by the achieved result, but by the fact that in 1949 the sea merchant fleet in the PRC did not exist at all, and in 1995 no one considered the PRC fleet as a more or less significant participant in maritime trade.

At the same time, COSCO Shipping Lines is only the fourth among the largest liner container carriers (Alphaliner, 2020). Other companies—Maersk Line, Mediterranean Shipping Company, CMA CGM, Hapag-Lloyd, ONE Ocean Network Express, Evergreen Marine Corporation—each came to the present state in their own way and at different times. Almost all companies are "high-tech industrial clusters" by analogy with COSCO.

3 Russian Merchant Marine Fleet, Liner Shipping, Separately

Unfortunately, the Soviet merchant fleet, being one of the recognized leaders of world sea trade for at least two decades (1970–1980s) in terms of capabilities and authority, "dropped out of the competition" in 1991. After the collapse of the Soviet

Union, the once large shipping enterprises, combining the fleet, port, ship repair, science and education, and much more, were divided into companies of little importance on a global scale, some of which were initially unviable, and the rest, in the overwhelming majority of cases, were doomed to a miserable existence. In our country, decentralization processes were taking place opposite to the tendencies mentioned above. What is the result? It is paradoxical. According to the information of the United Nations Conference on Trade and Development (UNCTAD), for 2020 the sea merchant fleet of the Russian Federation consists of 1403 ships flying the national flag, 339 ships flying the flags of foreign states. The total number of vessels is 1742, the total deadweight is 23,105,563 tons, including 64.11% under a foreign flag. Vessels flying a foreign flag make up one-fifth of the total, while their deadweight is two-thirds of the total.

In the general list of the world merchant fleet, the fleet of the Russian Federation takes twentieth place—1.13% of the total deadweight (UNCTAD, 2020). At the same time, quantitatively, the merchant fleet is not inferior to the deadweight of the USSR merchant fleet during the period of its maximum development, but its share in the world fleet is significantly lower than before, and there is a critical imbalance in the specialization of ships.

Indicative is the estimated cost of the fleet by types of ships (in millions of dollars): ships for the carriage of bulk and bulk cargo—246; oil tankers—3966, offshore vessels—1456, ferries and passenger ships—74; container ships—72; gas carriers—1489; ships for transportation of general cargo—1227; chemical tankers and product carriers—633; others—849; in total—10,014 (21st place in the general list of the world merchant fleet) (UNCTAD, 2020).

Thus, the most modern, large, and expensive vessels in the Russian Federation are those whose work is associated with the production and transportation of oil and gas (75% of the total cost of the fleet). Probably, the population of our country predominantly consumes oil and produces gas.

Only 2% of the total cost falls on ships for the transportation of bulk and bulk cargo. For a country that produces 4% of the steel consumed in the world, 12% of coal, and 7% of grain, this is an inexplicable phenomenon (UNCTAD, 2020).

But the real Tsushima (as synonym of a great damage) takes place in a segment of the fleet that can be used for liner shipping. These are container ships, Ro-Ro ships, ferries, and cargo-passenger ships. The cost of this fleet is less than 1.5% of the total value of the Russian merchant marine fleet ($146 million, including $72 million of the costs of all container ships) (UNCTAD, 2020). In comparison, the cost of one new 21,000 TEU standard cellular container ship in 2019 was approximately US $147 million.

In the list of sea carriers operating any vessels capable of transporting containers, not just cellular container ships, only FESCO is present among the "Russian" companies. In Alphaliner TOP100 statistics for July 2021, it ranks 51st with 13 vessels with a total container capacity of 16,146 TEU. Comparisons are inappropriate, but let us call the companies operating a fleet of more than one million TEU Maersk Line—4,185,292 TEU (17.0% of the world fleet), Mediterranean Shipping Company (MSC)—4,040,134 TEU (16.4%), CMA CGM Group—

3,031,223 TEU (12.3%), COSCO Shipping Lines—3,008,881 TEU (12.2%), Hapag-Lloyd—1,772,312 TEU (7.2%), ONE (Ocean Network Express)—1,586,396 (6.4%), Evergreen Line—1,362,385 TEU (5.5%) (Alphaliner, 2020). The container capacity of the vessels of the first company on the list is ten times greater than the capacity of the fleet of the tenth company, 100 times the thirtieth and 250 times the fiftieth. The conclusion is obvious—the Russian Federation has no liner fleet. This is a serious barrier to the development of Russian foreign trade.

We often talk about the glorious history of our country. The merchant marine is directly related to this. On January 1, 1922, the Soviet merchant fleet in all four seas consisted of only 143 steam vessels with a net tonnage of 81,996 tons. During the period from 1913 to 1922, the national merchant marine fleet lost 82.3% of the total number of steamships.

On June 13, 1922, the Labor and Defense Council issued the Regulations on the State Merchant Fleet." The general part of the Resolution says: "For the development of maritime shipping and the operation of state maritime transport facilities, State Shipping Enterprises are established under the name: "State Baltic Shipping Company" in Petrograd; State Northern Shipping Company in Arkhangelsk; "State Black Sea-Azov Shipping Company" in Odessa; "State Caspian Shipping Company" in Baku.

By the decree of the Council of People's Commissars of July 14, 1922, despite the proletarian denial of everything that was old-regime, the activities of the Volunteer Fleet, established in 1878, were restored. A decree of the Labor and Defense Council dated July 21, 1924, formalized the merger of the State Merchant Fleet, the Volunteer Fleet and Arkos (a joint British-Soviet enterprise) into a single state joint-stock company—JSC Sovtorgflot. At first, Sovtorgflot tried to simply copy, first of all, the activities of ROPiT, the largest shipping company in the Russian Empire, as well as the Volunteer Fleet and other companies, taking into account the available modest funds, but with a strong desire to return to a decent organization of the transport process. Already in 1925, JSC "Sovtorgflot" provided the operation of three lines in the Baltic Sea, 23 lines in the Black and Azov Seas, eight lines in the Far East and six lines in the White Sea, including Onego-Kemskaya (weekly waste from Arkhangelsk), Kandalaksha, Mezen, Murmansk (from Arkhangelsk every 2 weeks); Pechora (five flights for navigation from Arkhangelsk); Novaya Zemlya (two voyages per navigation from Arkhangelsk to Novaya Zemlya with calls to the islands of the Arctic Ocean) (Sovtorgflot, 1925).

How can one explain the presence of liner shipping in the country 3 years after the end of the devastating civil war and the absence of a national liner carrier in modern Russia, whose merchant fleet has surpassed the Soviet deadweight, and the amount of cargo handled in ports is constantly updating records?

4 The Modern Form of Associations of Sea Liner Carriers

Let us go back to the modern market of sea liner shipping. In 2013, the United Nations Conference on Trade and Development (UNCTAD) reported: "There are two important trends that reflect two sides of the same coin. The size of ships is increasing, but the number of companies in most markets is decreasing. This trend has serious consequences for the level of competition . . . On certain specific routes, especially on routes serving small developing countries, a decrease in the level of competition leads to the formation of oligopolistic markets" (UNCTAD, 2020).

What is the scale of this oligopoly and are the largest line companies, which we talked about above, self-sufficient?

For over 150 years liner shipping has been predominantly conference shipping. Recall that "a linear conference is a group consisting of two or more sea line carriers that provide services in a certain direction, within specified geographical boundaries, on the basis of a single or common tariff" (United Nations, 1975). Since 1983, conferences have been governed by the UN Convention on a Code of Conduct for Liner Conferences. The Code is a regulation with clearly defined positive objectives. These include the orderly expansion of world maritime trade, the development of regular and efficient linear services that meet the needs of trade, and the balance of interests of all parties (Rusinov et al., 2016b). We mentioned that in 1998, a rapid process of destruction of the conference system began. Alliances have replaced line conferences. The alliances were initially positioned as "technical" agreements of maritime liner carriers, not related to tariffs.

The United States Shipping Act (1998) should be considered the starting point for major changes in the liner shipping system. The main thesis of the US Federal Maritime Commission (FMC) is that "the decline of the traditional conference system and the emergence of shared service agreements are the main signs of the era of this law" (Federal Maritime Commission, 2001). According to FMC, carriers turned to this form of agreements in order to "achieve a significant increase in the efficiency of the fleet and expand their presence on a global scale" (Federal Maritime Commission, 2001). Alliances of sea container carriers in a short time became the main tool that ensured entry into new markets and the widespread dominance of large shipping companies. Mergers and acquisitions have been a characteristic feature of liner shipping throughout history. FMC welcomed the creation of alliances as a "healthy alternative" to takeovers: "The situation in the shipping industry is changing rapidly and becoming extremely complex. Competition among shipping companies is intensifying."

In general, but not always, consumers are demanding faster and more diverse services at extremely low prices. As a result, shipping companies are forced to develop and use innovative technologies for flexible response to customer requests, efficient organization of cargo transportation. To survive in the industry, shipping companies actively cooperate with competitors, creating various strategic alliances to reduce risks and costs, as well as to improve their competitive advantages.

In this regard, a paradigm is being formed. It lies in the fact that strategic alliances allow line carriers to obtain a number of advantages—to expand the geographical boundaries of the service market (to increase the number of ports of call and diversify delivery routes); reduce costs by sharing capital investments with partners and reducing management risks; increase market share through economies of scale; to ensure effective exchange of professional knowledge and skills within the framework of joint work.

However, considering the change in the market situation over two decades, it can be concluded that "technical" cooperation did not prevent mergers and acquisitions. The process stopped only when, on the one hand, there were practically no companies left that could become a serious target for takeover, and on the other hand, such takeovers began to contradict the national interests of the leading (for the linear market) maritime countries—the USA, Great Britain, EU, China, Taiwan, Japan, Republic of Korea, and Israel (Nelogov & Ouami, 2021).

International law, as the basis of work, open rates, and the principle of public carrier, was typical for the conferences after the adoption of the Code. In modern liner shipping, individual agreements (service contracts) between carriers and customers prevail. The existence and content of such "confidential" agreements are known to the regulators of the "maritime" countries, which makes it possible to more effectively pursue the state policy in the field of liner shipping. At the same time, references to the "weak," to the conditions proposed for the "strong" are excluded. The "me too" principle, which annoyed carriers and large cargo owners, stopped working with the development of service contracts.

The main task of the modern maritime liner shipping market is to serve the largest companies. The requirements of key customers lead to the fact that even the largest liner company is not able to provide adequate service to customers' requests only on its own. Alliances are no longer a form of cooperation aimed at streamlining operations. They have become a prerequisite for work. At the same time, "technical" conditions determine the results of the company's work. These conditions have a more significant impact on income and expenses than the agreed tariff policy.

Standard conditions, consisting of the same technical and technological solutions, excluded the competition based on the quality of services. Companies with standard ships, consuming standard raw materials and using standard procedures, are only able to deliver a standard product, that is, the same and reasonably predictable result. Standard analytical information leads to expected solutions. Standard processes fit into similar IT technologies. This fundamentally meets the requirements of global companies and is adapted to the requirements of regulators. However, the right to define standards is the essence of this "monopoly." Alliances are a kind of closed club, joining which requires a certain status and financial situation. As a result, a shipping oligopoly appears, which is in symbiosis with the largest companies in the global market, and the decisive word remains not with the transport companies, but with their clientele. Danish A.P. Moller-Maersk, which includes Maersk Line, a recognized leader in the liner industry, is ranked "only" 214 on the list of the world's largest companies in the Forbes table of rankings. COSCO Shipping (not a line, but the entire cluster)—409th place (Forbes, 2021). Probably, no one sets themself the task of being higher on this list, because it is more important to be in harmony with this market in terms of opportunities and scale of economic activity. That is, to know your place and purpose.

Contrary to the initial declaration of a "healthy alternative to mergers and acquisitions," with the emergence of alliances, the number of globally significant global container operators has decreased from two dozen to seven, currently united in three alliances:

- 2 M Alliance: Maersk Line and MSC
- Ocean Alliance: COSCO Shipping Lines, CMA CGM and Evergreen
- THE Alliance: Hapag-Lloyd, ONE and Yang Ming

Currently, the share of alliances in the main directions of container shipping reaches 95% (OECD/ITF, 2018) (Fig. 1).

The technical cooperation agreements concern only a portion of the shipping assets of these companies operating in certain geographic directions. In any case, these are hundreds of ships and millions of TEUs of container capacity. Almost all cargo on the main routes is transported by companies that are members of alliances, and the rest are transported on local lines and a commercial feeder.

This is approximately what modern liner shipping looks like. COSCO Shipping is rather an exceptional example of revolutionary development, while most of the other largest companies are the result of two centuries of evolution of the global liner fleet and its adaptation to the modern realities mentioned by Samuel Huntington. For 200 years, hundreds of well-known large liner companies from Great Britain, France, Germany, USA, Holland, Japan have been absorbed by those who are now in the top ten of the world liner transportation rating. The most illustrative example is Maersk Line (Fig. 2).

5 Conclusion

So, modern liner shipping is an instrument created in order to serve, on the one hand, and, on the other, to regulate global world trade. This instrument is subject to ownership, figuratively speaking "by inheritance" and in a broad sense, since a modern large shipping company "absorbed" the labor of those tens of thousands of enthusiasts and sailors who opened this enterprise in the first half of the nineteenth century.

In this regard, it can be assumed that transportation in transit through the Northern Sea Route will be viewed as an attempt by an outsider to "take a seat in the house" in a strange way. Moreover, this "Attila" has almost nothing that would have any significance for the existing system.

Re-routing is not a matter of saving on freight or reducing transit time, but of maintaining control over global processes. Perhaps this is the main doubt regarding the use of the Northern Sea Route for the transit of cargo in containers.

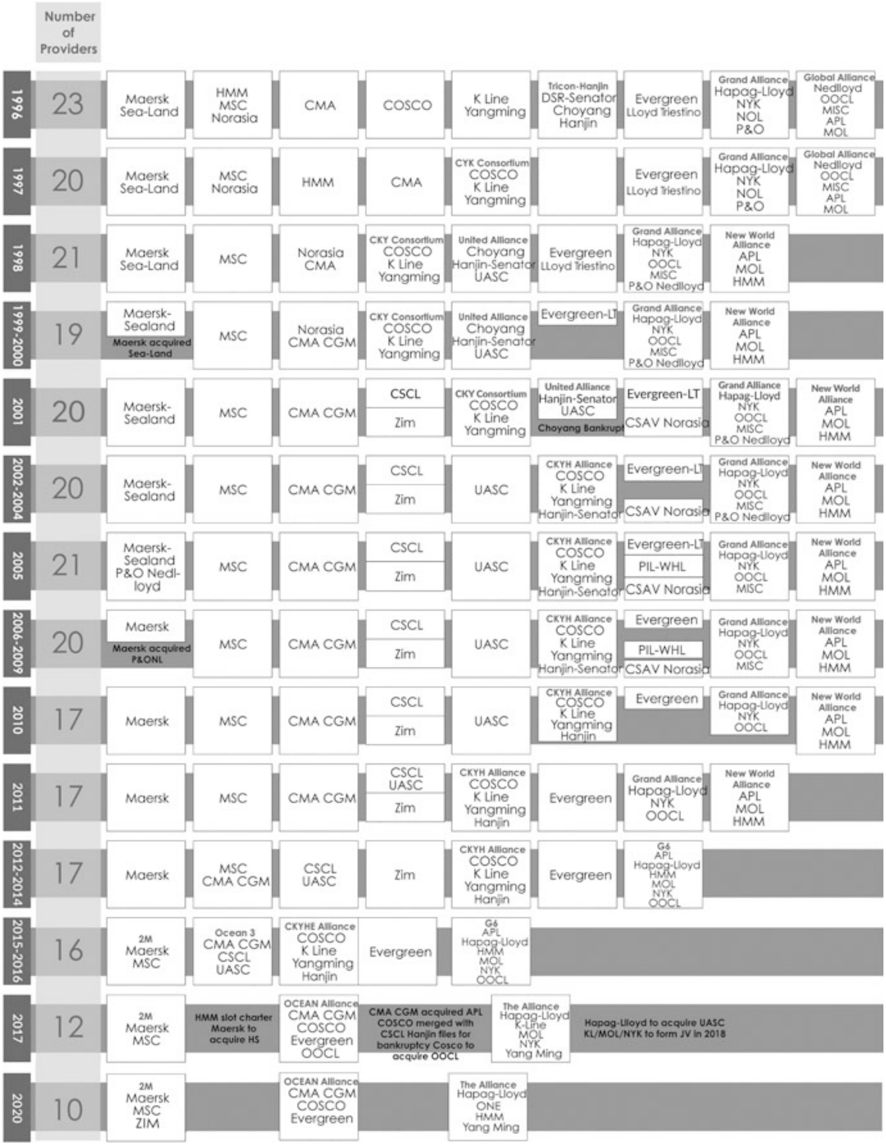

Fig. 1 Participation of global container carriers in shipping alliances. Source: PFE Express Ltd, 2019, www.pfe-express.co.uk

We have considered some of the problems and risks. These include the imperfection of the domestic regulatory framework for liner shipping, the lack of a proper fleet, experience of modern work in this market segment, narrowly utilitarian, and primitive knowledge about the cargo base.

The market as a whole is characterized by an incredible level of oligopoly, deep cooperation of the largest liner carriers with each other and with global companies,

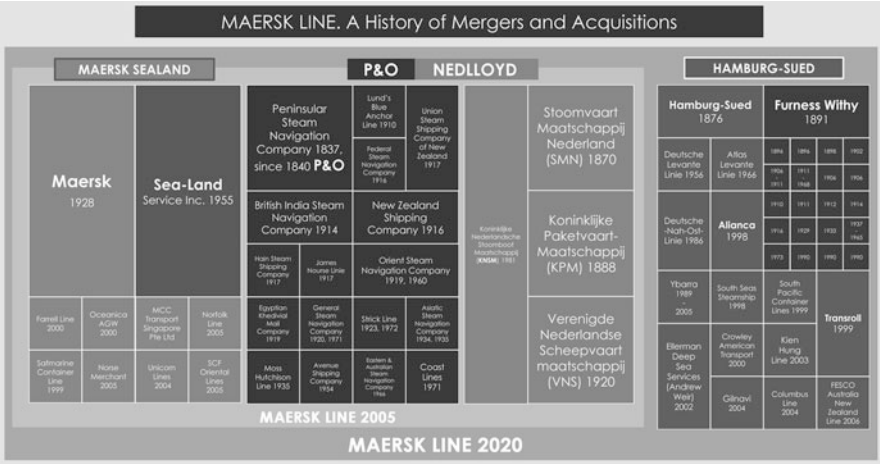

Fig. 2 Mergers and acquisitions that lead to the modern Maersk line

extremely high financial costs associated with the construction and operation of the fleet, specialized terminals, and equipment, etc., the most complex technical, technological, intellectual and organizational decisions on the verge of being able to control them.

The current state of liner transportation is the result of the transformation of the system that has developed over 200 years, including three decades that have passed since 1991 in a unipolar world and the intensive development of the global economy (Huntington, 2011).

But there must be opportunities. And they are. For example, the share of the Russian Federation accounts for about 2.5% of the world market of sea liner container transportation, if we estimate the container turnover of ports (UNCTAD, 2020). This is significantly more than the share of the all Russian merchant fleet. Thus, there is a disparity between production and consumption, which leads to large-scale (absolute) imports of liner carriers' transport services.

As mentioned above, by their nature, shipping lines are oriented toward a cargo base. The line is not created with a view to the appearance of foreign cargo. For the Russian Federation, the cargo base is millions of containers annually, sent to domestic importers and shipped by Russian exporters; this equipment and raw materials are purchased for enterprises in the Russian Federation; these are goods and products exported but not consolidated and containerized yet, etc.

It is not transit, but the goods of Russian foreign trade and internal (cabotage) transportation that should encourage the development of the national liner fleet and serve as the basis for such development. At the heart of modern liner shipping management is a thorough knowledge of the cargo base, close communication with the clientele. We should remember that foreign trade is at least a two-way process, and at present, it is even more complicated. Orders, instructions, and other good wishes can be limited to influence only a certain part of the cargo. Administration is a powerful resource that leads to positive results only when used appropriately and wisely.

The experience of the Soviet merchant fleet suggests that the cargoes of foreign charterers (CFC), traveling between foreign ports, in fact, have the same extra income as transit. It appears as a result of the domestic liner transportation system reaching a certain quality level, when the surplus maritime transport services can already be exported. For the USSR, the possibility of exporting fleet services appeared after 15 years of intensive development in favorable conditions (Vyshnepolski, 1937). At the same time, the CFC, which are not connected with Russian ports, almost immediately puts the work of the maritime fleet into a state of confrontation with the operating line carriers, with the exception of cases of mutually beneficial exchange of volumes. In this case, the merchant fleet becomes one of the first among the objects of sanctions and restrictions. In the hypocritical system of modern liner shipping, mutual benefit only comes from two strengths. Therefore, the initial development of liner shipping cannot be associated with the transit and cargo of foreign charterers, the quantity and quality of which cannot be influenced. Even more doubtful is the development of liner shipping infrastructure in the absence of its own fleet.

Positive prospects for liner shipping in the Arctic region lie in the existence of an understandable, predictable cargo base, not available to competitors for objective reasons similar to those that universally restrict “market” mechanisms. The notion of the market character of liner shipping is the same atavism as the assessment of modern relations in the economy from the position vividly stated by Thomas Joseph Dunning in the nineteenth century.

The strategy for the development of the Arctic zone of the Russian Federation and for ensuring national security for the period of 2035 indicates that the implementation of economic activities requires regular delivery of raw materials, equipment, vehicles, etc. As a result of the work of industry, a product is constantly produced in the region, which is not consumed locally but becomes a cargo that requires transportation. There appears the possibility of regular (semi-liner) shipping and the need for it. At the heart of this process is the planning of transport activities.

Probably, a national container carrier, a wider and more correct liner carrier, can successfully exist “in an Arctic vacuum.” But the restoration of domestic liner shipping is a complex task, the solution of which awaits the Baltic, Black, and Azov Seas, the Far East, and the Western Arctic. National lines can link all these basins in a form, specialization, and scale that suits the needs of the national economy.

Liner, as mentioned above, is not necessarily containerized. In our country, there is experience of successful operation of liner vessels of the Ro-Ro, Lo-Ro types, multipurpose vessels with the necessary cargo equipment, etc. Probably a line service using cellular container ships is not the best way to get started in an existing situation. Modern vessels with sufficient container capacity, a cargo ramp for loading and unloading rolling cargo, holds for transporting heavy cargo and appropriate cranes would be more appropriate.

In other words, the development of liner shipping should be considered in connection with the needs of the Russian Federation in transport support for economic activities, including foreign trade and issues of ensuring national security. This does not require blindly copying the model of work of global liner container carriers, focused on solving other problems, which does not correspond to either our capabilities or our needs. Consistent and pragmatic actions, constant study of foreign experience in the field of liner shipping and its state regulation, the formation of a "live" information base in relation to cargo and the fleet, an adequate assessment of the available resources, etc. can lead to a positive result.

A positive result can be considered the development of linear transportation in the Arctic and beyond, which will allow fulfilling the tasks formulated in the Strategy for the development of the Arctic zone of the Russian Federation and ensuring national security for the period of 2035.

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Digitalization of Global Container Shipping Lines

Igor Ilin, Svetlana Maydanova, Wolfgang Kersten, Carlos Jahn, and Jürgen Weigell

Abstract Digital technologies are currently present in nearly all activities of companies including customer interaction, competition, operations, and innovations. The maritime industry is here no exception. The current challenges force companies that are market leaders in their industry to change their strategies.

This paper covers the digital transformation of global container shipping lines. The proposed approach to the development of a global container shipping line IT-architecture could provide substantial support during the implementation of strategic initiatives based on the suggested Balanced Scorecard reference models and the multi-level matrix by comparing and linking indicators and IT-architecture models. Proposed ideas of virtual testing and experiments for IT-architecture models development correspond to the modern approach to innovation and allow rapid technology deployment and the company strategic resources adjustment in accordance with a changing environment.

1 Introduction

Maritime transport plays a significant role in global trade, serving 62% of the world's cargo turnover (Vladimirov, 2016). According to UNCTAD/RMT/2020 "the international maritime turnover in 2019 was 11.076 million tons despite a negative economic outlook and trade trends which affected the growth of maritime trade. The growth of the world GDP slowed down to 2.5%, after 3.1% in 2018 and 1.1 percentage points below the historical average of 2001–2008. Most of the total cargo

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consisted of dry cargo (4.682 million tons) but containerized cargo is also of great importance" (UNCTAD/RMT/2020).

Currently, there are several trends influencing maritime transport and trade:

- Accelerated shift in globalization patterns and supply chain designs
- Risk-management and resilience-building of supply chains
- New customer spending and behavior
- Increased need for standards and interoperability
- Use of electronic documentation
- Digitalization and cybersecurity (UNCTAD/RMT/2020)

The impact of these trends has increased significantly in the face of the Corona pandemic, forcing industry participants to adjust their strategies to the current economic environment. Companies are actively incorporating digital technologies into their operations in an effort to improve operational efficiency, increase customer experience, retain old and gain new market shares. The influence of the above trends will continue and companies need to constantly monitor emerging innovations and disruptive technologies to implement the most successful ones for maintaining a good position in the market.

Furthermore, the global environment is also changing. Companies are in a stage of digital transformation, which has five strategic domains: customer relationship, competition, data, innovations, and value creation (Rogers, 2016). Digital technologies become an effective tool to gain and maintain market share and company profitability.

In this paper, the authors propose a coherent approach to the digitalization of global container shipping lines. This approach could provide a substantial support for company strategy implementation and IT-architecture modeling. Recent research shows a gap between strategy development and strategy implementation. Furthermore, there is a lack of understanding of the impact of the IT-architecture on a company's financial results and its long-term market position. The proposed Balanced Scorecard for the global container line digital transformation helps to evaluate the impact of large-scale changes in a company's IT- architecture on its financial, customer, and operational activities and to provide benchmarks for the implementation of new technologies.

Additionally, the authors introduce a multi-level matrix to compare and link indicators and IT-architecture models of global container shipping lines. Together with the IT-projects portfolio management system and the best-in-class technology platform, it enables a company to improve its IT-architecture modeling. The authors propose the use of virtual testing and experiments which makes it possible to adjust the implementation of IT- projects depending on the expected results.

2 Strategic Approach to the Global Container Shipping Line Digital Transformation

2.1 Status Quo and Current Challenges

Liner shipping was introduced at the beginning of the nineteenth century and after several decades the British shipowners created an association of liner carriers on the route from British ports to Indian ports and vice versa, named the United Kingdom Calcutta Conference. Since this time, liner shipping had begun a worldwide expansion (Rusinov et al., 2016).

The United Nations Conference of Plenipotentiaries on a Code of Conduct for Liner Conferences (1975) clarifies shipping lines as vessel-operating carriers and divides them into national and third-country shipping lines. "A group of two or more vessel-operating carriers which provides international liner services for the carriage of cargo on a particular route or routes within specified geographical limits and which has an agreement or arrangement with respect to the provision of liner services are clarified as liner conference (conference)" (UN Conference, 1975).

The container transportation development led to a new phase of liner transportation.

Containerization is one of the factors of economic globalization, closely related to the processes of globalization and fragmentation of world production. The major volume of container transportations is carried out by a small number of liner carriers, which are divided into global carriers that perform transportation between continents, and regional carriers that provide transportation on short routes.

In this paper, the authors consider the digitalization of the global container shipping line. For the clarification of this subject, we need to address the global strategy definition.

According to Griffin and Pustey, multinational corporations, in their quest to balance the goals of global efficiency, multinational flexibility, and global learning, tend to follow one of four strategic alternatives, one of them is the global strategy. The goal of the global corporation is to create goods and services that can meet the needs of all consumers in the global market which in turn is seen as one. The global strategy implies doing business in one format in any country of the world; a global company is thus not influenced by one domestic market (Griffin & Pustey, 2004).

Since the advent of liner shipping, a number of standards, laws, and acts have been developed for its regulation. Most part of these are international agreements and conventions, but the role of national legislation should not be underestimated. Nevertheless, global container shipping lines introduce the global strategy for balancing the influence of regulatory factors and to obtain flexibility and clarity in their decision-making.

The top ten container shipping lines ranked by deployed capacity and market share are presented in Fig. 1.

The division of the liner container transportation market can be done by geography:

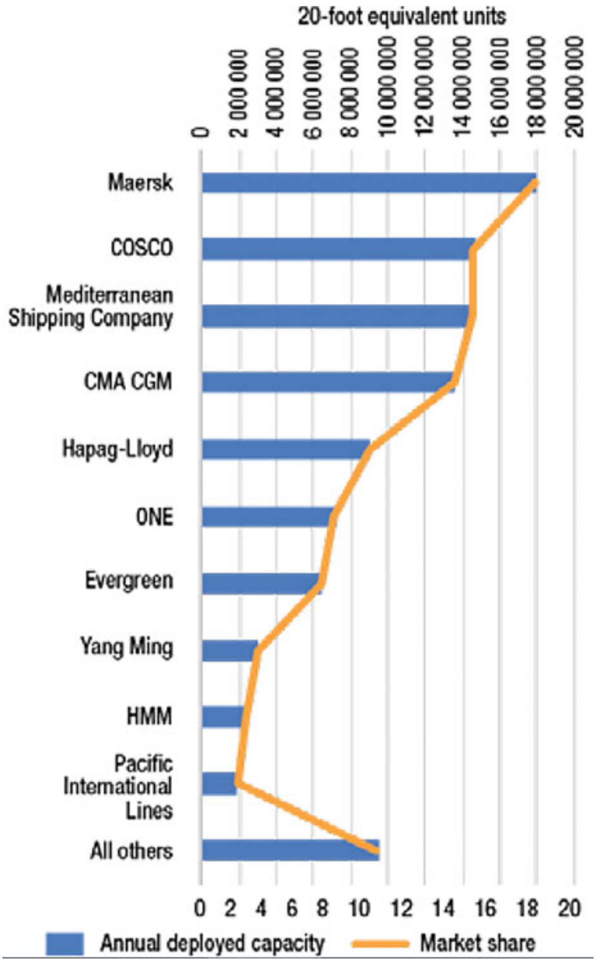

Fig. 1 Top 10 deep-sea container shipping lines, ranked by deployed capacity and market share, May 2020 (20-foot equivalent units and percentage) (UNCTAD/RMT/2020)

1. Intraregional
2. Mainlane East-West routes
3. Non-mainlane East-West routes
4. North-South routes
5. South-South routes (UNCTAD/RMT/2020)

In accordance with UNCTAD/RMT/2020, "Mainlane East–West containerized trade routes are Asia–Europe, the Trans-Pacific and the Transatlantic, which handle 39.1% of worldwide containerized trade flows. Trade on other routes, which involves greater participation from developing countries accounted for 60.9% of containerized trade. Together, intraregional trade, principally intra-Asian flows, and South–South trade represent over 39.9% of the total" (UNCTAD/RMT/2020). On the three major East–West container routes three global liner shipping alliances dominate the capacity deployed (93% of the deployed capacity): 2M, Ocean Alliance and THE Alliance. Mediterranean Shipping Company and Maersk are members of 2M. The Ocean Alliance consists of three shipping lines: CMA CGM, China Cosco Shipping, and Evergreen. “THE” Alliance was established by Hapag-Lloyd, Yang Ming, and Ocean Network Express, which is also a joint venture of Nippon Yusen Kabushiki Kaisha, Mitsui Osaka Shosen Kaisha Lines, and Kawasaki Kisen Kaisha (UNCTAD/RMT/2018). Global alliances are a tool limiting the risks and costs of individual companies. Such alliances essentially seek to maximize the benefits of operational collaboration, while retaining the full rights of companies to pursue individual policies. The members of these alliances share where appropriate all operational assets—ships, containers, terminals, equipment, and other facilities.

“In an oversupplied market, consolidation is expected to continue. Two thirds of the container ship order book capacity is accounted for by ships of over 14,000 TEUs, and only large carriers and alliances are in a position to fill these mega ships” (UNCTAD/RMT/2018).

Currently, the industry is in its maturity stage, which is characterized by a considerably smaller growth; therefore, global container shipping lines need to change their strategy. Such transition is always accompanied by challenges for market leaders and opportunities for new players (Jensen, 2017).

The following key challenges are existing in liner container shipping (Jensen, 2017):

1. The structural overcapacity will continue to have a negative impact on the markets

The outsourcing of industrial production in the 1990s led to its relocation from Europe and the USA to Asia. Containerized cargoes were shipped then out of Asia to customers in developed countries; this led to a rapid growth of the containership fleet. The problem is that the expansion of capacity did not match overall global average demand, and in 25 years nominal fleet overcapacity has exceeded the number of containers available for transportation by 110%.

To capture the market share and to save container transportation costs, global container shipping lines have bought larger vessels. Thus, in 2011 new containerships with a capacity of 18,000 TEU were introduced. Such mega-vessels allow to reduce transportation costs per unit; therefore, container shipping lines will continue to order them (Fig. 2 Germanischer Lloyd).

However, not all companies will be able to afford this, only the largest eight to ten container lines will realistically even contemplate ordering more mega-vessels. This process will be followed by a high level of vessels scrapping. By 2025 it will become increasingly normal to scrap vessels in the size range of 6000–8000 TEU, and 5 years later it will become the 10,000 TEU vessels (Jensen, 2017).

2. Demography challenges, resulting in demand changes (Jensen, 2017)

For the container shipping business, an essential factor is where population growth is occurring. In the long term, shipping will face three problems:

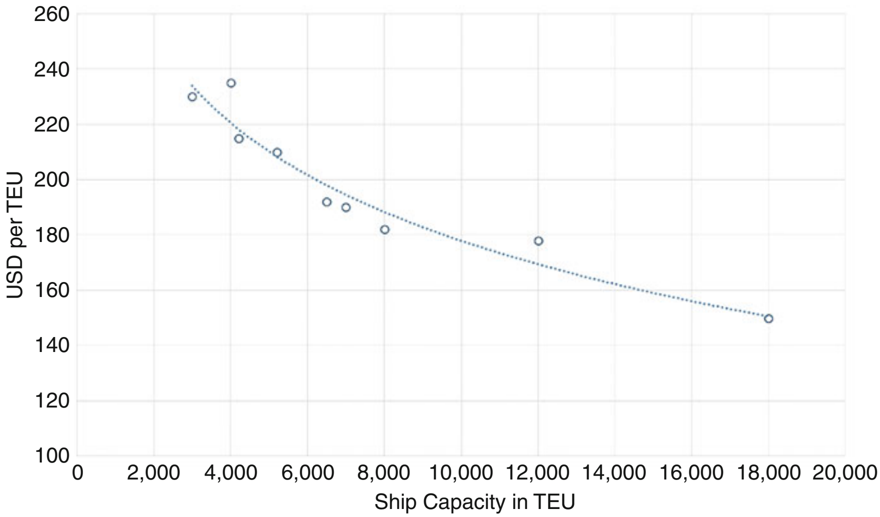

Fig. 2 Cost of 20-foot container transportation on the route Singapore-Rotterdam. Source: Germanischer Lloyd

- Increasing geographical dispersal of consumption
- Increasing geographical dispersal of manufacturing
- Demand structure change: shift from physical goods to services

3. Scientific and technical achievements.

In accordance with a recent UNCTAD report, “the spread of digital technologies in products and production over the past decade has led to a boom in trade and services, an increase of intangibles in global value chains and a very high increase of digital and tech firms among the largest multinational enterprises worldwide” (UNCTAD/WIR/2020). But, as argued in (UNCTAD/WIR/2017), “asset-light forms of international investments are just beginning to emerge and the full-scale digital transformation of the supply chains of firms that were not ‘born digital’ (especially in manufacturing) is only at the start. Digital Multinational Enterprises (MNEs) have grown partly in addition to, partly at the cost of, but mostly separate from traditional MNEs. And the digitalization of the supply chains of those traditional MNEs has in large part been bolted on to their existing international production configurations” (UNCTAD/WIR/2020).

New technologies influence all aspects of the global container shipping lines activity: customers, vendors, operations. Thus, in the UNCTAD “Review of Maritime Transport 2018” (UNCTAD/RMT/2018) experts mark out “technological advances in the shipping industry, such as autonomous ships, drones and various blockchain applications which hold considerable promise for the supply side of shipping. However, they also underline the uncertainty within the maritime industry regarding possible safety, security and cybersecurity incidents, as well as concerns about the negative effects on the jobs of seafarers” (UNCTAD/RMT/2018).

McKinsey & Company (Saxon & Stone, 2017) in their review of digital technologies influence on container shipping pay attention to the introduction of Big Data, the Internet of Things, Electronic Platforms, Advanced Analytics, and other technologies into the industry and recommend implementing the following to global container shipping lines:

1. Investments into digitalization
2. Consolidation
3. Integration (Saxon & Stone, 2017)

Furthermore, the Boston Consulting Group (BCG) points out the danger from "digital disruptors" and the need to introduce digital technologies to provide a transparent service. BCG defines seven directions of the digital transformation of the container shipping industry: Blockchain, E-platforms, Artificial Intelligence, Advanced Analytics, Internet of Things, Autonomous Vessels and Robotics Technologies, and Cybersecurity. The Boston Consulting Group analysts also note that the digital transformation agenda must be comprehensive, ranging from the strategic vision to the fundamental enablers (Egloff et al., 2018).

2.2 Methodology

Strategic alignment was introduced as a concept by Henderson and Venkatmaran (1999), this concept is also known as Business-IT alignment. Strategic alignment could be achieved by strategy formulation and strategy implementation processes which are interconnected and interact constantly.

Researchers have proposed a number of approaches to the alignment of the business and the IT architecture. Schelp and Stutz (2007) have adapted the Balanced Scorecard to use for IT measurements, Fritscher and Pigneur (2014) have proposed a model for the transformation between the Business Model Canvas and Archimate to improve Business-IT alignment. Other authors have proposed Enterprise Architecture (EA), a discipline for designing, planning, and implementing organizational change, for the strategic alignment improvement (Malta & Sousa, 2010) or have proposed a capabilities concept development for this purpose (Stirna et al. 2012; Teece & Pisano, 1994). The EA framework TOGAF (The Open Group Architecture Framework) standard has already introduced basic notions of capabilities and Capability based Planning.

Most of these approaches are extensions of established methods with a cross-domain approach but are focused on one or two domains. However, for the digital transformation of global container shipping lines, it is not enough to use only strategic model applications but you will also need to use technical approaches for the creation of the IT architecture. It is necessary to integrate a cross-disciplinary approach. The Enterprise Strategic Alignment Method (ESAM) can become such an approach (Aldea 2017).

ESAM is based on research results of the Twente University (Enschede, the Netherlands) and the BiZZdesign company (Enschede, the Netherlands) scientists

	Disciplines			
Phases	SM	CBP	EA	EPM
Visioning Process	+	–	–	–
Business Model	√	√	√	–
Environmental analysis	√	√	√	x
Strategic options	√	√	√	√
Strategic choices	√	√	√	–
Strategy elaboration	+	–	–	–
Strategic measurements	√	√	√	√
Implementation design	–	√	√	x
Transformation planning	√	√	√	√
Implementation governance	–	–	√	√
Strategy evaluation	√	√	√	√

+ = provides input to another/multiple discipline(s)

– = receives input from another/multiple discipline(s)

√ = provides and receives input to/from another/multiple discipline(s)

x = no interaction

Fig. 3 Cross-domain relationships (Aldea 2017)

group. This method represents a cross-disciplinary approach and consolidates existing approaches of such disciplines as Strategic Management, Capability Based Planning, Enterprise Architecture and Project Management. The ESAM cross-disciplinary interrelations scheme is provided in Fig. 3. The majority of ESAM phases have bilateral interrelations between the disciplines.

"ESAM have refined the strategic planning process into 11 phases: visioning process, business model, environmental analysis, strategic options, strategic choices, strategy elaborations, strategic measurements, implementation design, transformation planning, implementation governance, strategy evaluation (Fig. 4). Each of these phases contains at least one strategy model. ESAM presents a company activity business model as a subject domain, allowing to coordinate all strategic stages of the company transformation according to its changes" (Aldea 2017).

In this paper, the authors focus on the implementation of the company strategy, strategic measurements and metrics technique definition as well as the alignment of the business and the IT-enterprise architecture for the service-oriented enterprise architecture modeling. This allows the company to get a competitive advantage as a result of the implementation of the latest digital technologies.

For this purpose, in this paper strategic models like the Business Model Canvas (Osterwalder et al., 2010) and Capability Based Planning (Sandkuhl & Stirna, 2018;

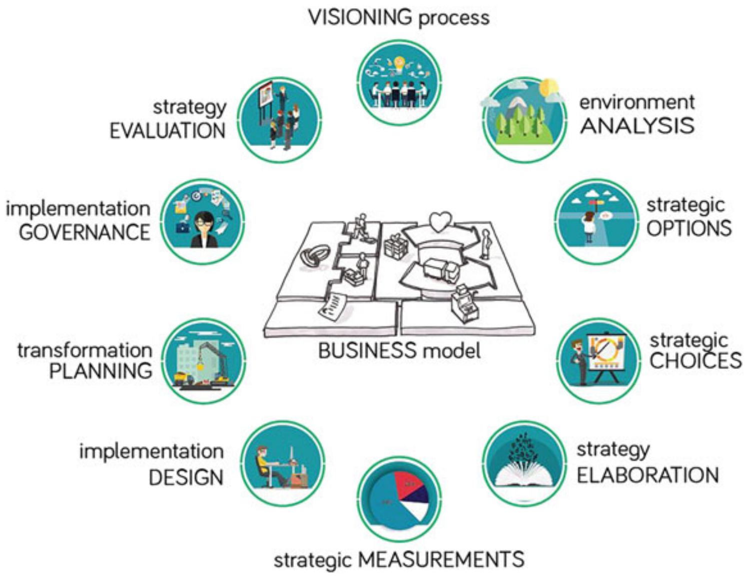

Fig. 4 The phases of the Enterprise Strategic Alignment Method (Aldea 2017)

Ulrich & Rosen, 2011) are used. The global container shipping line is considered as a logistics system in terms of the value-based Supply Chain Management concept (Brandenburg, 2013) and developed using the Balanced Scorecard (Kaplan & Norton, 2004) to allow an estimate of the digital transformation impact on the company long-term shareholder value. For global container shipping line Balanced Scorecard modeling the International Accounting Standards IAS (US-GAAP could also have been used), the strategic model Marketing Mix, the Supply Chain Operations Reference Model (SCOR), the BIMCO Shipping KPI's standard, the IMO standard, Capacity Management practice, and the international frameworks COBIT, ITIL as well as the enterprise architecture modeling language Archimate and the modeling tool Archi were used.

Reference models of the Balanced Scorecard strategic maps have been developed and ontologies have been proposed to be the basis for the global container shipping line "digital twin" creation.

The digital twin is a virtual model of a product, process, or system and represents complex multidisciplinary mathematical models with a high level of adequacy to real objects (Borovkov et al., 2019). This technology becomes an effective tool for high-tech product development and real-time enterprise or process management (Digital Twins Typologization, 2020).

A multi-level matrix of targets and resource constraints (real, financial, technological, and production) is an integral part of the digital twin development. Another part is Artificial Intelligence, which as a computer science discipline uses statistics methods as well as machine learning and deep learning instruments (Borovkov & Ryabov, 2019).

For this paper, the multi-level matrix comparing and linking indicators and IT-architecture models of the global container shipping line was developed, and using of ontologies was proposed.

Thus, the authors suggest supplementing the ESAM method for global container shipping line digitalization with the following steps:

1. Balanced Scorecard development
2. Company digital twin modeling
3. IT-architecture modeling based on virtual testing and experiments

These steps will provide an opportunity to assess the results of the proposed changes in the company IT-architecture and make the necessary adjustments in the process of the strategy implementation.

3 Balanced Scorecard as the Basis for Global Container Shipping Line IT-Architecture Modeling

As was already mentioned above, digital technologies transform the global environment, affect customers, competitors, data use, innovations, and value creation. To meet the external environment challenges, companies need to have a flexible IT-architecture that can both support daily operations and form a solid foundation for strategic changes, including the use of the latest disruptive technologies.

The architectural concept approaches to the global container shipping line information systems were already formulated by the authors before:

1. "Digital business ecosystem architecture
2. New network communications and new storage and data processing technologies development
3. Strong inherent relationship between three main aspects, namely EA models, data from enterprise information systems and IoT devices, and advanced analytics" (Maydanova et al., 2019).

Researchers have investigated for the last decades how organizations can gain and maintain a competitive advantage in dynamic situations. This has led to the formulation of multiple theories, with a focus on resources and capabilities as a source for a competitive advantage.

To characterize the global container liner shipping business capabilities more precisely it is necessary to consider the company as a complex logistic network, which "represents the multilayered closed flow process: the upstream and downstream flows of products, services, finances, and information. Logistic networks, united by logistic agreements, represent a supply chain" (Brandenburg, 2013).

Therefore, “the global container shipping line digital transformation should provide effects on physical, logistical, financial and service supply chain flows. During the company’s digital transformation, it is necessary to analyze technical capabilities and their influence on the company’s strategy implementation, for this purpose the value-based management theory could be used” (Maydanova et al., 2019).

“Value-based management (VBM) is a creation of an activity results assessment system on the company value basis and aligning management tools in accordance with this integrated indicator. Based on the comprehension of Modigliani and Miller (1958), the financial value of a firm is determined by the present value of its future cash flows. There is a direct interrelation between the company value and its business model as used business model determines company future cash flows” (Brandenburg, 2013).

The concept of value-based management (VBM) is linked to shareholder value. “Shareholder value and debt are seen as complementary portions of the total economic value of a company or business unit. The maximization of shareholder value is perceived as the primary objective of a company, and hence VBM stipulates that all parts of a company are managed in such a way that the equity value of this entity is increased, i.e. shareholder value is added. Being obliged to this objective by defined targets and effective compensation packages, management can apply decision making in financing, investing and operating in order to improve the operating profit, increase the capital turnover and reduce the effective tax rate. These value drivers in turn have an impact on the valuation components cash flow, discount rate and debt and ultimately influence the shareholder value of a company” (Brandenburg, 2013).

“As the global container shipping lines are a logistic network and international supply chain basis, it is necessary to consider company management as the value-based Supply Chain Management” (Maydanova et al., 2019).

The conceptual design of a framework for value-based SCM comprehended as production process, influences company value by four financial drivers: sales, cost, working capital, and fixed assets. The indicators system for global container shipping line digital transformation needs to ensure control by the influencing company on the value by above-stated factors. Investment and financial decisions quality need to be supervised as well (Fig. 5).

The Balanced Scorecard suggested by the authors (Maydanova et al., 2019) “is a logical extension of the value-based Supply Chain Management Framework.”

“The financial perspective represents a set of operating, financial, and investment activity goals. The strategic objectives of a company financial position should also be defined. The digital transformation strategic objectives achievement will allow to increase the company long-term shareholder value” (Maydanova et al., 2019). Strategic objectives from the customer, the internal processes, and organizational capacity perspectives are specified by a breakdown of the financial perspective goals into its drivers.

The company's long-term shareholder value is determined by the cost of capital, the tax rate, and the company value growth duration as well as logistic network

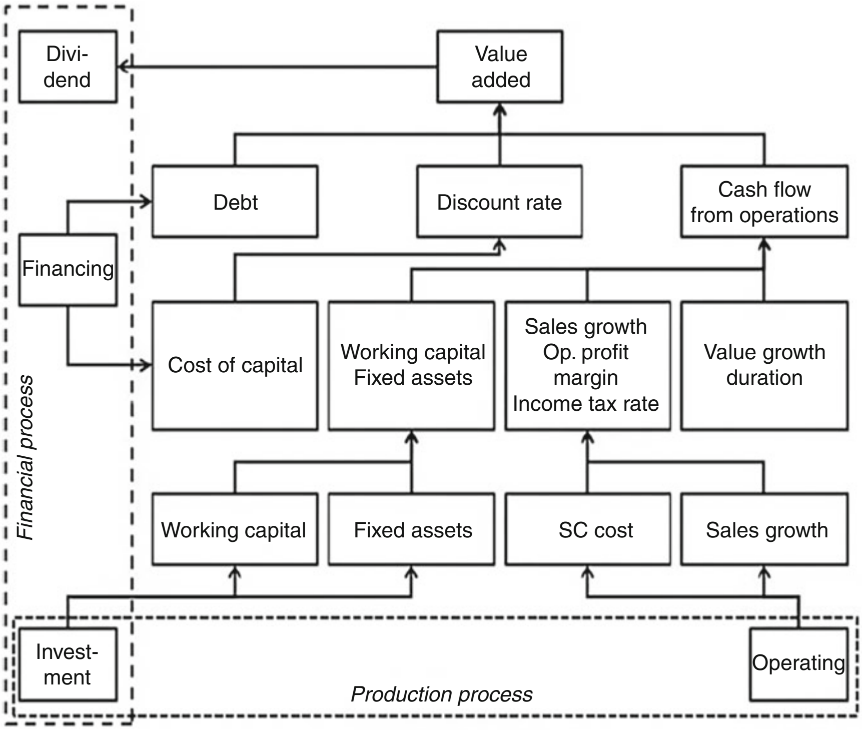

Fig. 5 Conceptual framework for value- based SCM (Brandenburg, 2013)

operational process management drivers like sales growth, working capital, supply chain operational cost, and assets efficiency. These items allow formulating a digital transformation strategy. "Achieving these objectives will increase the long-term shareholder value of global container shipping lines by:

1. increases in market share;
2. new products and services sales;
3. sales to new customers;
4. value co-creation;
5. maximization of working capital effectiveness;
6. reduction of service maintenance costs;
7. maximization of assets utilization effectiveness" (Maydanova et al., 2019).

Additionally, the company's financial activity strategic objectives are specified (Maydanova et al., 2019). Financial perspective strategic indicators could be set in accordance with the DuPont Formula theory (Fig. 6).

In the marketing environment, there are a number of critical business transformations, all with significant implications for supply chain management. "They could be characterized as follows: a shift of marketing strategy from the supplier to customer; from the push strategy to the pull strategy; from inventory to information;

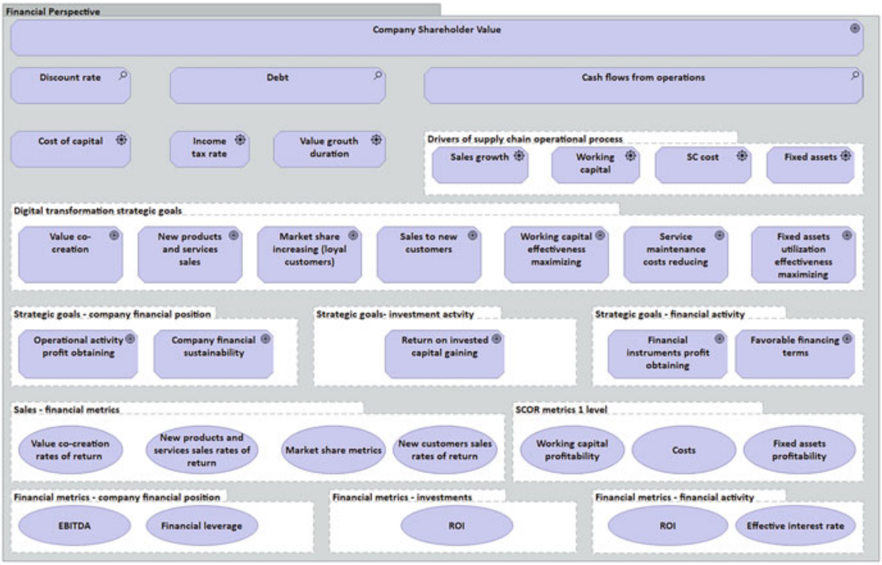

Fig. 6 Financial Perspective strategic map (Maydanova et al., 2019)

from transactions to relationships; from 'trucks and warehouses' to end-to-end pipeline management; from functions to processes; from the stand-alone competition to network rivalry" (Christopher, 2005).

The customer perspective drivers reflect "the processes happening in supply chain management and the factors influencing their changes:

- real demand information obtaining;
- customer relations management;
- flexibility and efficiency for customers;
- delivery process end-to-end integrated management;
- resources flexibility;
- focus on the processes creating value for clients;
- effective use of resources and competences of partners;
- use of digital marketing tools".

"For the customer perspective strategic objectives definition, it is necessary to use a strategic model marketing mix and strategic and digital marketing tools" (Fig. 7) (Maydanova et al., 2019).

The customer perspective strategic objectives are as follows:

1. Obtaining information about actual demand in a timely manner
2. Partners competences and use of resources
3. Lead generation
4. Increase of the customer service level
5. Omnichannel sales

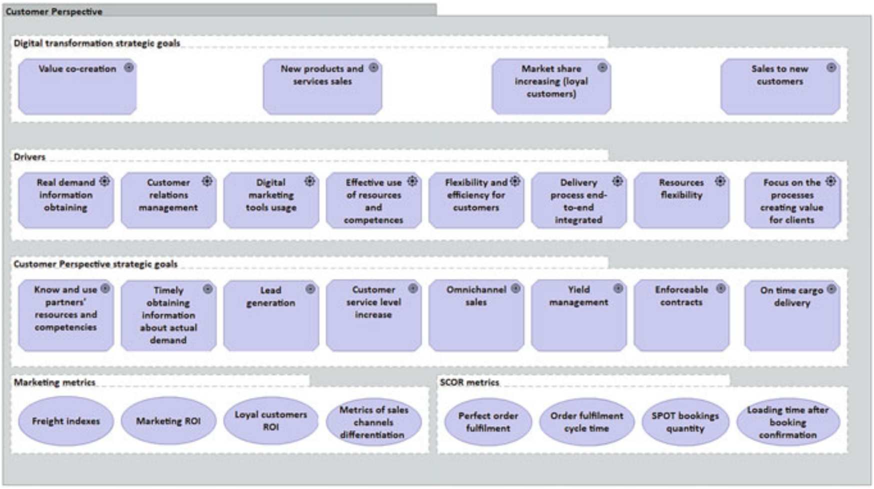

Fig. 7 Customer Perspective strategic map (Maydanova et al., 2019)

6. Yield management
7. Enforceable contracts
8. On-time cargo delivery

The customer perspective strategic indicators could be set with the metrics, used in strategic and digital marketing (Fig. 8).

As a basis of the internal process perspective in this paper, the Supply Chain Operations Reference Model was used. “This model is built around six major processes: Plan—Source—Make—Deliver—Return—Enable and covers the key supply chain activities from identifying the customer demand all the way through to delivering the product and collecting the money. The aim of SCOR is to provide a standard way to measure the supply chain performance and to use common metrics to benchmark against other organizations” (Christopher, 2005).

Internal process drivers in accordance with SCOR are defined as performance, processes, practices, and people. Strategic goals are determined as strategic characteristics of supply chain performance: reliability, responsiveness, agility, costs, and asset management efficiency. SCOR provides an opportunity to analyze supply chain processes and to correlate the internal process perspective indicators with other Balanced Scorecard indicators; therefore, the SCOR model becomes extremely an effective tool during the company’s digital transformation. “SCOR does not attempt to prescribe how an organization should conduct its business or tailor its systems/information flow. Every organization that implements supply chain improvements using SCOR will need to extend the model, using industry, organization, and/or location-specific processes, systems, and practices” (APICS, 2017).

The global container shipping line network is deployed based on the major vessels on deep-sea routes connecting hubs as well as major other ports. In addition to this, there are also localized niche and feeder services. Established cargo flows as

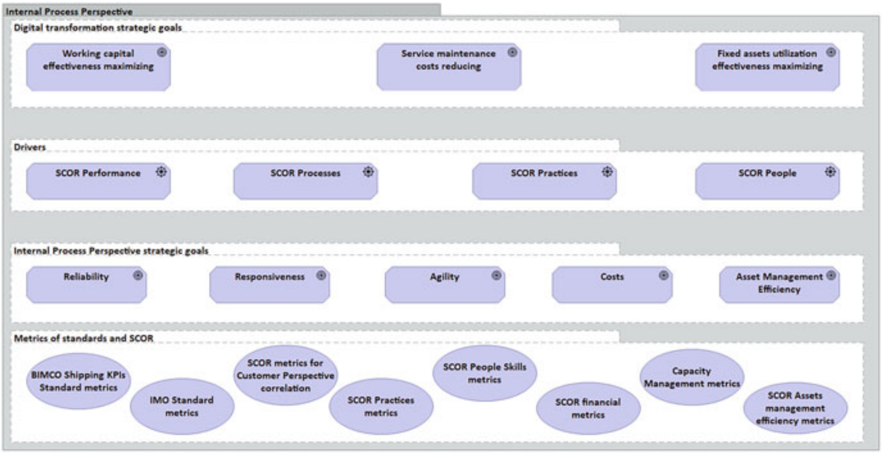

Fig. 8 Internal Process strategic map (Maydanova et al., 2019)

well as effective assets management have a high influence on global container shipping line processes.

The system of key performance indicators for the commercial fleet operating activity analysis and benchmarking was developed by the Baltic and International Maritime Council (BIMCO)—the international sea trade transportations industry association. This system was organized as a standard, named BIMCO Shipping KPI Standard.

A considerable influence on a vessel efficiency indicators has the following special vessel characteristics such as loading capacity, speed, and consumed fuel. However, the modeling of the vessel calls network has the most significant effect on commercial fleet efficiency.

The commercial fleet utilization in the container transport is called liner ship fleet planning and consists of three main objectives:

1. Optimum vessels size and fleet structure
2. Optimum fleet operation mode
3. Optimum vessel calls network

Capacity management is an important part of supply chain management, allowing the companies to be competitive in the market and to fulfill customer requirements in the most flexible way with minimum expenses.

The container liner shipping industry possesses a considerable impact on the environment due to its global activity. Compliance with environmental protection standards is an essential indicator of global container shipping line activity. Universal safety and environmental efficiency standards are defined by the International Maritime Organization (IMO). Additionally, safety and environmental efficiency standards can be established by national laws.

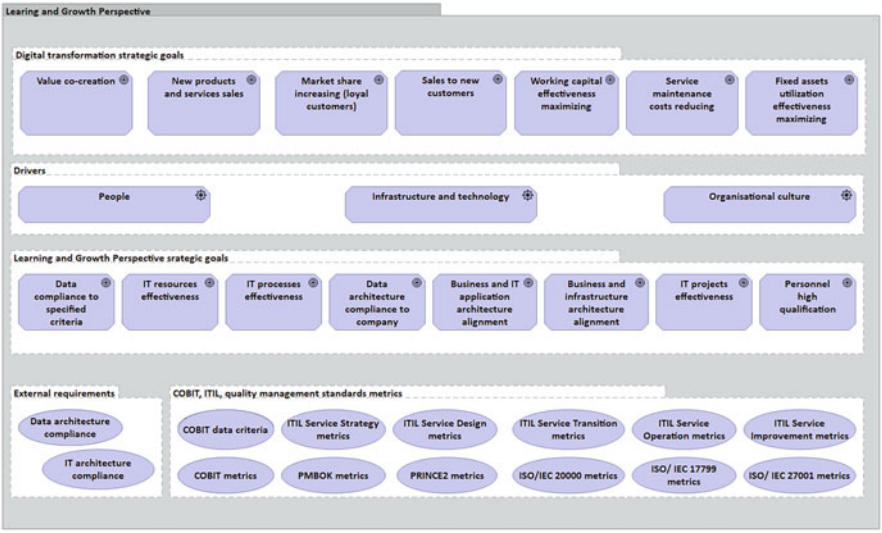

Fig. 9 Learning and Growth Perspective strategic map

Internal Process Perspective indicators need to be amended with the BIMCO Shipping KPI Standard, the IMO standard, and capacity management metrics.

Learning and growth perspective drivers are people, infrastructure and technology, and culture (Fig. 9).

The SCOR model allows the "correlating of performance, processes, practices indicators with the supply chain personnel skills. Additionally, the BIMCO Shipping KPIs Standard establishes requirements for human resource management to ensure safe and efficient operations of the ships" (Maydanova et al., 2019).

During the global container shipping line digital transformation, IT-architecture strategic indicators, initiatives and problems definition, and IT-architecture changes control by expert organizational structure are needed.

"The Open Group Architecture Framework (TOGAF) originated as a generic framework and methodology for development of technical architectures but evolved into an enterprise architecture framework and method could be tool for enterprise architecture design" (Ilin et al., 2017). "The Architecture Development Method (ADM), which is considered the TOGAF core, and consists of a stepwise cyclic approach for the development of the overall enterprise architecture" (Lankhorst, 2017), will provide the necessary support for the global container shipping line IT-architecture modeling.

To set strategic indicators for company EA governance it is relevant to use COBIT and ITIL frameworks (Maydanova et al., 2019).

The learning and growth perspective strategic goals of global container shipping lines have to provide to a company digital transformation strategic objectives achievement and could be formulated as follows:

1. Data compliance to specified criteria
2. IT resources effectiveness
3. IT processes effectiveness
4. Data architecture compliance to company strategic goals
5. Business and IT application architecture alignment
6. Business and infrastructure architecture alignment
7. IT projects effectiveness
8. Personnel high qualification

Learning and growth perspective strategic indicators have to provide data architecture and IT architecture compliance both legislation requirements as well as requirements of the standards and frameworks.

4 Global Container Shipping Line Digital Transformation and Enterprise Architecture Modeling

The software lifecycle management standards and methodologies place great importance on metrics collection and management. IT-project metrics are indicators that reflect their individual characteristics, measurement, or combination of measurements performed within the IT-project or the IT-process. The IT-project management problems could be defined as follows: the ambiguity and complexity of selecting indicators for tracking; the difficulty in interpreting the results and the use of the obtained data for the IT-project development.

The collection of the metrics itself is practically useless without a thoughtful implementation—it is necessary to correctly interpret the results, to identify IT-project risks, to determine corrective actions, and to forecast metrics.

The authors have suggested the use of an ontology to standardize the knowledge collection and presentation approach (Maydanova et al., 2019). Ontology (in computer science) is an attempt to detail and comprehensively formalize a certain field of knowledge by using a conceptual scheme. One of the main advantages of using an ontology is the ability to combine the information obtained from various information sources. The use of ontologies will create a unified knowledge database that contains information about IT-projects and in particular metrics and experience with their use.

For the global container shipping line digital transformation control, the following ontologies are proposed:

1. The Balanced Scorecard metrics ontology. The main properties of metrics will be a list of primary indicators, recommended targets and critical thresholds and a recommended frequency of reading. This ontology should be linked to the IT-project database through the metrics usage precedent database.
2. The risks and constraints ontology: categories of risks and constraints—technical, external, risks and constraints of the environment and project management, risks

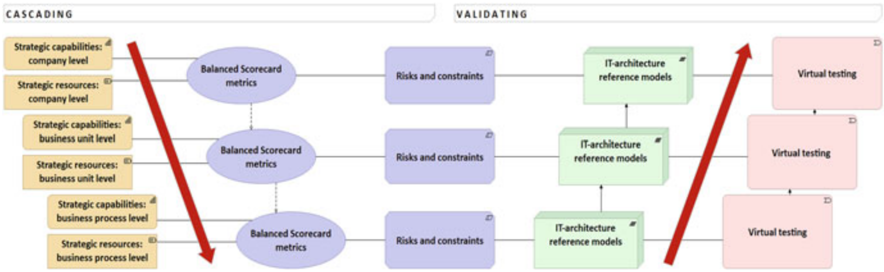

Fig. 10 Multi-level matrix comparing and linking indicators and IT-architecture models of the global container shipping line (Maydanova & Ilin, 2019)

and limitations of testing. The risks and constraints ontology through the history of risks and constraints database should be linked to the IT-project database.

3. Forecasting methods ontology, associated with the IT-project database through the forecasting precedents database.
4. The IT-architecture reference models ontology, related to the IT-project database, as well as to the risks and constraints ontology through the history of risks and constraints database.

Digital technologies have an impact on the innovation process, which is based on rapid experimentation and continuous learning. Unlike the old approach, which focused primarily on the finished product, the new approach focuses on identifying the right problem and then developing, testing, and learning on the many possible solutions. This approach focuses on developing minimally viable prototypes and iterating them repeatedly—before, during, and even after launch. Each assumption is tested and decisions are made. Because digital technologies make it easier and faster than ever to test ideas, this new approach to innovation is needed to get new ideas to market faster with less cost, less risk, and greater organizational efficiency cost and more organizational learning.

The proposed ontologies used are based on the developed reference models of the Balanced Scorecard strategic maps that can become a basis for the creation of a global container shipping line "digital twin". A digital twin is a dynamic data-driven software model for representing and analyzing the organization's activities and its current business model. The digital twin can be used to respond to changes in the external and internal business environment. Such an approach will allow the company an IT-architecture modeling, based on virtual experiments and will increase productivity and efficiency of strategic changes implementation.

To create the company's digital twin, it is necessary to correlate a large number of strategic indicators, risks and constraints, forecasting precedents, and IT-architecture reference models. Figure 10 represents a multi-level matrix comparing and linking indicators and IT-architecture models of the global container shipping line as a whole and its business units and business processes.

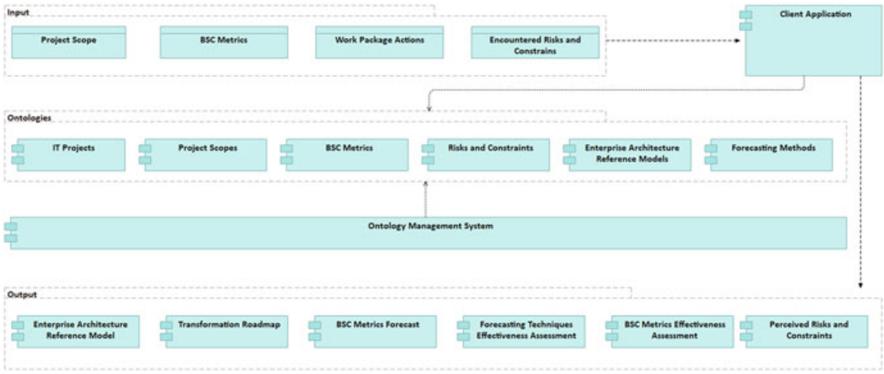

Fig. 11 IT-projects portfolio management system

The strategic indicators cascading takes place from the top down, from the company level to the level of the business processes, since the global container shipping line implements a unified strategy for all business units. The Balanced Scorecard metrics are correlated with risks and constraints, as well as with the IT-architecture reference models. At each level, there can be several IT-architecture reference models depending on the technologies proposed for implementation.

The multi-level matrix should provide the ability to not only track the metrics, risks and constraints, and IT-architecture models mutual impact, but also allow to make necessary changes and clarifications as soon as possible, to carry out operational management of the company digital transformation. For this purpose, the IT-architecture model is validated, from the pilot project of business process level to the strategic changes of the company IT-architecture. The validation occurs as a result of virtual testing using various forecasting methods. After the pilot project launching the ontologies of strategic indicators, risks and constraints, IT-architecture models and forecasting methods should be refined and supplemented by comparing prognosis and actual indicators.

The digital transformation of the global container shipping line requires a number of pilot IT-projects implementation but companies frequently are limited with tools of its management and evaluation (Ilin et al., 2014). For the purpose of IT-projects portfolio management, the authors have proposed to use an intellectual system, represented in Fig. 11.

The third platform for the modeling of the global container shipping line digital transformation should represent best-in-class technologies, available at the moment for the company's development. Representation means benchmarking of digital technologies implementation by industry leaders. Such technologies could be used by the company for its digital transformation but could be refused due to risks and constraints in regard to the implementation but awareness of the performance of these technologies is crucial. Such a knowledge base cannot be created overnight, consistent and ongoing work is needed to monitor and evaluate emerging technologies. For this purpose, research and testing of technologies should be carried out and virtual experiments can also be conducted to obtain benchmarks for the use of the latest technology. This work should be done either by a special department or by an expert organization specializing on technologies in maritime transport.

The proposed approach is an effective tool for planning, implementing, and monitoring of strategic changes in the context of the global container shipping line digital transformation. It allows avoiding errors and inefficient management as it will enable the company to analyze the impact of a significant number of indicators to achieve strategic goals, as well as to adjust the strategy due to changes in external and internal capabilities and resources.

5 Conclusion

The maritime transport industry is currently under the influence of trends related to changes in the structure and volume of demand, excess capacity, and the digital transformation of its customers and partners. Industry participants need to adjust their strategies, improve operational efficiency, create new channels to promote their services, improve relationships with customers, to create new value propositions. The consolidation processes currently underway in the industry are leading to the consolidation of key players which in turn are making efforts to build business ecosystems and digital transformation of operations. The implementation of new technologies is now widespread in the maritime industry but a rapidly changing environment requires changes of the company IT-architecture on the sustainable manner and demands integrated approach.

The Enterprise Strategic Alignment Method provides such an approach, its application for the digital transformation of global container shipping lines will allow a transition from a company strategy to practical actions, company business processes and an IT—architecture alignment, development of company activity strategic indicators, and performance control. As proposed in this paper the Balanced Scorecard provides an opportunity to track the impact of changes in the global container shipping line IT-architecture and its activities in terms of financial, customer, operational perspectives, and learning and growth perspective. To align the company's business and IT-architecture, it is relevant to use ontologies of strategic indicators, risks and constraints, forecasting methods, and the company's IT-architecture reference models.

The proposed multi-level matrix comparing and linking indicators and IT-architecture models allows creating a company "digital twin" that will ensure information support and tracking the impact of IT-architecture changes on the company's performance. The global company digital transformation involves the implementation of multiple pilot projects, the results of which must be monitored to obtain the necessary information for the prediction and modeling of IT- architecture. The proposed IT-projects portfolio management system makes it possible to monitor processes and results of pilot projects implementation and making the necessary adjustments to the indicators to build a company "digital twin". Virtual testing and experiments based on the BSC metrics, risks and constraints, pilot projects results implementation and the knowledge base of the best-in-class technologies will allow modeling of the changes in the IT-architecture of a global container shipping line, which are necessary to achieve strategic results and adjust the strategy in accordance with changes in the business environment.

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Digital Platforms for Maritime Logistics Ecosystems

Igor Ilin, Svetlana Maydanova, Alissa Dubgorn, and Manfred Esser

Abstract The role of digital platforms in different economy areas is increasing every day. For such industries, where the interaction between different ecosystems members is crucial for their economic success, digital platforms both as technological and business tools are indispensable. The research is aimed at analyzing existing digital platforms in the area of supply chain management with a focus on maritime logistics industry. Several existing maritime logistics platforms are described, as well as their categorization based on capability-driven approach is presented.

1 Introduction

It is fair to say that we live in an age when data has become of the greatest value. The amount of data, produced from different sources, thanks to the active development of digital technologies, is increasing exponentially. The United Nations Digital Economy Report 2019 introduces the "data value chain" concept stressing that "value creation arises once the data are transformed into digital intelligence and monetized through commercial use" (UNCTAD, 2019). Citing reasons why data has come to play a large role in economic processes, platformization was one of the first to mention by the UN. Platform-based businesses have a major advantage in the digital economy in view of their data-driven character.

Against the backdrop of a slowdown in global economic growth, the success of sustainable development of both public and private organizations in leading countries of the world largely depends on innovative solutions and business models that they use. Research in this area shows that only the introduction of breakthrough solutions, both in the field of management and in the field of digital transformation,

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can give a powerful impetus to development. One of the most relevant areas of business development is the development of digital business ecosystems and digital platforms, aimed at providing information and technological support for such ecosystems.

The maritime logistics industry also tends to implementation of such business trends, as business ecosystems and platformization. There are a number of digital platforms already existing in the industry, developed by the ecosystem leaders, such as global logistics companies or container liner shipping companies together with IT companies. Based on a capability driven approach these platforms are analyzed and categorized in this paper.

2 The Role of Digital Platforms in Digital Economy

To understand the role of platforms in digital economy it is necessary to analyze the existing types and characteristics of digital platforms. There are several state-of-the-art papers representing the present state of scientific development in the area of digital platforms. Asadullah et al. (2018) divide the existing approaches to digital platforms definition into two conceptualization views: technical (e.g., software development) and non-technical (e.g., B2B and B2C transactions). As the most comprehensive definition from the first group the following can be considered: "a building block that provides an essential function to a technological system and serves as a foundation upon which complementary products, technologies, or services can be developed" (Spagnoletti et al., 2015, p. 364; Yoo et al., 2012, p. 1400). For the "non-technical" definition the following deserves attention: "multisided platform . . . exists wherever a company brings together two or more distinct groups of customers (sides) that need each other in some way, and where the company builds an infrastructure (platform) that creates value by reducing distribution, transaction, and search costs incurred when these groups interact with one another" (Pagani, 2013, p. 625).

Parker and Van Alstyne (2018) name the network of producers and consumers as the main asset of a platform. The producers and consumers exchange value by using the features of the digital platform. Depending on the type of the platform, they share a different type of resources (incl. data) and one of the main economic results can be seen in reducing transaction costs for the participants of the platform ecosystem (Parker & Van Alstyne, 2018).

Jacobides et al. (2018) present a research on ecosystems, which can be seen as a core of platformization. In their research, three views on ecosystems are identified: with a focus on platform ecosystems, with a focus on a firm and its environment, with a focus on innovation ecosystems. So, the ecosystems of the digital platform participants (producers and consumers) may result from the production and development of such a platform. But also, the digital platform may be developed as a need for communication and interaction of an existing ecosystem.

It is important to understand that the platform itself is not a source of value for the interacting parties, since it itself does not produce any material products, but acts only as a coordinator and data source for its participants. At the same time, with the help of the tools offered by the platform, a large number of new communications between ecosystem members are generated, which results in the generation of a network effect: the more involved parties interact through the platform, the more valuable it becomes for its participants.

The platform as a business model represents a model of direct interaction and transactions between entities through a technological platform using new ways and forms of interaction, value creation, and pricing. This differentiates platforms from merchants and classical mediators, where there is no direct interaction between interested other parties, as well as from vertically integrated companies that combine one side of the market within a single ownership structure (Geliskhanov et al., 2017).

The world-leading consulting companies develop more practical-oriented research on how digital platforms can be used in different economy and business areas. BCG sees digital platform as a tool to develop data-driven business management within a single organization, without reference to an industrial or innovation ecosystem. They name following mail characteristics of such digital platform (BCG, 2020):

- Data can be liberated from old, inflexible legacy core systems.
- Data can be owned by the business, not IT, which is critical to prioritizing and driving business use cases.
- The business side can roll out new use cases independent of IT's decisions about how and at what pace to upgrade the core.
- New digital services can be delivered every few weeks, powered by artificial intelligence and leveraging open-source software and cloud services.
- Differentiating engineering capabilities can be re-shored and built in-house, improving time to value.

This approach shows that digital platform can be used as a tool for developing the IT architecture of one particular organization and be faster and more efficient in comparison to implementing or developing Enterprise Resource Planning system or different integration services. The concept of having producers and consumers is still applicable for such platforms, while the main sharing resource in this case becomes the data, produced by different sources and consumed by both internal and external consumers of an enterprise.

Numerous research has been presenting the potential of different industries to be platformized, as well as results of qualitative and quantitative studies on the effects of platformization in the economic processes. Kenney et al. (2021) make the following conclusions based on previous research on platform pervasiveness and power review:

- There was no clear understanding of how platforms will change the economy in the late 1990s when the first attempts were made to create an intermediate level between vendors and customers.

- The main driver of broad adoption of platforms can be seen in the introduction of smartphones into the day-to-day lives of customers, which resulted in moving social and economic activity into online format.
- There are several clear measured effects of digital platforms usage on other industries (e.g., ridesharing platforms depressed taxi, mass transit, and car rental market; Airbnb negatively impacted hotel industry and long-term rent).
- The power of platforms used in different industries is not only about leveraging the strength of network (ecosystem) effects, but also about the possibility to use the data captured to expand it into new markets or deepen the services offered in particular industries.
- One of the main driving forces of the platform lies in how it orchestrates the activities of different participants, as well as the ability to determine the operation of far more ecosystem-complementary actors.

The last point is especially interesting to be analyzed in the context of digital platforms used for maritime logistics ecosystems.

3 Review of Existing Maritime Logistics Digital Platforms

When talking about logistics digitalization, especially maritime logistics, the main question arises—how to automate the interaction of different parties, involved in the complex supply chain. The logistics itself is a cutting-edge industry in terms of digital technologies (such as IIoT, Blockchain, Cloud Technologies, Artificial Intelligence, Big Data Analytics, cyber-physical systems, etc.) implementation. Maritime logistics is no exception, so several digital platform cases can be analyzed to draw conclusions and formulate some discussion questions.

As mentioned above, the maritime logistics system includes several actors, which are combined together into ecosystems of different levels: the local, the national, the regional, the international. On the highest level the actor groups can be divided into senders, receivers, and logistics providers (Fruth & Teuteberg, 2017). The latter include, e.g., forwarders, port and terminal operators, shipping companies, traffic control centers, transaction brokers. The analysis of digital platforms usage in maritime logistics operations can start with the local level (digital platforms, used for automation/digitalization of specific organization's processes, e.g., port or shipping company) and finish with the international level, where logistics systems of different countries have to interact.

Bergman (2021) discusses the Maritime 4.0 concept, where port authorities and commercial companies need the ability to process digital data and integrate it with critical business systems and workflows. So, the crucial functions of maritime digital platforms are: processing needed data into meaningful information, making it easily perceived (via visualization) to the maritime ecosystem participants. The data harmonization and standardization issues become especially relevant in the context of Maritime 4.0.

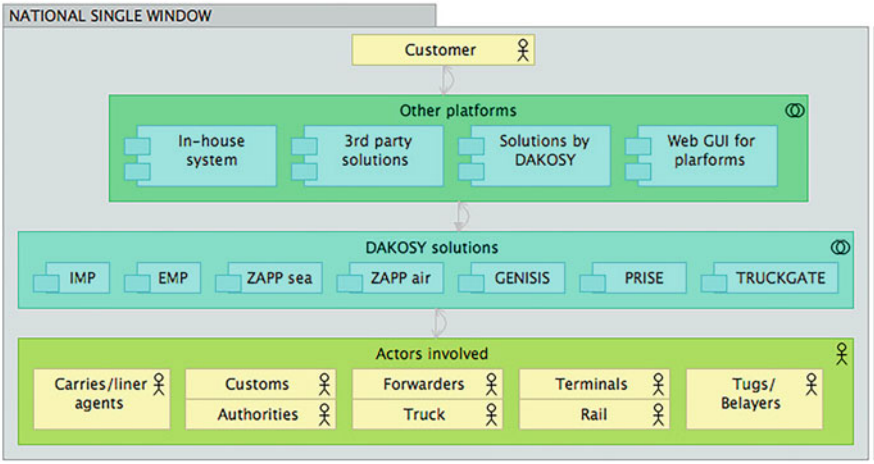

Fig. 1 Digital business ecosystem of Hamburg port (Kapkaeva et al., 2021)

One of the cases how a digital platform can be used by a logistics provider, or rather port and terminal operators, is to support the data and information exchange happening around the port activities. Thus, the issues of delays in barge container handling caused by an increasing size of deep-sea vessels led to developing a digital platform for Port of Rotterdam, which is one of the largest maritime logistics centers in Europe. One of the solutions, used in the Port of Rotterdam is developed by the Port of Rotterdam Authority, is aimed at automating operations that take place in a port. It is based on modern digital technologies, such as big data analytics and artificial intelligence, and is called Portmaster (for external marked sold as PortForward) and realizes the following features: providing accurate information about vessel times of arrival and departure (including predictive AI analytics tools); visualizing operational KPIs on dashboards for monitoring safety and sustainability performance of the port, as well as decision support; keeping track of information about cargo; automated calculation of port dues for port authorities; managing information about accessibility and availability of port infrastructure (quays, berths, etc.). The platform is provided as a service and has a modular structure, that is why the Port of Rotterdam Authority declares that it is suitable both for small and large ports all over the world (Port of Rotterdam, 2020).

An example showing how a port gets more effective with a help of digital technologies, enabling fast and efficient interaction with the local ecosystem parties, is the Port of Hamburg. Kapkaeva et al. (2021) described, how the specialized DACOSY solutions (DACOSY, 2020) integrated with other systems (export custom clearance, GEGIS system of the waterway police; the Port River Information System Elbe, and other platforms) helped the Port of Hamburg to become paperless and improve its operations with the help of electronic data exchange between different parties involved in the port ecosystem. The authors also present a high-level architecture of information systems and services, used in the Port of Hamburg

(Fig. 1), which can be used as a reference for other ports, which are on their way to automation and digitalization.

In their previous study authors analyzed the types of digital platforms, used in the logistics system of the Russian Federation (Ilin et al. 2020b). The following types, based on capabilities of the platforms, have been identified together with the examples of existing digital platforms:

- Platforms, enabling functional support of logistic operations: Platon and ERA-GLONASS
- Platforms, enabling submission of standardized information and documents to state bodies (B2G oriented): KPS Portal Seaport and Unified State Information for Transport Security
- Platforms, pretending to support the whole business ecosystem of transport logistics on a national/transnational level: RZD digital platform, EAEU digital platform

One of the main concepts discussed in the context of maritime logistics development and digitalization is the Single Window System (SWS). The concept of SWS is basically the idea of a single-entry point and single-submission (or single interface), enabling traders to comply with regulatory requirements of export and import in a more efficient manner. Furthermore, SWS enables coordination and connection among different border government agencies ensuring that trade activities and transactions are safe, legitimate, and seamless across trade and supply chains (APEC, 2018). The World Customs Organization introduced the concept "Single Window System Environment," defining it as "a cross border, 'intelligent', facility that allows parties involved in trade and transport to lodge standardized information, mainly electronic, with a single entry point to fulfill all import, export and transit related regulatory requirements" (WCO, n.d.).

As fulfilling regulatory requirements in the case of maritime supply chain means interaction of different ecosystem parties and data/document exchange between them, the SWS environment obviously has a need in a specialized digital platform. Such platforms are in the process of active development/implementation/usage in different countries on a national level (e.g., PortNet in Finland, MSW Reportal in Sweden, TradeNet/TradeXchange in Singapore, INSW in Indonesia, SP-IDC in Korea, etc.). According to Tijan et al. (2019) implementation of Maritime National Single Window lead to sustainable seaport business expressed in three sustainability aspects—economic (through reduction or elimination of paper documents, long-term cost savings, data re-use, reduced fees charged, etc.), environmental (through efficient use of natural resources, decreased emission of polluters, reduced use of paper for printed documents, etc.) and social (through improved communication and information exchange between stakeholders, standardization of information and documentation, common regulations, decreased man-hours of supply chain members, etc.).

Another important concept, if talking about larger ecosystems, is interoperability. This concept is crucial for international trade, where the SWS of different countries and regions have to interact. The recommendations on Single Window

Interoperability (SWI) were published by UN/CEFACT (2017), which defines SWI as “the exchange of specified foreign trade-related information in a structured format between two or more Single Window systems in different economies” (UN/CEFACT, 2017). Thus, the EU has been working on the development of the European Maritime Single Window (EMSW), which will offer possibilities for ship operators to provide required information all across the EU via special interfaces (Tijan et al., 2019). A similar project on developing a platform for enabling SWS interoperability has been realized for a consortium of five southeast Asian countries: Indonesia, Malaysia, Singapore, Thailand, and Vietnam and is called ASEAN SWS. Among others, one of the declared features of such a platform is the possibility of data reuse.

The International Maritime Organization (IMO), which acts as one of the main regulators for maritime logistics, launched the e-Navigation initiative as “the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment” (IMO, 2019). In 2019, IMO published the initial descriptions of maritime services in the context of e-Navigation. The high-level structure of maritime services is presented as follows:

1. Vessel Traffic Services (VTS) Information Service: information related to navigational situation, navigational warnings, meteorology, hydrography, electronic navigational aids, etc.
2. VTS Navigational Assistance Service: information related to requests for vessel identification, navigational information to individual vessels, advices or instructions to individual vessels (i.e., to alter the course/speed), warnings.
3. Traffic Organizational Service: information related to traffic clearance, anchorage, enforcement, waterway management.
4. Port Support Service: information related to berth and mooring details, waste handling arrangements, fuel/bunkers, cargo handling arrangements, customs and immigration, etc.
5. Maritime Safety Information Service: information related to hazards to navigation, marine weather warnings, and forecasts.
6. Pilotage Service: general information related to pilot requirements in the area, local regulations, requirements and procedures for ordering the pilot and pilot boarding, contact information to pilot station; as well as operational information related to the position of pilot station, boarding speed, required arrangements for pilot boarding, communication, etc.
7. Tug Service: deep-sea information, local port or river information, tug information.
8. Vessel Shore Reporting: information related to reporting regulations, reporting tools, shore receivers, and support.
9. Telemedical Assistance Service: a single point of contact to get decision support and advice to the seafarer onboard responsible for medical care whenever the

provision of treatment cannot wait, as well as real-time monitoring of the patient's current health status.
10. Maritime Assistance Service: general information related to ongoing operations in an area, geographical coordinates, contact information, capacity, available resources for lightering/pollution combating and recovery/towage/stowage/salvage/storage, contingency planning, etc.
11. Nautical Chart Service: information related to geographical features, transits and routeing, ports approaches and entry, regulatory information, navigation aids, metadata, etc.
12. Nautical Publication Service: information related to transits and routeing, summary information about port facilities, marine radio services, prevailing natural conditions, climatic information (incl. predictions), chart catalog, etc.
13. Ice Navigation Service: information related to ice conditions, ice reports and bulletins, routeing aids, navigation planning.
14. Meteorological Information Service: information on wind, waves, atmospheric conditions, ocean, weather systems, ship observation, etc.
15. Real-time Hydrographic and Environmental Information Service: information related to water levels and under-keel clearance water along a planned route.
16. Search and Rescue Service: information related to dangers such as dangerous substances, SAR resources in area, type of search and rescue operation, vessels and opportunity within and near the search area, on-scene commander, assistance information, etc.

Obviously, the planned e-Navigation system will use data and information from existing information systems, as well as digital platforms of maritime logistics ecosystem members. But also, the companies and organizations involved in the maritime logistics supply chain may become the users of such platforms themselves in order to get comprehensive information about maritime environment, especially if digital technologies, such as big data analytics (e.g., predictive), artificial intelligence, etc. will be applied to data conversation.

Many digital platform concept-oriented solutions are based on blockchain technology. The technology has shown its large potential for supply chain management, which is confirmed by a large amount of researchers (Di Gregorio & Nustad, 2017; Eryurt, 2017; Weernink et al., 2017; Maydanova & Ilin, 2018; Lammi & Genadijs, 2017). One of the blue-chip players of the global supply marketplace, Maersk announced a blockchain solution TradeLens based on the Hyperledger Fabric and built together with IBM. The expectations are to not only reduce the cost of goods for consumers but also make global trade more accessible to a much larger number of players from both emerging and developed countries (Burnson, 2017). The attributes of blockchain allow partners to establish a shared, immutable record of all the transactions that take place within the maritime logistics ecosystem and enable permissioned parties access to secured data in real time. Other benefits of using such a digital platform for maritime logistics ecosystem players are the possibilities to speed up the industry's business processes and improve inventory management, further cutting down frauds, costs, and delays (Scott, 2018).

Following Maersk, other container shipping companies also understood the need of developing a platform, that could not only automate their own interactions with all kinds of supply chain stakeholders but also become a main digital platform for the whole logistics industry. Based on the BlueX Freight Commerce Platform, the Evergreen Line developed the GreenX digital platform, which is announced to be used in more than 240 ports worldwide to work with such services, as digital search for quotes and routes, online booking and payment, tracking the shipment, insurance, customs, and warehousing (Greenxtrade, 2021).

Japanese shipping giants Kawasaki Kisen Kaisha, Ltd. ("K" LINE), Mitsui O.S.K Lines, Ltd. (MOL), and Nippon Yusen Kabushiki Kaisha (NYK) have in 2019 begun sharing of operational data acquired from the monitoring system installed in their container ships with their charter, Ocean Network Express Pte. Ltd. (ONE), through the IoS-Open Platform (IoS-OP) promoted by Ship Data Center Ltd. (ShipDC) (Mitsui O.S.K. Lines., 2019).

The Crane Worldwide Logistics developed traffic management platform CTMS that offer shippers "real-time management of the full order-to-settlement process, quote management, pricing and routing functionality, track and trace with proactive exception management and financial settlement and audit capabilities" (The Loadstar, 2020). The solution is cloud-based and can interact with other platforms and providers and pretends to be sold both for logistics firms and shippers to manage their transport.

Another example of digital platforms used for global supply chain management, including maritime logistics, is CALISTA. It is a Supply Chain Orchestration platform that allows you to manage supply chain needs, i.e.: access to physical port and logistics services, secure trade financing and insurance, fulfill Customs compliance (CALISTA Logistics, 2021). It uses API or EDI to get other systems access to share their information or data and is designed as an open platform with the ability to connect to many different modules. The platform is actively used in Singapore but is meant to be a global set of digital services offered in the whole world (e.g., the cross-border payment system is already applicable for more than 20 currencies).

As for future development of maritime logistics digital platforms, Lehmacher, (2019) tell about revolution new step of digitization—combining the potential of digital platforms and smartphone applications. They present the Port-as-an-app (PAAA) concept, which is that ports themselves represent the applications of maritime ecosystem and digital economy, as well as society. With the help of the PAAA approach it is expected to enable approximately two-thirds of the value for business and society based on platform-driven interactions.

4 Categorization of Maritime Logistics Digital Platforms Based on Capability Driven Approach

This study uses the "Capability Driven Approach (CDA), a modern approach to information systems development.

In the perception of The Open Group, a business capability is a special ability or power that a business can possess or exchange in order to achieve a specific goal or result. A business capability can be defined by a description of what needs to be done with some details added. The name of the capability is, therefore, proposed as a complex noun, for example, 'resource planning', followed by a brief description of the capability, for example, "the capability to plan organizational resources in order to develop and support business tasks" (Ilin et al. 2020a, b).

A further, detailed definition of the capability requires an understanding of how this can be achieved by combining such supporting components as roles, processes, information, and tools (Fig. 2). It is necessary to take into account that a business capability is determined with the aim of lasting as long as possible, while the content of the components is subject to frequent changes (Sandkuhl & Stirna, 2018).

Authors have already presented before digital platforms classification for different sectors of the logistic industry (Ilin et al. 2020a, b).

Table 1 represents the results of the analysis of maritime logistics digital platforms in the context of CDA.

The categorization given above helps to distinguish different existing digital platforms, based on their capabilities.

Although, as was mentioned above, in the maritime logistic industry exists a number of digital platforms, Capability Driven Approach provides a tool for their classification and a better understanding of their capabilities and resources.

The most widespread are Maritime Community Cloud and technological processing of information platforms. This is obvious as maritime industry has a solid background in data processing and exchange, which is constantly improved and modified, based on industry standards and new technologies implementation.

Single Window concept, as was mentioned before, is also a subject for wide implementation by different countries and authorities, this concept provides tools for industry transparency improvement and faster data exchange.

The newest trend in maritime logistic industry becomes the business ecosystems digital platforms as they provide capabilities of interrelations of different participants

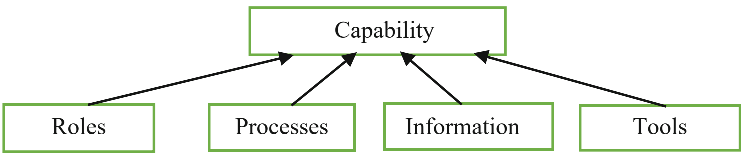

Fig. 2 Aggregation of enterprise architecture components into a business capability (Sandkuhl & Stirna, 2018)

Table 1 Maritime logistics digital platforms classification based on capability driven approach

Capability	Cross-border trustworthy e-services to all commercial ports and their users in a cost-effective way	Functional support of operations	Submission of standardized information and documents with a single-entry point to fulfill all regulatory requirements	Supply chain transparency and agility
Roles	Maritime community cloud	Technological processing of information	Single window	Business ecosystem
Business processes	• Vessel & Cargo Management. • Inland logistics. • Communication at port level. • Integration services. • Security services.	• Navigation. • Vessel registration. • Insurance. • Financing services.	• Obtaining necessary permits and clearance related to import, export or transit-related requirements. • Obtaining international trade-related data and statistics in a comprehensive and timely manner.	• Booking placement. • Cargo tracking. • Rate analytics. • Procurement. • Supply- chain control. • Financing services. • Marketplace. • Obtaining information for custom clearance. • Financing services.
Information	B2B, B2G information exchange on local /national/ regional level	B2B, B2G information exchange on local /national/ regional level	G2G, B2G information exchange on local /national/ regional level	B2B information exchange on local /national/ global level
Tools	Cloud computing, electronical data exchange, big data, robotics, IoT, RFID, sensors, cyber-physical systems, GPS, Blockchain	Cloud computing, electronical data exchange, big data, robotics, IoT, RFID, sensors, cyber-physical systems, GPS, Blockchain	Cloud computing, electronical data exchange, big data, robotics	Cloud computing, electronical data exchange, big data, Blockchain, IoT, RFID, GPS, sensors, cyber-physical systems, robotics, Blockchain

regardless of their location, size, or language, the criterion for their involvement becomes their participation in the transportation process (Ilin et al. 2021). Business ecosystems digital platforms in the maritime logistic industry become a modern tool of collaboration and competition, and their further development will be continued by the various industry and non-industry players.

5 Discussion

Ecosystems and platforms orientation is transforming the economy, including many separate businesses, which is also true for maritime logistics. The organizations, included in the supply chain management, and having enough resources to take the lead, have been developing digital platforms in various forms, which the analysis of research and industrial publications clearly shows.

The question for further research is reviewing and analyzing the benefits, which the ecosystem members receive when using different digital platforms in order both to interact with each other and optimize their own processes. The capability-driven approach, as well as enterprise architecture approach and balanced scorecard, may be used to delve into these issues.

6 Conclusion

Visibility, agility, and transparency are becoming increasingly important for the effective and efficient supply chain management. Together with an increasing number of data from and about different steps and elements of the supply chain, as well as possibilities of digital technologies, the need for integration into ecosystems of different levels in order to get the synergistic effect for overall optimization of the supply chain, becomes obvious and inevitable.

The possibilities of digital platforms for sharing data, speeding up operational processes, as well as improving communication between various participants in the ecosystem, pose an obvious task for market participants to introduce such platforms into their activities. At the same time, the more significant market share a company occupies, the more obvious the task of independent development of such a platform and the subsequent integration of other market participants into its activities becomes. Platforms will definitely change the global maritime logistics market, and this process has been already happening nowadays.

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The Role of Data-Driven Logistics in Arctic Shipping

Klara Paardenkooper

Abstract Modern economic conditions are characterized by a large volume of generated data. The challenge for companies is to make the most of their data, providing a competitive advantage. This is also relevant for the field of logistics, in particular logistics in the Arctic. Data analysis in determining the optimal route, reducing environmental impact, predicting shipping conditions, calculating expected arrival times, assessing risks, and determining ways to reduce their impact, and others, helps to make the most correct business decision. Data-Driven Logistics is used to carry out complex calculations to make an optimal decision. Key digital technologies are used for computing, such as Big Data, Blockchain, Robotics, sensor technology, the Internet of Things, Artificial Intelligence/Machine Learning, and 3D Printing. All of this enables Data-Driven Logistics to help add value to Arctic Shipping while keeping in mind the most gentle impact on the fragile environment of the region.

1 Introduction

Data-Driven Logistics has gained importance in recent years. The reason for this is the increasing conviction that the enormous amount of data produced by the internet and diverse sensors (Big Data) represents a major value for companies (Vicario & Coleman, 2020). Data is also called the new oil, the new fuel for the economy (Borst & Verbene, 2019). Companies that are not able to exploit their data will lose the competition (Vicario & Coleman, 2020). This is especially true for the logistics sector, which has major inefficiencies, especially in the field of capacity optimization, cooperation, and transaction costs. This traditionally conservative sector increasingly acknowledges the potential of Big Data and there have been numerous articles written on the use of data in different subdomains of logistics and supply

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chain management (Hamister et al., 2018; Hazen et al., 2016; Song et al., 2021) However, there is no clear definition of Data-Driven Logistics to be found in the literature yet. The working definition of Data-Driven Logistics in this chapter is data-driven decision-making in the logistics domain, aiming to create value from existing data and mining additional data to create more value. Thus, Data-Driven Logistics is closely connected to data science, which is defined by Vicario and Coleman (2020) as “a science offering methodologies for processing and interpreting massive volumes of data collected by an increasing number of new devices.” Data Science has a quantitative approach and belongs to the domain of mathematics and statistics. Data-Driven Logistics, as defined here, on the other hand, has a qualitative approach and focuses on the connection between the business model and data in the logistic domain. Its results are not calculations, but a system design. Which data and which technologies are necessary to create value?

The emerging possibilities of Arctic Shipping provide major opportunities to make global transport flows more efficient and sustainable. The shrinking ice gives more space for transport, especially because it is expected that the Arctic seas will be nearly ice-free during the whole year by 2050 (Marchenko et al., 2018). Consequently, the Arctic seas are becoming increasingly safe for navigation. Since 2005, Arctic shipping has been growing significantly, especially in September, when there is a minimum of ice coverage. The Arctic route has several advantages. The navigational distance between East Asia and Europe via the Arctic Northeast Passage is 30–40% shorter than the present route via the Suez Canal, 40–50% shorter than the Panama Canal route, and 50–60% shorter than the route around the Cape of Good Hope. The Arctic route especially offers a major shortcut to ships that are too large to pass the Suez Canal and as the only option, they can round the Cape of Good Hope. This way, the distance can be reduced, which leads to the reduction of fuel and operational costs. Furthermore, the Artic route does not have fees and ships do not need to pass politically unstable countries and there is no piracy at the Arctic seas (Zhang et al., 2019). As opposed to these advantages, there are disadvantages too, such as harsh weather, remoteness, and vulnerability of nature. Even though the projection is that the Arctic Seas in the long run will be ice-free, presently there is still a danger of ice movements and the route is not available during the whole year, only seasonably. Furthermore, the Arctic seas are situated between multiple countries, which also poses regulatory challenges (Marchenko et al., 2018).

This chapter focuses on exploiting the advantages and mitigating the disadvantages of the new Arctic Route using Data-Driven Logistics. The central research question is: How can Data-Driven Logistics create value for Arctic Shipping? After this introduction, Sect. 2 elaborates further on Data-Driven Logistics, exploring the following subjects: its definition and function, the classification of its parts followed by the explanation of the separate parts, Big data, Blockchain, Robotics, Sensor technology, Internet of Things, Artificial Intelligence/Machine Learning, and 3D printing. Section 3 describes the specific challenges of Arctic transport, namely, route choice, environment, navigability, calculating the expected time of arrival, and risk analysis. In the discussion in Sect. 4, the research question is answered by describing how Data Drive Logics can help add value to Arctic Maritime Shipping and what the impact is of the needed actions. Section 5, the conclusions summarize the chapter.

2 Data-Driven Logistics

This section explains Data-Driven Logistics, first its definition and function, followed by an inventory and explanation of its techniques, Big data, Blockchain, Robotics, sensor technology, Internet of Things, Artificial Intelligence/Machine Learning, and 3D printing.

2.1 Definition and Function

Data-Driven Logistics is a recently introduced notion, which has not been clearly defined in the literature yet. The working definition in this book of Data-Driven Logistics is data-driven decision-making in the logistics domain, aiming to create value from existing data and mining additional data to create more value. Especially the last part of the definition is important, data should be closely aligned with strategic goals and the value propositions. The introduction of Web 2.0, Industry 4.0, the Internet of Things (IoT), and other related digital technologies makes it possible to aggregate large amounts of data from different sources. A recent International Data Corporation (IDC) forecast predicted that investment in Big Data technology will grow yearly with 26.4% annual, reaching $41.5 billion through 2018. There is a close relationship between the size of the data and its usefulness, the more data, the better predictions. Big data analysis has a direct relevance for logistics, recent literature has developed different tools and techniques to make data-driven supply chain management decisions. Real-time analysis and interpretation can assist enterprises in making better and faster decisions. It will also help organizations to improve their supply chain design and management by reducing costs and mitigating risks. Recently, various research studies have indicated the benefits of using big data methods in logistics and supply chain management, for example in effective logistics planning, scheduling, and tracking technologies (Govindan et al., 2018).

There has been a growing focus on data-driven decision-making in the literature since the 2010s as due to the availability of major data sets better decision-making became possible. Data is mostly raw data, from which information needs to be derived using different analysis techniques. Interpretation of this information provides a better understanding of the facts. This leads to better interpretation and better predictions. While in the past decision-making was mostly based on experience and intuition, the availability of different data sets from different sources allows decision-makers to make better-informed choices (Yang, 2020). A US survey carried out by KPMG and based on a sample of 400 CEOs highlighted that approximately

77% of them harbored mistrust about the quality of the data upon which their decisions are based (Vicario & Coleman, 2020). This shows the importance of collecting, combining, aggregating, and analyzing data for better decision-making.

2.2 Classification

Data-Driven Logistics operate using diverse devices and technology, such as Artificial Intelligence/Machine Learning, Big Data, Internet of Things/sensor technology, Blockchain, Robotization, and 3D printing. Before explaining all of them, it is useful to understand how data is collected and analyzed for decision-making, what the function of these devices and technologies are in it. Digital supply chain networks need to collect, process, communicate and store data from different sources. For this, it is necessary that the data is digital, that there is a possibility of electronical, real-time data exchange (Manners-Bell & Lyon, 2019).

Data-driven logistics operate according to a cycle, starting from a data source. The data source can be information technology systems, such as an Enterprise Resource Planning (ERP) system, sensors, such as temperature and humidity, operational tools such as machines and robots, news from social media, financial data such as transactions data. The data sources can come from within or outside the organization (Manners-Bell & Lyon, 2019). At this point, the data quality is an important challenge. Data analysis may seem to be smart, but it cannot recognize incorrect data or human errors. It is garbage in, garbage out. That is why it is better to use data collected by (well-calibrated) scanners and sensors. Providing valuable data largely depends on the level of automation, there should not be human interaction. The next step is storing the data. This step is often forgotten; however, it is essential that the source and processed data are stored safely. Data processing technologies aggregate and analyze the data and sometimes make decisions themselves or the decision is made by human interaction. The advancement of technology is making human interaction increasingly superfluous. Finally, the decision is performed, data processing technologies that make data-driven decisions and automated physical devices, which perform the actions, according to the decisions. Some technologies perform the combination of or even all of the tasks. The performing of the tasks is a data source themselves, which can be monitored by sensors and scanners and so the cycle repeats. The overview of the technology can be seen in Fig. 1.

According to this circle, the different technologies and devices can be classified. Big data, as opposed to big data analytics, is a data source and needs to be stored. Blockchain technology, being a database, operates as a data source, is dependent on data sources and sensors for data collection, it stores data, it analyses whether it corresponds to the rules of the transaction and can perform an action if smart contracts are included in it. Robots collect information and perform actions communicated to them. Sensor technology is limited to collecting data, while the Internet of things technology collects, stores, analyzes, and sometimes performs the decisions. Artificial intelligence (AI) and Machine Learning (ML) analyze data and help or

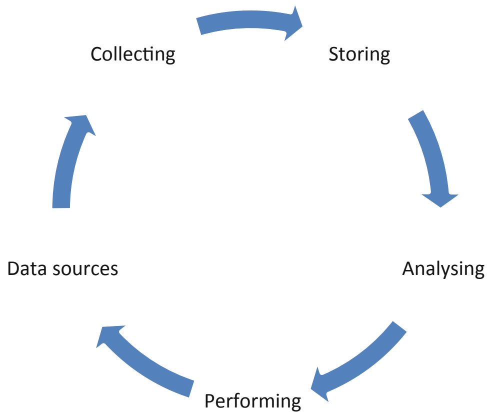

Fig. 1 An overview of the cycle of data-driven logistics

Table 1 The classification of the technologies and devices

Technology	Data source	Collecting	Storing	Analyzing	Performing
Big data	X	–	X	–	–
Blockchain	X	X	X	X	X
Robotics	–	X	–	–	X
Sensor technology	–	X	–	–	–
Internet of things	–	X	X	X	X
Artificial intelligence machine learning	–	–	–	X	–
3D printing	–	–	–	–	X

automate decision-making. 3D printing is a manufacturing process using major design data sets. Table 1 gives an overview of the classification of the technologies and devices according to their role in the cycle.

This classification is made in order to clarify the functions of different Data-Driven applications and devices; however, the division is quite artificial as there is a lot of overlap between them. Figure 2 gives an overview of the overlap.

The common denominator is Big Data. All the technologies either produce and/or consume major data sets. 3D printing is a part of robotics, as it performs an automated manufacturing action. Robots can communicate with Blockchain systems for example for the performance of an action automated by a Smart Contract. Robots heavily rely on sensor technology for example for their navigation, while blockchain only makes sense, when there is reliable data is stored in it for example collected by sensors. Sensor technology in its turn is a part of Internet of Things Technology, thus being a possible part of a Blockchain system, while Artificial Intelligence and Machine Learning are used to interpret and analyze the data from IoT systems, which in their turn can be a part of a blockchain system too.

A combination of these technologies results in cyber-psychical systems, which means that the physical assets are assigned a digital identity, which is communicated

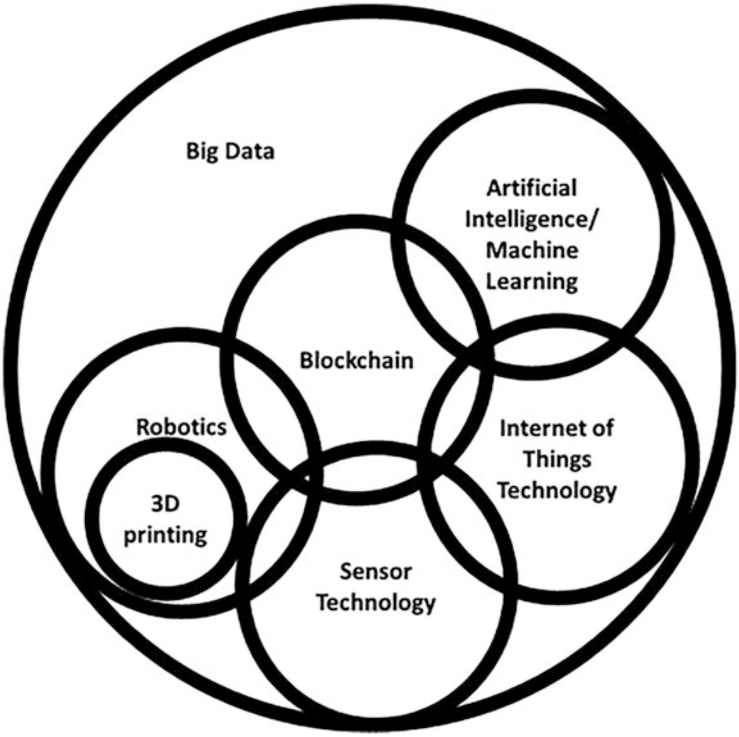

Fig. 2 Overlap between the technologies and devices

in the system. The physical and the digital identity are connected by tags, which can be read by scanners, forming an Internet of Things network, which is stored in a cloud. This way the physical and the virtual world are united in a joint system (Manners-Bell & Lyon, 2019).

2.3 Big Data

The availability of cheap sensors has made it possible to collect massive data sets. Big data can be characterized by five V's: Volume, Velocity, Variety, Veracity, and Value. Volume can vary according to industry and type of case. Velocity refers to the speed of data collection. By variety the diversity of the data is meant, it can consist of, for example, images, sensor or location data, or encrypted files. Veracity refers to the trustworthiness of data. Because of its quantity, it is impossible to evaluate the data quality manually; however, algorithms are getting increasingly better at screening data. Value is an important aspect of big data as analytics should make it possible to extract profits from the information derived from the data (Sinha et al., 2020). The value creation happens mostly by automated decision-making, which works best without human interference. The amount of data that is being aggregated is simply too much to oversee for humans. Big data analysis could be done on for example rerouting in the supply chain, planning preventive maintenance for transport units of determining the storing place for a product in a warehouse. The calculations are made by a set of algorithms without human interference (Manners-Bell & Lyon, 2019) Big data is used in maritime transport for example for maritime data management infrastructure, automatic identification systems, optimizing escape routes, e-navigation services, tracking unidentifiable ships, and to improve navigational strategies (Sanchez-Gonzales et al., 2019).

2.4 Blockchain

Blockchain is most well known as Bitcoin, which has recently grown steadily in value. However, Bitcoin is only one type of blockchain. Blockchain in general is a peer-to-peer ICT network that keeps records on digital transactions of assets using Distributed Ledger Technology (DLT) DLT means that there is no central party or intermediary, that would own the data, the exact copy of the dataset is stored at a number of computers, called nodes. At the nodes, the transaction history is kept. This, in combination with its protection by cryptographic algorithms makes it safe from tampering. Hacking is made almost impossible by the fact that the blocks of transaction history are connected to each other, which makes hacking one block useless, and that the records are verified by a consensus algorithm, which means that in order to make a change a minimum of 51% of the nodes needs to be hacked (Min, 2019). Blockchains can be categorized in different ways, they can be public or private, permissioned or permissionless. Bitcoin is the most often discussed blockchain, however, it is together with the other cryptocurrencies a particular application, a public permissionless system. Because of this, the number of its participants is almost limitless, which has consequences for its consensus algorithm, called proof-of-work. This algorithm, in order to guarantee the safety of the system, requires miners with major computational power who make the transactions possible. (Pilkington, 2015) As private blockchains are working with a limited number of nodes, they require a lot less computational power to make the transactions possible and no mining is necessary. For logistics applications the private permissioned systems are used most often; however, open systems are expected to be used in the future (Castellon et al., 2019; Paardenkooper, 2020). The most important advantages of blockchain networks are fast and cheap transactions, the becoming superfluous of intermediaries, supply chain transparency, and connectivity between supply chain partners. However, blockchain still faces some challenges too. For example, there is a lack of organizational readiness (Min, 2019). This can be explained by the fact that Blockchain technology has not reached maturity yet, it has just passed being a hype. According to Gartner (2018), it is likely to be applied widely in 5–8 years. On Gartner's curve, it is on its way to the trough of disillusionment, as it is increasingly recognized that blockchain is no magic solution to all problems (Gartner Hype Cycle, 2018). This is in accordance with Capgemini (2018). It explains that in 2018 the only a minority (23%) of Blockchain applications were developed past a proof of concept (Capgemini, 2018). Additionally, blockchain still suffers from the lack of scalability and financing (Min, 2019).

Blockchain has numerous applications, in health, education, privacy and security, business and industry, data management, finance, integrity verification, governance, and internet of things (Casino et al., 2019). In the academic literature, this innovation is often mentioned as an enabler of more efficient logistic processes. There are numerous possible applications, it can make paper documentation superfluous, combined with sensors it can be used for tracking and tracing, it has financial applications and it can help to automate processes using Smart Contracts. Kshetri (2018) identifies the benefits of the application of blockchain in the supply chain as costs, speed, dependability, risk reduction, sustainability, and flexibility.

An important aspect of blockchain within Data-Driven Logistics is its quality to store data in secured, time-stamped blocks, which makes it possible to trace transactions in a reliable way. As mentioned earlier, the quality of data is essential for the prediction accuracy of Big Data Analytics and for data sharing (Sinha et al., 2020). Blockchain gives the security that the stored data cannot be tampered with. However, blockchain has a weak point; the data can be manipulated before entering it into a blockchain. This emphasizes the importance of collecting information from reliable sources, such as scanners and sensors (Kopyto et al., 2020). A possible application of blockchain in maritime communication, which reaps the benefits of safe data communication provided by blockchain is described by Rahimi et al (2020) as a secured communication system for Unmanned Maritime Vessels (UMV) in order to make it impossible to hijack them (Rahimi et al., 2020). Other applications of blockchain for maritime shipping include an electronic Bill of lading and the earlier mentioned container tracking; however, these applications are not specifically meant for Arctic Maritime shipping.

2.5 Robotics

Robotics includes industrial automation solutions and self-driving cars, drones, and robots for different household applications. According to Merriam-Webster, a robot is "a device that automatically performs complicated, often repetitive tasks." Robotic systems are best known to be applied in warehouses (Sinha et al., 2020). Automating processes are meant to let robots perform repetitive, tiring, or dangerous tasks. This means that both humans and robots can do what they do best, robots are best in precise tasks and humans in problem-solving, creativity, and innovation (Manners-Bell & Lyon, 2019). Within logistics, robots are mostly used for handling and process operations. Robots can be autonomous, in this case, as mentioned earlier, Artificial Intelligence is included. This is still a developing area; however, there are already applications, such as autonomous surveillance robots for energy efficiency and leak monitoring. The introduction of robotics has been criticized as they will probably lead to a loss of employment, even though they will also create new jobs. At the same time, they can reduce, for example, annual maintenance costs by 10%, inspection costs by 25%, and downtime by 20%. Sinha et al. (2020) point out a few possible applications of robotics in combination with AI, of which the following are relevant for this chapter: Data-driven supply chain planning, route optimization and delivery planning using real-time data, automated risk monitoring, zero downtime by data-driven predictive and preventive maintenance and real-time tracking of cargo (Sinha et al., 2020). Application for maritime shipping includes the use of areal and marine unmanned devices to mitigate disasters, which is especially relevant in remote arctic waters with harsh weather conditions (Murphy & Arkin, 2017).

2.6 Sensor Technology

There is a large variety of sensing devices from simple thermo-sensors to advanced video systems. The main reason for the growth of IoT technology is that the sensors are becoming smaller and of affordable price. There are simple sensors with straightforward input–output systems, such as diverse temperature sensing devices, photoelectronic sensors, detecting light, warmth, distance, movement, voice, and pressure sensors. Another category of sensors is smart sensors, such as vision systems, which generate a more complex output. The data from different sources can be combined by sensor fusing, which makes information from the data. For example, it can indicate that somewhere a crowd is forming with temperature sensing. Time correlated data from multiple sensors can facilitate decision-making (Lea, 2020).

In maritime practice, sensors are used for tracking containers, checking, whether they have been opened and whether the transported goods are in good condition. Sensors can be attached to devices to perform predictive maintenance, do self-diagnostics, and if necessary order new parts themselves (Manners-Bell & Lyon, 2019). Sensor technology in Arctic Shipping can be used for diverse purposes, for example, to collect real-time data on weather conditions, the importance of which will be explained later in the chapter.

2.7 Internet of Things

The Internet of Things (IoT) is a term related to the use of sensors, technology, and networking to allow buildings, infrastructures, devices, and additional “things” to share information without requiring human-to-human or human-to-computer interaction. It can create richer data and deeper intelligence for all parties in a supply network. Sensors can be attached to appliances to perform predictive maintenance (Manners-Bell & Lyon, 2019). IoT technology is used in maritime shipping for example the tracking of containers in combination with Radio Frequency Identification (RFID) technology (Sanchez-Gonzales et al., 2019).

2.8 Artificial Intelligence/Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) contribute to automatization on the cognitive level thus they can be called cognitive automation, as opposed to robotics, which is physical automation. AI and ML date back to the 1950s when they were described as problem-solving without specific programming for the task. This definition is still used. Ever since they were developed further, with a dip in the 1960s to the mid-1980s. Since then, due to the emergence of neural networks, AI algorithms and applications have been growing steadily. AI and ML are often confused, the difference is that AI is a concrete application in a specific domain using ML to process data and produce insights independently from human interaction, while ML is a general adaptive, intelligent automated system. This means that ML is a part of AI based on statistics, mathematics, and visualization, using different algorithms to produce insights from big data (Manners-Bell & Lyon, 2019). AI is used in maritime shipping for example for dynamic positioning systems, navigational aids, alerts, and fleet risk management (Sanchez-Gonzales et al., 2019).

2.9 3D Printing

The connection of 3D printing to data-driven logistics is twofold; first, the printing process is fed by massive design data, second, 3D printing has a major impact on logistics. It is also called additive manufacturing, as opposed to derivative technologies, which remove parts of the material in order to make a product. 3D printing works by building a product layer by layer and was initially developed for making prototypes. 3D printing has numerous advantages, it can be set up fast and the manufacturing process itself is also quick, the production needs less tools, the products are lightweight, but still strong, the products are printed in one piece, and computer-aided designs can be optimized easily. Furthermore, because of its additive nature, it produces hardly any waste. 3D printing also minimizes supply chain risks as the supply chain is shortened, and the inventory can be reduced. The designs made this way can be easily adjusted to the individual needs of customers offering ample possibilities for customization. There are technologies available for a broad scale of materials, from plastic to polycarbonates. The most well-known technologies are selective Laser Melting and Direct Metal Laser Sintering. The adoption of the technology has still some limitations, for example, because it is difficult to control whether the locally produced products fit quality standards. 3D printing is a typical disruptive technology, that has the potential to revolutionize supply chains, especially that of spare parts. This means that instead of semi-finished or ready products, raw materials will be transported and the products can be manufactured close to the customers. According to a Deloitte report from 2018, 3D printing will be used most widely in the car, aerospace, and defense industry. Manners-Bell & Lyon

(2019) estimates that the market of 3D printing will grow from 13 billion USD in 2016 to 36 billion USD in 2021.

3D printing has a major potential in the shipping industry, as maritime assets are capital intensive and their downtime is costly. As ships are mostly far away from ports and they are moving, they are comparable to aircraft, aerospace, and defense units, where 3D printing has been applied before successfully. This is especially true for Arctic maritime shipping, which operates in remote areas. The fact that there is a possibility to produce spare parts on board or in close-by ports simplifies spare parts inventory management. Printing spare parts for ships has been tested extensively, a pilot project resulted in printing seven maritime parts in 2017 and the world's first-class approved 3D printed ship's propeller was manufactured at Damen Shipyard in the Netherlands in 2017. The US navy has also tested 3D printing for maintenance purposes. The technology is still improving and it is not yet used widely, however, it has major potential (Kostidi & Nikitakos, 2018). What 3D printing has to offer to Arctic shipping is on board in a close-by port printing of spare parts, which decreases repair costs, reduces risks and downtime.

3 Data-Driven Logistics and the Challenges of Arctic Shipping

This section describes five challenges of Arctic shipping and explains existing data-driven solutions for them, route choice, environmental friendliness, navigability, the prediction of the expected time of arrival, and risk assessment.

3.1 Route Choice

The Arctic Route provides a new alternative to the Suez Canal Route and rounding the Cape of Good Hope during a growing part of the year. Due to economic reasons, it is of major importance for shippers to choose the right route. The decisions are increasingly data driven as a lot of variables need to be included and there is a growing pressure on the profit marge in maritime shipping, caused by fluctuating capacity, increased shipper demands, and disruptions within the industry creating a volatile environment. Both shippers and forwarders are increasingly using information and analytics to drive their decisions. According to a survey in 2018 71% of shippers, said that real-time data analytics from third-party logistic providers help them make better choices, and 61% gave high value to the service providers' assessments of trade lanes. In the survey, nearly all logistic service providers and shippers indicated that data-driven decision-making is essential for the future of supply chains, and that big data analysis skills will be needed in the future for their supply chains (Govindan et al., 2018).

The route calculation needs to be made on more levels. The first one is, which global route to take: the Suez Canal, Cape of Good Hope, or the Arctic route. The second level is which particular Arctic Route to choose. The Arctic route has several advantages in comparison with the Suez Canal and the Cape of Good Hope route. Taking the Arctic Route can reduce the transport times between East Asia and Europe compared to the Suez Route by 10 days and the distance by approximately 5000 km (Zhang et al., 2019). Due to the reduction of ice, even the sailing times are expected to be reduced, by the mid-twenty-first century, summer season sailing times along the route via the North Pole are estimated to be only 13–17 days (Aksenov et al., 2017). The shorter transit time helps reduce fuel and operations costs. When speed is not a critical issue, a lower navigation speed can even cause more savings than the reduction of navigation time. Especially cargo bulk vessels can benefit from this as they depend less on precise schedules for loading, shipping, and unloading to keep costs down. An extra advantage of the Arctic route, as opposed to the Suez Canal route, is that there are no fees and there is no piracy on the Arctic Seas. However, there are more variables to consider to make a good analysis. The main costs for Arctic maritime transportation consist of fuel costs, ice-breaking costs, operating costs, and vessel depreciation costs. Fuel costs depend mainly on sea ice conditions and navigational distance combined with speed. The navigational speed can be calculated using the Arctic Transport Accessibility Model. As ice conditions are constantly changing, the calculation needs to be done over and over again (Zhang et al., 2019). The fuel costs can be reduced by fuel efficiency, for which there are several solutions. To reduce fuel consumption, shipping lines have taken various measures, including slow steaming, virtual (just-in-time) arrival at ports, weather routing, hull and propeller cleaning, engine maintenance, and optimization of the operating plan for each ship or fleet. Furthermore, there is an option to develop artificial neural networks that optimize fuel efficiency by advising ship captains on optimal speed. This measure can cause fuel savings of 7–8% (Du et al., 2019). The Arctic ice-breaking fee depends among others, on vessel size, ice class, and the chosen route. The main operating costs include loan costs, hull and machinery insurance, protection and indemnity insurance, repairs and maintenance, administration, and other costs. Vessel depreciation costs and operational costs can be increased by harsh weather and fog. The choice between the different Arctic Routes should be made based on data from remote sensing observations and predictions of global or regional models. The calculations are different according to ship type, and their ice classification. However, according to Zhang et al. (2019), cost-benefit analyses are still immature and need more research. He pleads for establishing a big data-driven Dynamic Optimal Trans Arctic Route system, which combines sensor and satellite data from diverse sources to determine the optimal route on the Arctic Seas (Zhang et al., 2019).

It can be concluded that decision-making for the route choice includes numerous variables and for making the choice a combination of a major amount of Big Data is needed. The cost-benefit analyses need to be developed further and there is a need for a Cyber-physical system that can combine sensor and satellite data for finding the optimal route on the Arctic seas.

3.2 Environment

Up till now the internal costs, the ones that are paid for, of Arctic Shipping have been discussed. However, the external costs, the ones that the shipping causes but does not pay for, are equally important. The most important external cost of Arctic Shipping is the cost of CO_2 emissions. In spite of the reduction of the distance, choosing the Arctic route does not necessarily make transport more sustainable, as making use of an icebreaker produces major black carbon emissions and produces local pollution, which contributes to the further warming of the Arctic seas (Zhang et al., 2019). According to Yumashev et al. (2017), even though large-scale commercial shipping on the Arctic Seas will be probably only possible from mid-2030 for bulk carriers and from 2050 for small and medium-size container ships climate feedback from Arctic shipping can cause $2.15–1400 trillion extra negative impact for global climate change until 2200, depending on the climate scenario, which is the third of the expected global economic gains projected for Arctic Transport. Reducing global emissions would slow down the melting of the sea ice, which would reduce the economic gains 3.5 times, but reduce the emissions five times (Yumashev et al., 2017). Thus, there is a tradeoff between the external costs of transportation and the commercial gains. At least improving fuel efficiency is of utmost importance, as maritime transportation is a major source of emission. According to the International Maritime Organization (IMO) in 2012 maritime ships emitted worldwide 949 million metric tons of CO_2 which is 2.7% of the total emissions (Du et al., 2019). According to Schøyen and Bråthen (2011) the choice for the Arctic Route, can more than double the fuel efficiency and deduce the CO_2 emissions by 49–78%. However, the saving in fuel will not necessarily lower the costs, because of other factors, such as higher building costs for ice-classed ships, service irregularity and slower speeds, navigation difficulties, greater safety risks, and most importantly, fees for icebreaker services (Aksenov et al., 2017; Schøyen & Bråthen, 2011).

Schroder et al. (2017) are optimistic about the relation between travel time and fuel consumption; they claim that it will cause major fuel savings which will only increase in the future. According to them, a contributing factor to fuel efficiency is the safe speed at areas with an ice coverage, which is lower than at the Suez Canal route. Slow steaming causes lower fuel consumption and exhaust gas emissions. However, outside September, the fuel consumption is higher for low ice class vessels. In order to predict future scenarios, the development of sea ice conditions needs to be explored (Schroder et al., 2017).

Concluding it can be stated that due to the reduction of distance, the choice for the Arctic Route on one hand causes a reduction of CO_2 emissions, and on the other hand causes extra emissions, as ice breaker services are necessary. Furthermore, the chosen speed has a strong influence on the emissions, which in its term depends on the ice conditions. In order to minimize the emissions, it is necessary to calculate the CO_2 emissions for the different routes well, so that a choice based on these external costs can be made.

3.3 Navigability

The route choice also depends on the navigability of the Arctic Seas. Due to global warming, sailing the Arctic Seas is becoming increasingly commercially feasible, especially in the summer season. However, harsh weather and sea ice still endanger arctic shipping, for example, ships can get trapped in ice. As the movement of sea ice depends among others on currents and winds, and other parameters, their location is continually changing. Therefore, a good prediction of the position, volume, thickness, and drift patterns of sea ice is of utmost importance (Zhang et al., 2019). Despite a general tendency toward less sea ice cover in summer, internal variability will still be large, and shipping along the Northeast Passage might still be disturbed by sea ice blocking narrow passages. This will make sea ice forecasts on shorter time and space scales and Arctic weather prediction even more important (Gascard et al., 2017). The prediction should be based on real-time datasets gathered by remote sensing devices. Large datasets of weather and climate modeling can help make a short-term forecast and long-term prediction on changes in Arctic sea ice and related weather and climate conditions. These can be included in dynamic maps, which helps the captains of vessels to avoid icebergs and sea ice, in order to reduce risks, save time and fuel and reduce operational costs (Zhang et al., 2019).

Concluding it can be stated that even though the navigability of the Arctic Seas is increasing, there are still major challenges caused by weather and ice conditions, which makes it important that these are monitored well to be able to make good predictions about navigability. For these predictions, a combination of massive amounts of historical and real-time data from different sources is needed.

3.4 Calculating the Expected Time of Arrival (ETA)

As mentioned earlier, presently, the Arctic Route is mostly used by bulk carriers. In order to make the Arctic Route attractive for break bulk and container ships, a precise calculation of the Expected Time of Arrival (ETA) is necessary. Container vessels depend heavily on as exact as possible scheduling, especially if they are a part of a Just-in-Time delivery system. Thus, for container transport, it is important to manage uncertainties. Uncertainty in maritime shipping can have five sources, the shipper, the customer, the control systems, carrier, and external environment. Delays are mostly caused by large and infrequent deliveries, delays in loading–unloading, variability of shipment time, damages, accidents, etc. (Urciouli, 2018). On the Arctic seas, ice movements and a safe traveling speed add to the delaying factors.

The calculation of the ETA consists of a predictive and a prescriptive phase. The predictive phase can start already when the order is placed and the bill of lading number is issued. Firstly, historical data about the proposed route is collected, which makes it possible to calculate the sailing time. The calculations need to be redone, when new information about the route becomes available. The adding of new data makes the results dynamic. Unlike for rail and road transport, for the calculation of maritime ETA, no topographic network information is available; consequently, it needs to be based on the dynamic scheduling and routing applied today by shipping companies. Based on this a proposed route needs to be identified. The next step is to collect historical information about the past delays of vessels on this route. Then again, real-time information needs to be collected based on a risk analysis of the historical information. Real-time information can be obtained from maritime traffic web services, which provide data gathered from satellite and terrestrial AIS that are publicly shared by vessels during the shipments. Further data that can be collected is GPS position, latitude and longitude, gross tonnage, deadweight, maximum and average speed, wind speed and direction, and temperature. Then the collected information about risks, weather conditions, and interrelationships with vessel performance are updated based on the real-time information collected. Machine learning algorithms can be used in this step in order to ensure that correlation factors with vessel performance are also updated. Delay times are estimated for both traveled routes and loading/unloading time necessary in seaports. The analyst initially computes the risk-free traveling times of vessels along the route, thereby proceeding by combining the risk-based traveling time estimations. Compute ETAs. The predictive or prescriptive algorithm will compute and return the estimated expected times of arrivals. The computed ETAs are then visualized in a dashboard to facilitate user interaction and decision-making (Urciouli, 2018).

This section has shown the importance of the correct calculation of the ETA. This complex sequence of calculations also needs massive data sets. The delay calculation can be made difficult by the lack of historical information on this route and for the Arctic route, the weather conditions also need to be taken into account, which means that the calculation needs to be combined with the calculations on navigability, mentioned in the previous section.

3.5 Risks Assessment

Due to the shrinking ice at the Arctic Seas, the maritime traffic of oil and gas, other cargo, fishing and passenger vessels is increasing, which impacts risk patterns. Risk assessment is essential to prepare a suitable level of emergency response. This involves both private and governmental involvement. The Arctic Council's Search and Rescue (SAR) Agreement divides the region into five areas that largely differ in environmental, ship traffic, and infrastructural aspects. An influential aspect is the upcoming Russian Arctic offshore oil and gas industry. Risk assessment estimates the amount of damage that can occur in a time period caused by a certain event. Risk is defined as the probability of an incident, multiplied by the damage that it causes. After determining and analyzing risks, a mitigation strategy should be developed. Risk assessment in the Arctic Region is complicated by the lack of historical data, and dynamic weather conditions. The most common risks are grounding, collision, which also includes colliding with sea ice, violence, which is rare in the region, and construction and engine failure. The cold climate can be especially harmful to humans in an emergency situation; the danger of hypothermia needs to be considered when planning emergency action, as even people in good body condition have problems surviving after 24 hours in a life raft. However, historical data on accidents does not involve occurrences, that have not happened yet, the so-called “Black swan” incidents, which are especially interesting for risk analysis. For this reason, a risk assessment can be performed best by the combination of quantitative, historical, and qualitative, derived from interviews with experts, information. For a reliable risk assessment according to Marchenko et al. (2018) the following variables are necessary: the density of maritime traffic, the capacity of fishing vessels, the size and number of cruise vessels, both for commercial and scientific purposes, the number of oil and gas exploration licenses issued, cross border government and industry regulations the efforts of international, local governmental and industrial efforts to increase safety and the availability of emergency response in the different areas. Risk assessment helps to plan the emergency response capacity, development of rescue equipment, communication, navigation, and coordination resources (Marchenko et al., 2018).

The role of Data-Driven Logistics for risk assessment and the development of an emergency response is twofold. An Artificial Intelligence system can help optimize risk assessment algorithms and robotized systems can assist in the emergency response, in tasks, which are too dangerous for humans. However, the prerequisite is again, the availability of data to perform these tasks.

4 Discussion

As explained above, Data-Driven Logistics can add value by collecting relevant real-time data by the Internet of Things technology, using sensors creating Big Data sets, analyzing the data using Machine Learning and Artificial intelligence, constantly improving the algorithms for decision-making on which is the best and most environmentally friendly route, the ETA and the risks. The potential for Blockchain can be best used in the maritime supply chain for electronic Bill of Lading, paperless solutions, circumventing middle man, generally improving the information flows. This application will reduce transaction costs and improve the maritime supply chain. However, this application is not specific to the Arctic route. In the field of robotization, the use of drones and 3D printing have special benefits for Arctic transport due to the harsh weather conditions, for dangerous tasks, collecting real-time data, delivering packages, producing spare parts on board of ships in remote areas. The operation of these assets can be partly driven by aggregated big data for example about weather conditions. For all these applications this data should be made available to all involved parties.

In order to finally answer the central research question of this chapter—How can Data-Driven Logistics create value for Arctic Shipping?—the potential of Data-Driven Logistics technologies and devices are matched with the major challenges or

Arctic Shipping. First, the question raises, what is value? Based on the section on the challenges of Arctic Shipping the value can be defined as optimization of distance, lead time, costs, fuel consumption, the minimization of CO_2 emission, and risks. In short, this means that the Arctic Route should be chosen when it is the shortest, fastest, cheapest, most environmental friendly, and safest option, as opposed to the alternative routes. This means that in order to spare the fragile environment of the Arctic Seas, this route should be only taken, when there is a strong economic and environmental case to be made for it. In order to make the decision, massive calculations need to be made, on different topics. Furthermore, the challenges are interrelated. The route choice has a major impact on the environment, navigability influences the route choice, just like the calculation of the ETA. Risk prediction also influences route choices and insurance fees, which on their term have an impact on transport costs thus also on route choice. In order to be able to make a decision on these complex issues, both historical and real-time data need to be combined from different sources. The currently available data are not sufficient for this.

However, the question is, which party is going to collect and disclose this data? To start with, setting up such a cyber-physical system requires major investments. Data collection is possible by satellites, onshore and offshore radars, and different sensors attached to maritime devices. The data should be stored and made available for multiple parties. However, as data are increasingly considered a major asset that can generate comparative advantage to parties against their competitors, why would parties make it available free of charge to their potential competitors? This is an economical consideration. The environmental consideration is that in order to decrease CO_2 emissions to the minimum, all parties should be able to optimize their processes, which is opposite to the economic argument. There should be a compromise found in this question, in a way that all stakeholders can benefit, both companies and the global environment. The goal is, as Urciouli (2018) proposes: "The ultimate goal is to develop digital ecosystems combined with sensor data to allow companies, including suppliers, logistics service providers, transport carriers, freight forwarders, manufactures to jointly and openly share data, improve visibility, and optimize operations" (Urciouli, 2018). In this case, it includes a lot more parties, for example, oil companies, shipping lines, local and international organizations and authorities. Further research is needed on how to operationalize this, including an underlying business model.

5 Conclusion

In this chapter, Data-Driven Logistics is defined, its function is explained and seven of its parts are elaborated on, Big Data, Blockchain, Robotics, sensor technology, Internet of Things, Artificial Intelligence/Machine Learning and 3D Printing, followed by a description of five major logistic challenges of Arctic Shipping, Route choice, environment, navigability, calculating the expected time of arrival and risks and their possible solutions. As shown, in the case of all of the five challenges, complex calculations need to be carried out for an optimal decision-making. These calculations are based on economic considerations and concentrate on the internal costs of transportation. To calculate the external costs, especially the CO_2 emissions, require more, even more complicated calculations. These calculations are based on the combination of different data sources, both historical and real-time; however, the insufficient availability of the data obstructs the optimization of the processes. The chapter concludes that in order to optimize the shipping process, a cyber-physical system is needed in which both historical and real-time data is made available to parties, to be able to make decisions on shipping routes, which will both serve their economic considerations and spare the environment as much as possible. Further research needs to be done on the operationalization of the cyber-physical system. Notwithstanding, a case could be made that the whole process of global supply chains could be changed by reshoring production, and place it close to the consumer, by for example customized 3D printing, which would change global production and consumption patterns in a way that a lot less emission creating transport is necessary. That way, the vulnerable Arctic environment does not need to be compromised at all.

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Innovations in Self-Organizing Maritime Logistics

Berry Gerrits and Peter Schuur

Abstract Maritime logistics, where competition is fierce, is in dire need of efficient modes of transport. Automated systems are inevitable, ultimately developing themselves into self-organizing logistic systems. This chapter highlights some promising recent innovations in that area. As innovative automated systems, we discuss: (i) autonomous yard tractors, (ii) unmanned cargo aircraft, (iii) truck platooning, (iv) autonomous vessels, and (v) extended gates. To control these systems, we discuss innovative forms of intelligent decision-making, namely: (i) distributed planning, (ii) matching platforms, (iii) cooperation between barges and terminals, (iv) shared services and fair optimization, and (v) gamification in container supply chains. Moreover, we design a unifying framework that classifies automated systems within maritime logistics according to their potential to grow out to self-organizing systems.

1 Introduction

This chapter focuses on promising recent innovations in maritime logistics. We discuss innovations based upon two pillars: automated systems and intelligent decision-making. We show how these pillars intertwine and sketch a road toward self-organization.

To exploit to the fullest the many features of modern transport, we need a system to support us. Decision-support systems like automated braking and adaptive cruise control are already helpful. But why not delegate the entire control to some kind of autonomous system? In the field of maritime logistics, where various modes of transport come together, practitioners need to be efficient in order to outperform the fierce competition. Availability of human labor may be scarce, especially 24-7. Here, automated systems come to our rescue. But they may be conceived as a first step.

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Ultimately, a far more advanced idea would be a self-organizing logistic system. Such a system consists of autonomous units, each with its own goal. By mutual cooperation, they are able to achieve a common goal. We argue that an increasing degree of automation has the potential (or urge) to become more autonomous and simultaneously pushes toward self-organization.

Our aim is to highlight some interesting novel applications of automated systems within maritime logistics that have the potential to grow from automated—via autonomous—to self-organizing. Our discussion splits up into two parts. In Sec. 2, we consider innovations related to hardware (autonomous systems), such as autonomous vessels. In Sec. 3, we consider innovations related to processes (intelligent decision-making), such as Multi-Agent systems for barge handing. Subsequently, in Sec. 4, we elaborate on the concept of self-organization. More specifically, we combine autonomous hardware with intelligent decision-making and present a positioning framework. Sec. 5 gives our conclusions.

2 Innovations in Autonomous Systems

This section highlights some promising innovations regarding autonomous transport and automated systems in maritime logistics. Next to the key elements of maritime logistics, such as container terminals and vessels, we also address innovations in related areas, such as hinterland transport and first- and last-mile transport. Section 2.1 introduces autonomous yard tractors, which can be used for the horizontal transport of containers in container terminals or port areas. Section 2.2 focuses on hinterland connections using unmanned cargo aircraft. As for conventional hinterland transport by means of trucks, Sec. 2.3 introduces an optimization approach using truck platooning. In Sec. 2.4 we discuss the usefulness of autonomous vessels and in Sec. 2.5 we consider the use of extended gates, such as pre-gate parking areas and floating terminals.

2.1 Autonomous Yard Tractors

Container terminals worldwide have adopted increasing levels of automated or unmanned systems to increase productivity. In the early 1990s, the first Automated Guided Vehicles (AGVs) were introduced, and many related automated systems, such as automated ship-to-shore cranes and automated straddle carriers, have found their way to market, as an incentive to increase operational productivity (Montoya-Torres et al., 2015) and reduce the dependency on the availability of human labor.

Deploying AGVs in container terminals comes with certain infrastructural and safety requirements (e.g., transponders in the ground and separation of manual and automated transport). Therefore, AGVs and other highly automated solutions are typically only deployed in green field terminals as the required infrastructural and

Fig. 1 Illustration of automated yard tractors. Adapted from Gerrits et al. (2020)

safety-related changes are too costly. To exemplify, AGVs are exclusively deployed in so-called perpendicular oriented terminals, given the orientation of the stacks compared to the shore. Opposed to parallel-oriented terminals, where the stacks are parallel oriented to the shore. In perpendicular oriented terminals, the stacks create a physical barrier between the automated systems (i.e., horizontal transport between the shore and the stacks) and the manual operations (e.g., pick-up and drop-off by road trucks), resulting in a safe and controllable environment. These types of terminals are common in Europe, exemplified by the ECT Delta Terminal and the APM Maasvlakte II Terminal in Rotterdam, the Netherlands. However, the vast majority of terminals worldwide are parallel oriented and therefore lack a physical barrier. Mainly due to this layout, the adoption of automated vehicles in brownfield terminals is minimal. Instead, manual-operated yard tractors are used in many of these terminals for the loading and unloading of containers at both the ship-to-shore cranes and the stack cranes.

Recent advances and innovations have created opportunities for brownfield terminals to adopt automated vehicles in the form of Automated Yard Tractors (AYTs). Examples include the Volvo Vera and the Terberg AutoTUG, as illustrated in Fig. 1.

These AYTs are able to drive unmanned and autonomously. Theoretically, AYTs can be deployed in any parallel-oriented terminal, but they also pose additional challenges. In these terminals, (non-automated) road trucks and yard tractors share the same infrastructure. Therefore, introducing AYTs results in a so-called Mixed-Traffic Terminal (MTT). In an MTT the road infrastructure is shared between AYTs and road trucks. Gerrits et al. (2019) show how this merging process should be managed in order to create a safe, understandable, and efficient system. When new (parallel-oriented) terminals are planned and designed, it is crucial to take into account the impact of AYTs. Moreover, the business case of AYTs compared to manually operated yard tractors should be made explicit in order to positively influence the uptake of AYTs in practice. Besides the reduced dependency on human labor, which can be a serious issue when this specific skill set is little available, particularly in remote areas, it is also important to consider the impact on operational efficiency (e.g., ship-to-shore crane utilization).

A first step to explore the latter is presented in Gerrits et al. (2020). The authors develop a simulation model to address the impact of AYTs in parallel oriented terminals with mixed-traffic. They show that high utilization rates can be achieved with a modest number of vehicles. On the other hand, they show that when mixing in manual traffic (e.g., road trucks to pick-up and drop-off containers), such systems are prone to traffic congestion and thus a drop in performance can be expected. To counteract the latter, the authors propose to introduce a pre-gate control to manage the inbound flow of road trucks.

Moreover, AYTs can be used in combination with extended gates (see Sec. 2.5) to decouple pick-up and drop-off operations with long-haul transport. Also, inter-terminal or inter-company transport (e.g., from and to empty container depots) are application areas of AYTs. In these latter cases, the AYTs move away from an MTT to the open road, which poses additional challenges in terms of safety, legislation, and societal acceptance.

2.2 Unmanned Cargo Aircraft

Crucial for any seaport is a smooth connection to the hinterland (Merk & Notteboom, 2015). Cargo should be transported to the destination in an efficient way. Rail, road, and inland water are traditional modes to accomplish this. An interesting innovation—that is still in its childhood—is the use of unmanned cargo aircraft (UCA). There are basically two types of UCA: small drones like those developed by Amazon for delivering small packages over short distances, and large UCA that can fly loads of a few hundred pounds over large distances. The latter are particularly interesting for hinterland connectivity, so let us dwell on those in this section.

Depending on the type, a UCA has a cargo capacity between 2 and 20 tons, a range varying from 1000 to 10,000 km, and a cruising speed of around 450 km/h. A UCA is highly autonomous. It only needs a remote human controller giving general instructions on course, altitude, etc. This person can monitor multiple UCA simultaneously (Heerkens, 2017).

According to the Dutch platform for unmanned cargo aircraft (PUCA), UCA can be more productive and cheaper to operate than manned cargo aircraft. An obvious advantage of a UCA is the savings in crew costs. In addition, there is no need to take into account the duty lengths of the on-board crew. Therefore, UCA can fly with low cruising speeds so as to reduce fuel consumption. This leads to larger ranges compared to manned aircraft. Lower speeds can do with shorter runways, simplifying the infrastructure needed. Another advantage of a UCA is that no pressurized cabin is needed, since no living creatures will be inside the aircraft. Thus, a complicated and maintenance-intensive air-conditioning system can be eliminated (Heerkens, 2017).

A further advantage also has to do with the construction of the UCA. The ideal shape of an aircraft from a fuel efficiency point of view is a “flying wing,” a tailless fixed-wing aircraft that has no definite fuselage. Accommodating passengers or crew inside the main wing structure—next to cargo, fuel, and equipment—would require

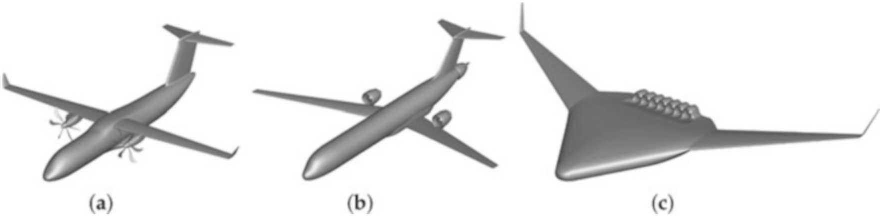

Fig. 2 Illustration of different types of unmanned cargo aircraft. (**a**) Tube and wing, (**b**) tube and wing, (**c**) blended wing body

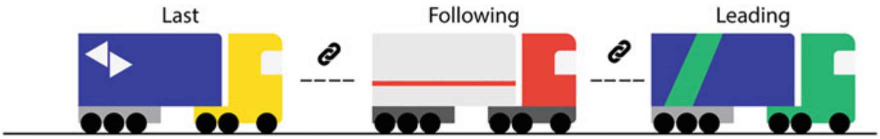

Fig. 3 Illustration of a truck platoon. Adapted from Gerrits et al. (2020)

a deep and heavy structure. On the other hand, since most cargo can be transported in relatively small containers, a flying wing with just a small thick section in the middle can in theory be an excellent UCA. Such a "blended wing body" (Liebeck, 2004) ideally uses up to a quarter less fuel than a conventional "tube and wing" aircraft, see Fig. 2 (Heerkens, 2017).

Because of the ability to start and land from short runways—roughly at least 150 m—and the high range of a UCA, it can reach destinations almost everywhere in the world without needing much infrastructure. Where other transport modes fail, they can easily reach regions affected by disaster.

A major barrier to the introduction of UCA is the problem of how to integrate them into controlled airspace. Until standardized "sense & avoid" equipment is certified worldwide and procedures like protocols for communicating with air traffic controllers are developed, UCA will be confined to dedicated airspace. Nevertheless, the American Federal Aviation Administration predicts that in 40 years, 40% of air cargo will be transported by UCA.

2.3 Truck Platooning

The concept of truck platooning has been around for several years and is an intermediate solution in the transition from manual to fully autonomous driving. Similar to army platoons, a truck platoon is a convoy of digitally connected trucks, as illustrated in Fig. 3. In at least one of the trucks, there is a human driver to coordinate the platoon in order to comply with (future) legislation regarding autonomous driving. Through digital connectivity and advanced sensor systems like lidars, the trucks are able to maintain a short, but safe following distance on for example highways. One may view truck platooning as an advanced version of adaptive cruise control found in consumer cars, and we denote this as Cooperative Adaptive Cruise Control (CACC). Given the short following distances as a result of CACC, one can expect a decrease in fuel consumption and related emissions due to a decrease in aerodynamic drag (Alam et al., 2015; Robinson et al., 2010). Moreover, it increases road capacity (Li & Ioannou, 2004), without sacrificing safety (Taleb et al., 2010).

Taking into account the operational side of truck platooning (e.g., finding a truck to platoon with) is also an important step to facilitate the integration of truck platooning in the supply chains of logistics service providers. This particular aspect of truck platooning is denoted by *platoon matching* and is further discussed in Sec. 3.2.

Besides the benefits mentioned above, platoons reduce the dependency on the availability of truck drivers. Ignoring (current) regulatory issues, it is possible that only one driver is needed in the leading truck and the other truck(s) follow automatically, without the need for a person in the driver seat. Moreover, truck drivers may be replaced by a control room, where platoons are remotely monitored. This is particularly useful when few truck drivers are available in a certain region, for example in remote areas. Long-haul transport can be carried out using platoons with only one driver, or using teleoperators. Besides the obvious cost reduction, this also allows the shift from daytime to nighttime operations. Particularly in highly congested areas, moving away from peak hours has multiple benefits, both for the traffic system as a whole, as well as for logistics service providers. To exemplify, trucks typically operate a large part of their operations during the day, due to the dependency on human labor and opening hours of businesses. When deploying platoons, fewer drivers are required to transport the same amount of goods and thus an opportunity arises to execute this during the night time or in less congested time periods. The platoons can be parked and split on strategic (secured) locations when platoons arrive outside the opening hours of the destination (e.g., a container terminal). When the terminal opens the next day, the (inbound) goods are immediately available for further processing. Similarly, at the end of the day, transports can be prepared for (nighttime) transport using platoons. Obviously, when a platoon arrives at a destination, the very last mile is operated manually. However, this can be done by the driver of the leading truck, operating every truck in the platoon one at a time. Moreover, at the destinations (e.g., container terminals) personnel is typically readily available to execute these final operations (e.g., entering the terminal, taking care of paperwork or rear-ward docking). Similar to unmanned cargo aircraft, truck platooning is also beneficial for connecting container terminals and businesses in (far away) remote areas with more densely populated business areas.

2.4 Autonomous Vessels

The shipping industry is vital for our global economy. Maritime transport is the only option for transporting large volumes of cargo among continents (Gu et al., 2021). In coping with growth and complexity, traditional solutions such as building larger ships have reached their limits. Major innovations, such as autonomous vessels, are believed to be necessary (Kretschmann et al., 2017). The interest within academic literature on automated marine vessels is rapidly increasing. In (Gu et al., 2021) a comparison is made between the existing literature on autonomous vessels and autonomous vehicles. It is observed that, in both cases, significant work has been done on navigation control and safety. Due to the high maturity of self-driving vehicle technology, the attention from the logistics research community shifted from fundamental topics (control and safety) to application topics (transportation and logistics).

For autonomous vessels, the development of real-world applications is slower. Therefore, the research priority still remains on the basic issues today (control and safety) and has not yet switched to transportation and logistics issues. The situation is gradually changing. In December 2018, Rolls-Royce and the Finnish state-owned ferry operator Finferries demonstrated the operational feasibility of the world's first fully autonomous ferry (Rolls-Royce, 2018). In the trial voyage, both navigation and docking are handled by the ferry with zero human intervention. Furthermore, the world's first fully electric and autonomous container ship, Yara Birkeland, will start fully autonomous operation by 2022 (Kongsberg, 2018).

The focus of autonomous vessel literature on control and safety is understandable. Collision avoidance is critical when no human is on-board monitoring the surroundings and controlling the vessel. In Gu et al. (2021), studies are reviewed about individual and group navigation control problems for unmanned vessels. The most discussed issue in the literature regarding the control of one single autonomous vessel is the planning of its path or trajectory. Methods are manifold. They vary from Dijkstra's algorithm to fast marching methods and multi-objective particle swarm optimization. To complete certain tasks, multiple autonomous vessels are needed. Therefore, the group control of these vehicles in such scenarios becomes critical. One of the most popular formations used in group control of autonomous vessels is the leader-follower structure. In leader-follower strategies, one or more vessels can be considered as leaders, and others regarded as followers. The followers track the locations and velocities of the leaders to achieve a desired formation pattern. Similarity with truck platooning (see Sec. 2.3) is obvious, albeit that the latter requires a more rigid formation.

As the technology of autonomous vessels matures, we expect—as for autonomous vehicles—an attention shift from control and safety to transportation and logistics, which will motivate researchers to start working on realistic applications of autonomous maritime transport.

2.5 Extended Gates

The notion of extended gates in maritime logistics comprises operations by different firms (e.g., terminal operators) beyond their own gates. In this section, we discuss two specific uses of the extended gate concept: pre-gate parkings and floating terminals.

Pre-gate parkings are useful to decouple long-haul and last-/first mile transport. By establishing a parking area close to a port, firms can use this area as a temporary buffer or as a physical decoupling point. When using a pre-gate parking as a buffer, inbound transport no longer drives directly to a terminal, but to the pre-gate parking instead. The terminals close to the parking area decide when to call the truck. This allows terminals to streamline their processes, as the predictability of arrival times can be increased and trucks arrive neither too late nor too early. This also reduces congestion in the port area itself as there are fewer queues. Moreover, trucks can park safely at a pre-gate parking. In addition to a buffer function, a pre-gate parking can also function as a decoupling point. In this case, inbound trucks decouple their cargo after which the last-mile transport is carried out by a yard tractor. Similarly, outbound cargo is transported by a yard tractor from the terminal to the pre-gate parking, after which a truck takes over for the long haul. Ideally, inbound trucks decouple their cargo and immediately pick up an outbound trailer on the pre-gate parking, thereby minimizing waiting time. Moreover, the first-and-last mile transport can be carried out by a fleet of autonomous yard tractors, as discussed in Sec. 2.1. Such advanced usage of a pre-gate parking, where connected and automated transport are combined is also referred to as a *smart yard*, see for example Brunetti et al. (2020).

Also on the seaside, it is possible to use the concept of extended gates, namely by deploying floating, off-shore terminals (Souravlies et al., 2020). To overcome the scarcity of land, it is promising to extend terminals toward the sea by using floating terminals. The core operations of a terminal, such as the loading and unloading of sea vessels can be carried out on such a floating terminal, eliminating the necessity of large sea vessels to enter the port. The transport from and to the floating terminal can be carried out by smaller vessels, potentially autonomous.

3 Innovations in Intelligent Decision-Making

This section highlights innovations regarding intelligent decision-making for autonomous systems. We argue that to exploit the full potential of the autonomous systems discussed in the previous section, such systems need to be combined with intelligent decision-making systems. In this way, the use of these (expensive) autonomous assets can be optimized. In this section, we highlight some intelligent decision-making solutions. Section 3.1 introduces the notion of distributed planning and Sec. 3.2 discusses matching platforms. In Sec. 3.3, we discuss a cooperative system to align barge and terminal operations. Section 3.4 focuses on the fair optimization of shared resources and Sec. 3.5 highlights the usefulness of serious gaming to support (strategic) decision-making.

3.1 Distributed Planning

Due to the increasing scale and complexity of logistics systems (e.g., fleets of hundreds of autonomous vehicles), the use of global optimization methods to plan and control these assets becomes less useful. Such centralized control approaches are less suitable for large, dynamic, and complex environments as they typically (i) require a lot of information in advance, which may not be available, (ii) are sensitive to information updates, which occur frequently, (iii) are not able to respond in a timely manner, and (iv) are not flexible enough to changing environments with multiple autonomous actors (Mes et al., 2007). In line with the delegation of autonomy regarding the execution of tasks currently performed by a human (e.g., driving, flying, sailing), also the delegation of planning and control to autonomous actors and assets is a promising area. When delegating control, we shift from central control structures to decentral control structures. In such a control structure, automated decision-making is delegated to lower levels in the control hierarchy, for example to the autonomous systems described in Sec. 2. By distributing decision-making capabilities, the system is less prone to single points of failure and reduces the complexity of decision-making. The latter is important in environments where fast decision-making is key for operational success. In Sec. 4 we will argue that such distributed decision-making systems can lead to self-organizing logistics. A notion closely related to distributed planning is that of agent-based systems, which are widely applied in maritime logistics literature. For example, within papers focusing on port management (Wibowo et al., 2015), inter-terminal cooperation (Nabais et al., 2013), collision avoidance (Marinica et al., 2012), yard crane scheduling (Fotuhi et al., 2013), dispatching of straddle carriers (Garro et al., 2015), terminal planning (Mes & Douma, 2016), and bay planning (Parthibaraj et al., 2017). Other studies focus on the comparison between centralized and decentralized approaches, such as yard crane coordination (Sharif & Huynh, 2012) and port regulation modes (Zheng & Negenborn, 2014).

Either denoted by distributed planning or agent-based systems, the notions are useful in real-world problems where centralized control might not be suitable (e.g., in dynamic and complex environments, as discussed above) or preferable (e.g., a central unit might not reflect the interests and preferences of the individual actors and assets adequately). The interested reader is referred to Mes and Gerrits (2019) for more details.

3.2 Matching Platforms

Online platforms are a popular approach to coordinate supply and demand, exemplified by platforms like Uber, Yandex, etc. Such matchmaking platforms are becoming increasingly popular in the logistics sector. In this section, we highlight a specific example of such a platform: truck platoon matching. As discussed in Sec.

2.3, a truck platoon consists of two or more digitally connected trucks that drive with a short following distance. In order to form a platoon, an agreement needs to be made on when and where to form the platoon, in which order the trucks drive, and how to divide the savings and costs among its members. We denote this process by truck platoon matching. In this section, we address three types of matching: scheduled, real-time and opportunistic. Although illustrated using truck platooning, the different variants can also be applied to other online platforms, e.g., pick-up and delivery services.

Scheduled platooning is an offline variant of matchmaking where all matches are generated before the trucks depart. Here, in order to find suitable matches, the matchmaking system needs to have access to information on the location, destination, and route of the trucks involved. When this information is not shared appropriately, or when it is only available for a subset of the available trucks, the performance of the matchmaking system decreases. Nevertheless, in some cases, this centralized approach may be relevant. For example, on frequently used routes with similar departure times (e.g., inter-terminal transport) or for logistics service providers that manage their own fleet. In the latter case, potential matches can be found easily, especially when there are many recurring trips (e.g., departures in the morning and arrivals in the evening). This is relevant for small countries, such as the Netherlands, where domestic deliveries are done within the time span of 1 day, with trucks departing from the depot in the morning and returning to the same depot in the evening (Gerrits et al., 2020). In larger countries, or in remote areas, this offline variant is useful when large distances need to be driven in combination with a relatively low density of trucks.

Real-time platooning is an online variant of matching, where the matches are made just before departure based on the latest information available. In practice, this may occur during breaks at truck stops or when refueling. These periods can be seen as small windows of opportunity for a truck to find a match based on nearby trucks with an overlap in routes. This type of matching is thus more dynamic in nature and focuses on local decision-making. It does not require any information in advance. Information is only required on the opportunities at the very moment. This type of matching is especially useful in unpredictable environments and for trucks of different logistics service providers, since gains can be shared without cumbersome coordination beforehand, as is the case with scheduled platooning (Gerrits et al., 2020). For large countries with low truck density, this matching variant is less relevant.

Opportunistic platooning is another online variant. Here, matches are made while driving. That is, trucks continuously seek for potential platoon partners while driving on the highway. This type of matching has a limited scope, since looking for matches far away leads to practical objections (e.g., speed changes may be required to get the trucks together). The matchmaking process focuses on trucks that are in the process of driving in the same direction as the truck, at most a few kilometers away. While this scope may be limited, matches are made easily as there is hardly any waiting time to form a platoon, since trucks are already driving and close to each other. The costs of forming a platoon are thus negligible; hence, the earnings of the platoon quickly become interesting. This type of matching is relevant in areas with high truck density and with enough opportunities to physically form the platoon (Gerrits et al., 2020).

3.3 Cooperation Between Barges and Terminals

The barge handling problem is the problem of how to optimize the alignment of barge and terminal operations in a port. Barge operators (companies that contract barges) have to decide on the sequence in which their barges visit the terminals in the port, aligned with the decisions of terminal operators (companies that operate a terminal) on the way they schedule the visiting barges at their terminal(s). Typical for the problem is that barge operators compete with each other (and so do terminal operators). Earlier research revealed that these companies are not willing to accept a central trusted party, since they want to stay in control of their own operations and are reluctant to share information as they fear undermining their competitive position by doing so. A few studies, therefore, propose a distributed planning approach by means of a Multi-Agent system (Melis et al., 2003; Schut et al., 2004). Barge and terminal operators made clear in discussions that they regard a Multi-Agent system as a promising concept, since it meets two important requirements as mentioned above that cannot be satisfied with central planning.

Douma et al. (2011) propose a Multi-Agent system using a specific interaction protocol (based on "service-time profiles") that enables barge and terminal operators to align their operations efficiently. The practical aspects the authors take into consideration are: (i) restricted opening times of terminals, (ii) sea vessels, (iii) closing times of containers, and (iv) unbalanced networks.

Let us briefly describe the basic notions of the Multi-Agent system proposed in Douma et al. (2011). The basic idea behind the Multi-Agent system is that every barge operator and every terminal operator is equipped with an agent. Each agent is empowered to make decisions on behalf and in the best interest of its principal, i.e., the company it represents (either a barge or a terminal operator). Barge operator agents have to decide on the sequence and the time a barge visits its terminals. Terminal operators have to decide which possibilities they offer to barges to be handled and how these barges are scheduled at the quays. Agents are assumed to behave opportunistically, similar to their principals. Key in a Multi-Agent system is the interaction protocol, describing the way agents communicate, the content of the communication, and the aimed outcome of the communication. Figure 4 visualizes the communication in the Multi-Agent system. As shown, barge operators and terminal operators communicate directly with each other. There is no mutual communication between barge operators nor between terminal operators.

The communication between barge and terminal operators consists of two phases and is initiated by a barge operator. In the first phase, the barge operator agent sends a request for service-time profiles to the terminal operators that have to be visited by the barge for which a rotation is being planned. We assume that these requests are

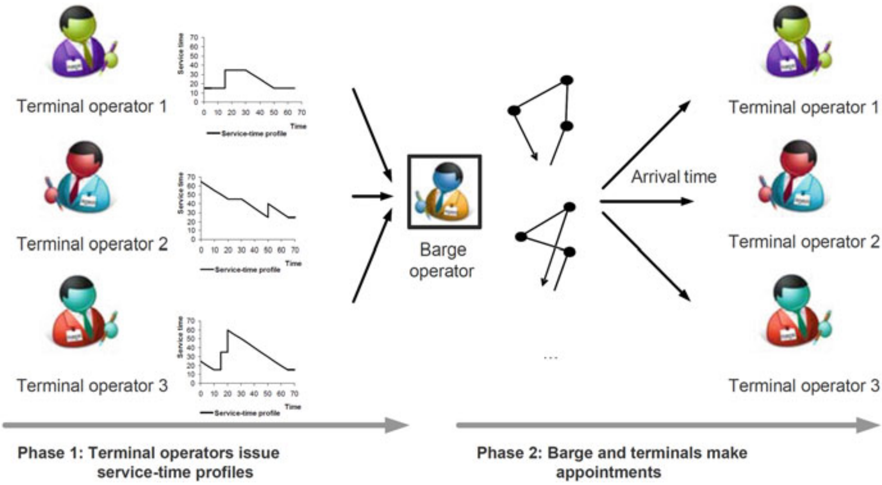

Fig. 4 Visual representation of the communication in the Multi-Agent system. Adapted from Douma et al. (2011)

sent prior to the first terminal visit of a barge, e.g., when a barge is approaching the port. Terminal operator agents reply instantaneously to the request of the barge operator agent with a barge-specific service-time profile. In the second phase, the barge operator agent determines the "best" rotation for its barge and makes appointments with the terminals concerned. A barge operator agent calculates the "best" rotation using the information expressed in the service-time profiles, i.e., the guaranteed maximum service time. Next to that, it uses information about sailing times between terminals. When a barge operator agent has determined the "best" rotation, then it makes an appointment by announcing the arrival times to the concerning terminal operators. The arrival time a barge announces to a terminal is also the latest arrival time of the barge at the terminal. Terminals confirm the appointment request by sending a confirmation of the guaranteed maximum service time.

Douma et al. (2011) show through an extensive simulation study for the Port of Rotterdam that distributed planning can perform well compared to central coordination and is a promising approach for solving the barge handling problem.

3.4 *Shared Services and Fair Optimization*

Autonomous solutions as discussed in Sect. 2 and related advanced planning and control systems require a large capital investment. Compared to manually operated systems, the hardware is relatively expensive, although operational benefits and cost reductions should allow viable long-term investment. Nevertheless, the hurdle to investing in autonomous solutions can be too big for single stakeholders, resulting in a slow uptake of these innovations. Therefore, it makes sense to invest and work together with other stakeholders. For example, a group of companies located in and around a container terminal can jointly invest in a fleet of autonomous yard tractors (see Sect. 2.1), to facilitate on-terminal and inter-terminal transport. In such a joint system, companies need to share the pool of vehicles with other users, but benefit from a risk-pooling effect. Moreover, such a collaboration can eliminate empty backhauls, raise vehicle utilization and increase the profit of each party involved (Dai & Chen, 2012). Furthermore, without a joint initiative, the investment may not have been feasible for all or multiple stakeholders. Such a joint initiative, therefore, facilitates a speedier uptake of innovations discussed throughout this chapter.

To coordinate the shared service, one may resort to a fourth-party logistics provider (4PL). Such a party coordinates the planning of the shared fleet, without owning the vehicles themselves. 4PLs have as their core business to make supply chains more efficient (Saglietto, 2013). When multiple parties agree to collaborate on a shared service, the 4PL manages the data (e.g., available capacity and jobs to be executed) and coordinates the planning. In such a control structure, information is typically only shared between the 4PL and the parties, but not between the parties themselves, as this is often confidential information. Such a structure enables cooperation between companies, without sharing confidential information with competitors. Opposed to the cooperation mechanism described in Sect. 3.3, this approach has the requirement of a "trustee," a trusted central party, namely the 4PL. Depending on the parties involved, this may not be a favorable approach and thus other coordination mechanisms (e.g., agent-based systems) can be more useful. In Alacam & Sencer (2021) the trustee concept is operationalized digitally, in a decentralized fashion, on a public blockchain network. The proposed design intends to ensure the neutrality of the digital trustee in its decisions, as well as preventing the single point of failure problem intrinsic to centralized trustee models.

Regardless of the coordination mechanism used, the involved parties need to be treated in a proper way. That is, in some sense the "shared" service needs to be shared fairly among the parties involved. For example, suppose one would use typical global optimization methods to allocate capacity to each stakeholder. From a system perspective, this can yield an optimal solution, but from an individual perspective, this may not be true. Or at least maybe wrongly understood from a single stakeholder's perspective. This is particularly of interest when a small group of large parties work together with a large group of small parties. To find such a balance between global optimization and "local satisfaction," we briefly introduce the notion of fair optimization, which combines fairness with optimization methods.

Fairness plays a role in allocation problems in which the number of resources to be allocated is limited or constrained. In many network allocation methods, the main assumption is that the *social* optimum is achieved by optimizing the sum of utilities of individual agents (e.g., parties sharing the service). With such an allocation method, a party can receive a disproportionate amount of resources as long as that player wants to and is able to pay for it (Sinha & Anastasopoulos 2017). To counter this imbalance in allocations, fairness can be factored in by using different allocation methods.

A resource allocation problem can be modeled as a cooperative game that can be captured by a set of users, the claim of a user, and the total amount of available resources. In the classical approach of measuring a user's satisfaction for a given allocation, satisfaction is maximal when the user gets exactly what it asks. Obviously, when resources are limited, maximum satisfaction may be out of reach. According to (Fossati et al. 2018) an allocation should fulfill three properties. First, all users should receive at least zero. Secondly, a user should not receive more than its demand. Lastly, the sum of all individual allocations should equal the total available resources.

In dealing with resource allocation problems, the most widely used methods are (i) the weighted proportional rule, (ii) max-min fair allocation, and (iii) α-fairness. The first is based on a logarithmic utility function and the idea that it captures the individual worth of a resource. The second gives the lowest claimer its total demand and evenly distributes the unused resources over the others. Lastly, the α-fairness algorithm is a family of assignment rules with the outcomes depending on a smoothing parameter α (Fossati et al. 2018).

3.5 Gamification in Container Supply Chains

When you design an innovative solution for a problem from practice, then the inevitable question is: will the future users accept it? Whether future system users are willing to accept a new technology is, in particular, depending on their *perception* and *expectations* of the system (Venkatesh et al., 2003). According to the Technology Assessment Model (Davis et al., 1989; Venkatesh & Bala, 2008), the two main factors for users to decide on the acceptance of new technology are (i) perceived usefulness and (ii) perceived ease of use. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" and perceived ease of use as "the degree to which a person believes that using a particular system would be free from effort" (Davis et al., 1989). In our experience, in order to let the intended user explore "perceived usefulness" and "perceived ease of use" of an innovative design, a "serious game" may be helpful.

To illustrate the added value of gamification, let us revisit the barge handling problem discussed in Sect. 3.3. There, in the process of designing a Multi-Agent solution for the barge handling problem, Douma et al. (2009, 2011) had a keen eye for design choices that could influence the acceptance of the users. In the early stage of their research, when they discussed their proposed solution to practitioners, they discovered that it was hard for these people to get a picture of how the system would work in practice. Practitioners experienced the approach as rather abstract and saw little benefit in supporting it. The researchers, therefore, decided to develop a *simulation game* to better communicate their ideas, thus providing future system users with a transparent picture of what the solution is about (Douma et al., 2012).

Their simulation game aims to realize the following four objectives:

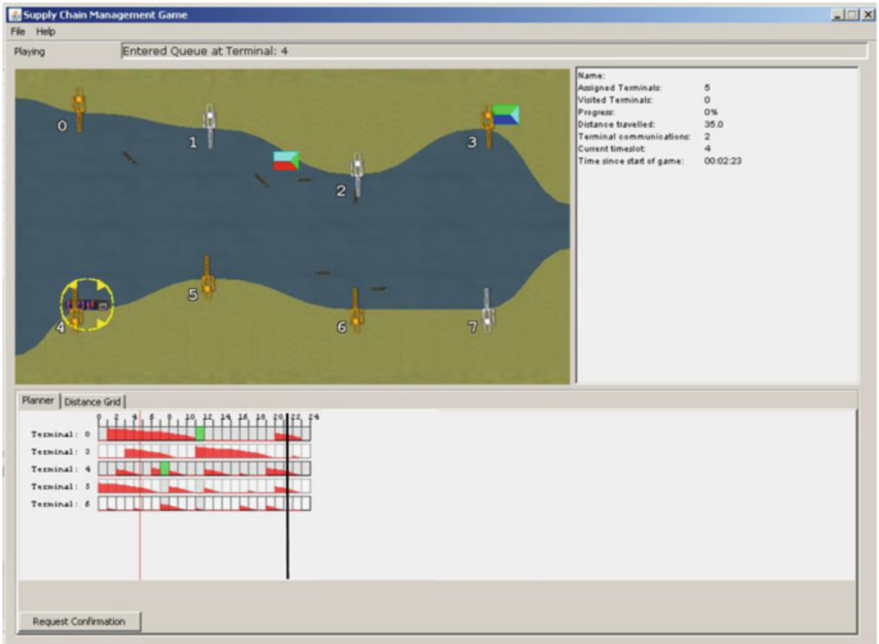

Fig. 5 Screenshot of the user interface. Adapted from Douma et al. (2012)

1. To *communicate the Multi-Agent solution to practitioners.* By playing the game, practitioners are able to compare the present situation—as it is modeled—to the proposed situation thus getting a clear understanding of the added value of the solution suggested. This may support the acceptance of the solution. Moreover, it may generate a discussion on design choices and assumptions. Furthermore, it may evoke a discussion about the conditions for implementation.
2. To use the game as a *practical validation of the proposed Multi-Agent system*. The game will show in what way people interpret and use the information provided, in particular how they use this information to base their decisions upon.
3. To use the game as a *prototype solution for the user interface*. The game will indicate to what extent the information presented is useful. It will also show to what extent the interface is intuitive and clear.
4. To *evaluate the way players perceive different interaction protocols.* It is interesting to observe how the perception of an interaction protocol will influence a player's performance.

The user interface consists of three parts (see Fig. 5). The upper left part is a graphical representation of the game state. It depicts the location of all the barges and terminals. The performance of the barge under consideration is presented in the upper right part of the screen. The lower part is reserved for planning a rotation. There, a time bar—divided into time slots—is given for every terminal the player has to visit. The player can select a time slot by clicking on it. The selected time slots can be communicated with the terminals by clicking the button on the left bottom corner of the screen.

Findings are that a simulation game has many advantages for communicating a Multi-Agent system to practitioners. It helps people to quickly get an understanding of the system and to decide whether they are willing to give support for implementation. The game is also useful as a prototyping technique for the user interface and to evaluate the way players perceive the different interaction protocols. To practically validate the performance of the Multi-Agent system, the game is less useful, unless players are trained in playing the game and play the game in multiple rounds to get statistically significant results. This was beyond the scope of the research. All in all, the experiences are that a simulation game is an effective means to contribute to the "perceived usefulness" and "perceived ease of use" of the proposed system by future system users.

4 Self-Organizing Logistics

Combining autonomous systems with intelligent decision-making is a promising area of research in (maritime) logistics. We argue that this combination can lead to self-organizing systems, where minimal or no human supervisory control is required. The notion of self-organization in logistics is thus one focused on automated systems (of systems) with certain decision latitudes in order to meet its design objectives. Due to the complexity of logistic systems, a self-organizing system should be fragmented into smaller autonomous units. This is similar to how we divide a company into smaller departments (i.e., sales, inventory management, production), each which their own responsibility, but working together to achieve a common shared goal (e.g., company profit). A self-organizing logistic system is thus a system of small(er) autonomous units (also commonly referred to as agents) each with their own goal, and by communication and cooperation striving toward a common goal.

Having discussed various options for autonomous hardware and related intelligent decision-making solutions in the previous sections, we now unify them in the framework presented in Fig. 6. The framework is presented alongside two axes: object autonomy and decision-making autonomy. The first refers to the ability of the system to perform its core tasks in an autonomous fashion. For example, an unmanned cargo aircraft should be able to take off, fly and land autonomously under various (weather) conditions. Such an aircraft thus has a high object autonomy, whereas a manually operated truck has a low object autonomy as the core tasks are executed by the driver. The latter axis refers to the system's decision-making autonomy. That is, the degree to which the system is able to make intelligent decisions on its own. These decisions are not related to the core tasks (e.g., driving, flying, sailing), but rather related to operational decisions, like scheduling and routing. These decisions include for example the work that a human planner typically does.

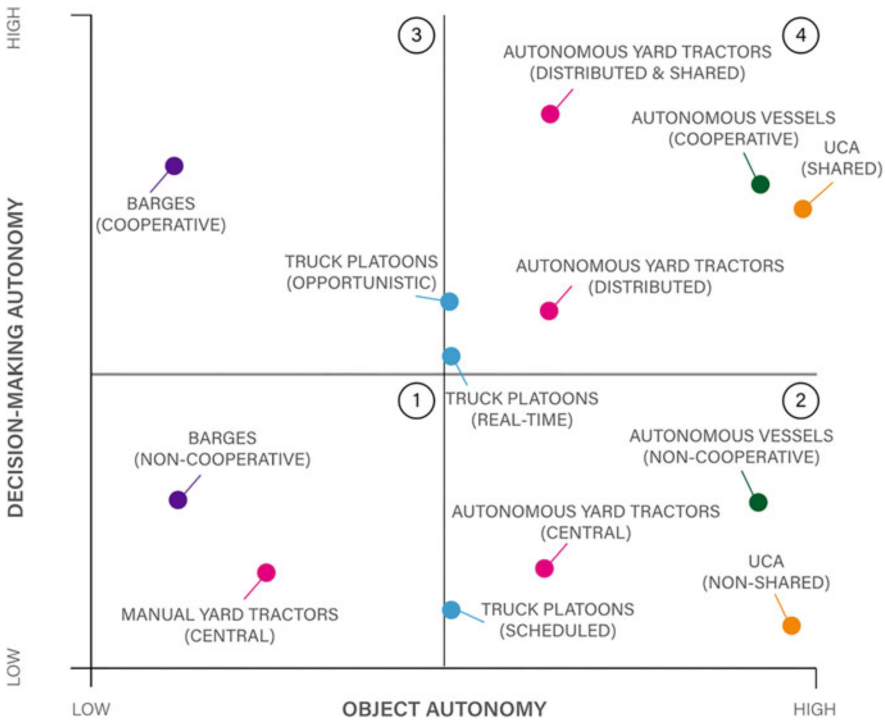

Fig. 6 Unifying framework for intelligent and autonomous systems

The examples provided throughout this chapter are plotted in the framework shown in Fig. 6. Moreover, the framework allows four different quadrants: (1) manual operated systems with manual decision-making, (2) autonomously operated systems with manual decision-making, (3) manual operated systems with automated decision-making, and (4) autonomously operated systems with automated decision-making. Obviously, the latter quadrant contains the most promising examples regarding self-organization, as both decision-making and execution are performed autonomously. Nevertheless, also quadrants two and three contain interesting examples where either the decision-making or the task execution is performed autonomously, stressing the fact that not *both* dimensions need to be carried out autonomously in order to make progress (toward self-organization).

To exemplify the transition from manually operated systems to more autonomous, and intelligent systems (e.g., toward self-organization), we highlight the following two examples: autonomous yard tractors in Sect. 4.1 (color-coded pink in Fig. 6) and autonomous vessels in Sect. 4.2 (color-coded green).

4.1 From Manual to Autonomous to Intelligent Yard Tractors

Regarding yard tractors, let us focus on their usage at container terminals and as a last-mile solution in combination with extended gates. In current practice, manually operated yard tractors are used for the horizontal transport of containers from and to the quay. Typically, a central control system determines which transport jobs need to be processed and in which order. Operators of the yard tractors receive information on the current job list and can select one particular job to be processed. The decision-making autonomy is thus low, as factually all decisions are made on a central level and the operator of the yard tractor has limited decision-making autonomy. The same goes for object autonomy, as the vehicle is operated manually by a human driver. The only autonomy of the vehicle itself maybe an emergency brake which is automatically applied in some safety-critical situations. Clearly, this system belongs in quadrant one, see ‘manual yard tractors (central)’ in Fig. 6. When making the transition to autonomous yard tractors (AYTs), one moves to quadrant two, where the driving tasks are performed autonomously and a human driver is no longer required. Typically, there are still operators involved, which monitor the tractors from a distance and can take over control (e.g., tele-guided) when required. The object autonomy thus increases, but not to the extent of, for example, unmanned cargo aircraft. Moreover, when the same centralized planning and control system is deployed, the decision-making autonomy does not change. When deploying a distributed planning approach, where decision-making is delegated to the vehicles themselves, as illustrated in Sect. 3.1, the system moves from quadrant three to four. In such a system, a human planner is no longer required to make decisions regarding dispatching, scheduling, and routing. Instead, the fleet of AYTs themselves controls these processes. Clearly, this moves in the direction of a ‘self-organizing’ system, where minimal or no human involvement is required. As a last step, one can also share the fleet of AYTs with other firms or stakeholders, for example when deploying a shared first- and last-mile transport system in combination with an extended gate (see Sects. 2.5 and 3.4). In such a system, the AYTs are not servicing a single stakeholder (e.g., solely for the horizontal transport on its own terminal), but are shared with other firms in the port. In addition to a distributed planning approach, which is useful in such a situation (see Sect. 3.1 on the advantages), the fleet of AYTs also needs to decide how to share its AYTs among (rival) users in a fair and efficient manner. This is a complex optimization problem and thus requires an advanced degree of decision-making autonomy by the autonomous system. This is denoted by “distributed and shared” in Fig. 6. The same options hold for unmanned cargo aircraft (UCA), namely shared service, operated by multiple stakeholders, or non-shared service, operated by a single stakeholder. This transition is also depicted in Fig. 6, color-coded yellow.

4.2 Manual, Autonomous, and Cooperative Vessels

Consider a barge that is currently manually operated with manual decision-making. By cooperating with other barges and terminals (cf. Sect. 3.3), the barge may rise to a high level of automated decision-making. This transition is depicted in Fig. 6, color-coded purple. As another example, consider an autonomous vessel. Such a vessel can sail with an economic speed and coordinate its navigation plan—fully automated—with its due time in the port. Nevertheless, its decision-making potential may be rather low. By cooperating with other autonomous vessels, e.g., in a leader-follower structure, the vessel may acquire a higher level of automated decision-making, e.g., benefitting from the joint knowledge of sailing obstructions further ahead. This transition is depicted in Fig. 6, color-coded dark green.

5 Conclusions and Outlook

This chapter highlights some promising recent innovations in maritime logistics. As innovative automated systems, we discuss: (i) autonomous yard tractors, (ii) unmanned cargo aircraft, (iii) truck platooning, (iv) autonomous vessels, and (v) extended gates. To control these systems, we discuss innovative forms of intelligent decision-making, namely: (i) distributed planning, (ii) matching platforms, (iii) cooperation between barges and terminals, (iv) shared services and fair optimization, and (v) gamification in container supply chains. Next, we design a unifying framework that classifies automated systems within maritime logistics according to their potential to grow out to self-organizing.

One may wonder about the viability of the innovations discussed. Many of them, like unmanned cargo aircraft, are still emerging technology. Technical, regulatory, control, and safety issues have to be dealt with. As technology matures, and humans start to interact with it, unforeseen adaptations may be necessary. Nevertheless, the potential of autonomous systems for maritime logistics is huge. To stay competitive no seaport in the world can afford to ignore autonomous transport.

How to bring the innovations discussed to the market? We recommend the following general steps:

1. Evaluate the viability of the innovation by interviewing practitioners.
2. Develop a serious game (gamification, see Sect. 3.5).
3. Invite future users to play the game.
4. Evaluate their perception of usefulness and ease of use.
5. If this perception is satisfactory then proceed, else repeat steps 1, 2, 3, 4.
6. Introduce the innovation into pilot markets.
7. If successful, then proceed, else repeat steps 1, 2, 3, 4, 5, 6.
8. Extend to other markets.

Despite the immense potential of the innovations discussed, one may never forget the human factor. In our view, step 4 in the above list helps us to safeguard that.

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Maritime Logistics Systems of Europe and Asia

Yana Leksyutina and Maria Lagutina

Abstract This chapter characterizes the roles of Europe and Asia in global shipping system. By applying various metrics, it identifies the importance of European and Asian ports in the global shipping network and two region's ports connectivity. This chapter aims to demonstrate how maritime trade between Europe and Asia is logistically organized, discusses the current state of the Northern Sea Route as an alternative route for transporting cargoes between Europe and Asia, and discusses the implications of the Northern Sea Route on the existing Europe-Asia maritime logistics.

1 Introduction

In the contemporary globalized world, which is characterized by the interdependence of the economies, globalization of manufacturing processes, and the internationalization of world trade, the development of efficient logistics systems bears a particular importance. An effective logistics sector is one of the core drivers of world's development, economic growth, and competitiveness of individual countries. Logistics system is a network of services that support the physical movement of goods, cross-border trade, and commerce within borders (Arvis et al., 2018, p. 1). In a broader sense, it comprises multiple activities beyond transportation, including terminal operations, warehousing, brokerage, express delivery, related data and information management (Arvis et al., 2018, p. 1).

An integral part of the international logistics network which facilitates the global trade is maritime transport and logistics. According to UNCTAD, more than four fifths of world merchandise trade by volume is carried by sea (UNCTAD, 2019, p. 4). For some countries and regions, maritime trade is the prevailing mode of

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movement of merchandise goods. That is particularly the case for the trade between Europe and Asia, which accounts for around half of all world merchandise trade. Europe and Asia are the largest trade partners to each other with trade flows primarily supported by maritime routes, and they are also world's important maritime transport and logistics players. The international significance of the Northern Sea Route is manifested exactly in its capability to provide distance and time saving, safer and presumably cheaper—in comparison to the existing SLOCs—maritime logistics corridor between European and Asian markets.

This chapter characterizes the roles of Europe and Asia in global shipping system. By applying various metrics, it identifies the importance of European and Asian ports in the global shipping network and two region's ports connectivity. This chapter aims to demonstrate how maritime trade between Europe and Asia is logistically organized, discusses the current state of the Northern Sea Route as an alternative route for transporting cargoes between Europe and Asia, and discusses the implications of the Northern Sea Route on the existing Europe-Asia maritime logistics.

2 The Role of Europe and Asia in Global Shipping System

Europe, which coastline reaches from the Baltic all the way to the Mediterranean Sea and the Black Sea, is one of the leading maritime centers in the world. EU ports handled 3.6 billion tons of cargo in 2018 and more than 17,000 ships simultaneously move in EU waters, making about 2.2 million ship calls at major ports per year (Prichkin, 2021). According to the European Commission, Europe has 329 key seaports along its coastline, and EU companies control 32% of the world's merchant fleet (European Commission, 2018). Maritime transport bears a crucial importance to European economy. Ports play a role of gateways connecting European transport corridors with other regions of the world; the shipping sector provides the European market with links to its major trade partners. Three fourth of EU's external trade is shipped by sea (European Commission, 2018).

According to the study 'Modal share of freight transport to and from EU ports', prepared for the Members of the Committee on Transport and Tourism of the European Parliament, the EU is divided into several maritime basins: the North Sea, the Mediterranean, the Baltic Sea, the Black Sea, other (European Parliament, 2015, p. 19). The North Sea, which includes the largest and most important European ports, accounts for the major share of traffic for every type of load, while the Mediterranean Sea ranks second despite having a larger number of ports (European Parliament, 2015).

Adolf K. Y. Ng identifies the "Core-Six Ports" in the northwestern Europe: Antwerp, Bremerhaven, Felixstowe, Hamburg, Le Havre, and Rotterdam (Ng, 2009, p. 113). The "Core-Six Ports" are regarded as the key ports in northwest Europe due to their market shares and global impacts, where they serve as regional gateways, as the major trading regions, notably the Far East and North America (De Langen, 1998).

In terms of the total traffic handled at major ports in the EU, the second largest region—behind the North Sea—is the Mediterranean Sea region. It is followed by Baltic Sea ports. The smallest share is held by EU ports along the Atlantic Ocean coast and EU ports along the Black Sea coast (European Parliament, 2015, p. 19).

The UK, which is a European country but not a member of the EU since Brexit, also plays an important role in European maritime logistics system. The country has 116 commercial ports with a total cargo turnover of 483 million tons in 2018, including 34 ports with a cargo turnover of over two million tons (Prichkin, 2021). The country's largest ports are Grimsby and Immingham (55.6 million tons), London (53.2), Southampton (34.5), Liverpool (32.6), Milford Haven (30.9), Tees & Hartlepool (28.8), Felixstowe (28.2), Fort (26.6), Dover (24.9), and Belfast (18.9). In total, more than 98,000 ships visited the country's ports in 2018. The largest number of ship calls (over 17,000) is at the port of Dover due to ferry lines connecting Dover with ports on the mainland. The ports of Grimsby and Immingham (7200), London (7000), Liverpool (6800), Belfast (5500) are followed by the number of ship calls (Prichkin, 2021).

Through the lens of the hub-and-spoke system, the EU has two shipping systems: Northwest Europe and Mediterranean Sea. Northwest Europe, which is a core region of the global shipping network, does not have a single super hub port, instead it has three hub ports, which constitute three sub-regional shipping systems,—Antwerp, Rotterdam, and Oslo. In recent years Antwerp has become the major hub in the world and surpasses the role of Rotterdam port: the number of feeder ports of Rotterdam has been decreasing, while in parallel many European ports have become Antwerp's feeder ports (Wang & Wang, 2011, p. 60). Nevertheless, Rotterdam is a major hub port in the global shipping network and the busiest EU's cargo port. As of 2019, the EU's top five maritime cargo ports were Rotterdam, which handled twice as much cargo as Antwerp (440 against 214 million tonnes), followed by Hamburg port (117 million tonnes), Amsterdam (104 million tonnes), and Algeciras (90 million tonnes) (EUROSTAT, 2021b). Oslo and several small ports in North Europe form the third shipping system (Wang & Wang, 2011, p. 60).

Since the 1990s, Mediterranean Sea has become important in the global shipping network with multiple hub ports and sub-regional shipping systems. In particular, two shipping system concentrate around Valencia and Barcelona as the hub ports, they are connected with feeder ports in European part of Mediterranean Sea and North Africa correspondingly (Wang & Wang, 2011, p. 60). Moreover, there are some other shipping systems with comparatively small coverage areas (Wang & Wang, 2011, p. 60).

Just as for Europe, maritime logistics is equally important for Asian economies, many of which have direct access to the seas or are island nations. Currently, Asia is an important maritime transport and logistics player on a global level: it is a leading maritime hub, an important user of maritime transport services, and a large service provider. Given its deep integration into global and regional production processes and supply chains (its status in the world economy as the world's factory) and

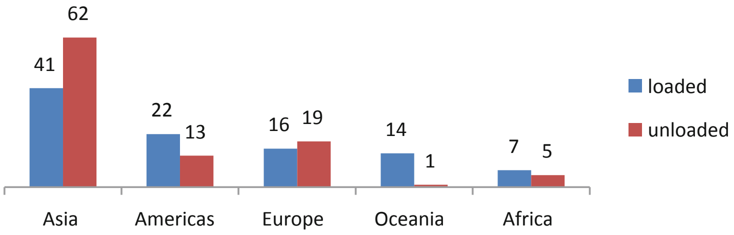

Fig. 1 World maritime trade by region, 2019, in percent (UNCTAD, 2020, p. 7)

expansion of Asian maritime transport capacities, Asia dominates the global maritime trade. It is currently a maritime hub that brings together more than 50 percent of world maritime trade volumes. In 2019, for instance, 41% of the total merchandise goods loaded was originated from Asia and 62% of total goods unloaded was sourced from this region (see Fig. 1). In contrast, in the same year, Europe accounted for mere 16% of goods loaded and 19% of goods unloaded (see Fig. 1).

In terms of world container port cargo handling volumes, it is also Asia that occupies a prominent role in global shipping system. In 2019, almost 65% of global container port traffic was operated in Asia with China's share alone exceeding 50% (UNCTAD, 2020, 16). Europe ranked only second with share around four times smaller than Asia's.

Ports play an essential role in facilitating the movements of goods across different markets and supply chains. Ports connect different countries through maritime transport networks, and maritime transport with domestic and regional markets through multimodal transport connections in the hinterland. In the last 14 years, the number of container ports in the world with regular liner shipping services has increased by 13%, from 834 to 939 (in 2020), and the center of the global shipping network in terms of the largest nodes and the position within the network has shifted from Europe to Asia (Hoffmann & Hoffmann, 2020).

To compare ports and identify their place in the global shipping network various metrics and indicators can be applied: metrics, based on the comparison of ports' cargo handling volumes, number of shipping lines they serve, number of shipping vessels that depart or call at ports (monthly or yearly, for example), the node degree (the number of other ports with which the port has a direct connection), and different complex indexes, calculated from an array of indicators.

According to UNCTAD calculations, in 2018–2019, world's top 20 container ports (in a million 20-foot equivalent units—TEU)—the world's busiest container ports—in descending order were: Shanghai (China), Singapore (Singapore), Ningbo-Zhoushan (China), Shenzhen (China), Guangzhou (China), Busan (Republic of Korea), Qingdao (China), Hong Kong (China), Tianjin (China), Rotterdam (Netherlands), Dubai (UAE), Klang (Malaysia), Antwerp (Belgium), Xiamen (China), Kaohsiung (Taiwan), Los Angeles (US), Hamburg (Germany), Tanjung Pelepas (Malaysia), Dalian (China), Laem Chabang (Thailand) (UNCTAD, 2020,

p. 18). Out of these 20 world leading ports, 16 container ports are located in Asia with ten ports in Greater China.

In the past several decades, Asian ports and specifically Chinese ones have made an impressive progress as shipping hubs. Shanghai, for example, surpassed the container traffic of Singapore in 2010, ending Singapore's five year (2005–2010) reign at the top. Between 1999 and 2004, the Port of Hong Kong was the world's busiest container port (Asia Briefing, 2014). Due to rapid economic growth in China and the growth of its external trade, Shanghai has demonstrated an impressive progress as a shipping hub: in 2001, for instance, Shanghai was shipping less than half of the number of containers handled by Singapore.

However, port's status in the global shipping network is identified not only by its shipment volumes, but also by its shipping lines' number, its connectivity. That is, the Hong Kong port and the Singapore port are the world's and region's largest transshipment hubs, whereas Shanghai—the world's busiest container port—largely depends on domestic consumption. In 2019, the Port of Shanghai handled 43.3 million TEU, only half of which was transshipment volume (Port Technology International Team, 2021).

As a matter of fact, in the maritime sector there are ports that enjoy a privileged hub or transshipment hub status, and ports relegated to secondary status on the periphery of the hub-and-spoke system. World's shipping lines mainly concentrate in a few hub and transshipment hub ports. There are hubs of global, regional, and sub-regional significance.

Categorizing world's ports based on number of shipping lines they serve, Chengjin Wang and Jiaoe Wang indicate the first-tier ports, like the Hong Kong port, which owns maximum lines (503), and Singapore port with 502 shipping lines (Wang & Wang, 2011, p. 57). The Hong Kong shipping system covers ports from Mainland China, Japan, and South Korea, while the Singapore shipping system—most ports in Southeast Asia and Indian Ocean, some ports in the Persian Gulf and Pacific Ocean (Wang & Wang, 2011, p. 57). The Port of Hong Kong handles about five million TEU of transshipped goods a year and 18.36 million TEU overall. The busiest transshipment port in the world is Singapore which accounts for 20% of the globe's transshipment traffic. In 2019, it handled 37.2 million TEU, 30.9 million of which was transshipment (Port Technology International Team, 2021). Singapore is a major hub in the region: non-stop vessels from Europe, North America, and other regions tranship their cargoes at Singapore to feeder ships capable of getting into the physically restricted ports in other Asian countries (UNCTAD, 2001, p. 94).

The second-tier ports include Shenzhen, Shanghai, Kaohsiung, Rotterdam, Antwerp, Hamburger, Busan, Ningbo, New York, etc. Each of them owns the number of shipping lines from 200 to 380, and plays important roles in the global shipping network. Shanghai primarily serves as the hub port of East China and North China. The Busan shipping system influences the South Korea and Far East, the Tokyo system serves Japan, the Shenzhen system serves South China, the Tianjin, Qingdao, and Kaohsiung systems serve Bo Sea, Shandong, and Taiwan correspondingly. The third-tier ports are ports like Le Havre, Kelang, and Qingdao, which have shipping lines' number from 100 to 200. And finally there are ports like Jakarta and Tianjin,

Table 1 Ten leading ports based on Xinhua-Baltic International Shipping Centre Development Index, 2016–2020

Ranking	2016	2017	2018	2019	2020
1	Singapore	Singapore	Singapore	Singapore	Singapore
2	London	London	Hong Kong	Hong Kong	London
3	Hong Kong	Hong Kong	London	London	Shanghai
4	Hamburg	Hamburg	Shanghai	Shanghai	Hong Kong
5	Rotterdam	Shanghai	Dubai	Dubai	Dubai
6	Shanghai	Dubai	Rotterdam	Rotterdam	Rotterdam
7	New York—New Jersey	New York—New Jersey	Hamburg	Hamburg	Hamburg
8	Dubai	Rotterdam	New York—New Jersey	New York—New Jersey	Athens
9	Tokyo	Tokyo	Tokyo	Houston	New York—New Jersey
10	Athens	Athens	Busan	Athens	Tokyo

Source: Shipping Herald (2020)

which have shipping lines from 50 to 100, with relative low importance in the global shipping network (Wang & Wang, 2011, p. 57). Jakarta, for example, is the hub port of small shipping system that is connected to several ports in Philippines and Indonesia.

Roughly speaking, in Asia there are two shipping systems: Northeast Asia with Chinese, Japanese, and South Korean ports and Southeast Asia with primarily Singapore port at its core.

Under the measure "the node degree" (the number of other ports with which the port has a direct connection), the best-connected ports in 2020 were Shanghai with 288 direct connections, followed by Busan (274 direct connections), Antwerp (268), Rotterdam (264), Ningbo (258), Singapore (249), Hamburg (206), Hong Kong (205), Qingdao (201), and Shenzhen (193) (Hoffmann & Hoffmann, 2020).

According to Xinhua-Baltic International Shipping Centre Development Index, which is an annual ranking of the performance of the world's largest cities that provide port and shipping business services,[1] in 2020, five world leading shipping centers were Singapore, London, Shanghai, Hong Kong, and Dubai (see Table 1). Singapore has been ranked number 1 for seven consecutive years. Its competitive advantages include favorable geographical location, shipping industry ecosystem, and supportive government policies. London's attractiveness is derived from providing high-end shipping finance, insurance, and legal services. Shanghai has seen an improvement in port facilities and shipping service levels.

There are a number of other data indicating Asia's, as well as Europe's, prominent place in maritime transport sector. For example, as of 1 January 2020, among

[1] Xinhua-Baltic International Shipping Centre Development Index is based on such factors, as port throughput and infrastructure, depth and breadth of professional maritime support services, the general business environment, etc.

Table 2 Deliveries of newbuildings by countries of construction, 2019 (thousand gross tons)

Vessel type	China	Japan	Republic of Korea	Philippines	Other countries	Total	Percentage
Bulk carriers	12 773	1010	7942	652	338	22,716	34.5
Oil tankers	4200	11 827	2811	128	946	9912	30.2
Container ships	3712	4545	2521	19	94	10,891	16.5
Gas carriers	420	3888	1881		1	6189	9.4
Ferries and passenger ships	214	3	59	3	1903	2182	3.3
General cargo ships	452	202	267	–	387	1307	2.0
Offshore vessels	651	135	4	–	332	1121	1.7
Chemical tankers	368	49	574	–	71	1063	1.6
Other	285	12	182	0	50	530	0.8
Total	23,074	21,670	16,242	802	4122	65,911	100.0
Percentage	35.0	32.9	24.6	1.2	6.3	100.0	

Source: UNCTAD (2020, p. 45)

the top 20 ship-owning countries—ranked by either cargo-carrying capacity in deadweight tons or in terms of value—almost half were located in Asia, and half located in Europe (UNCTAD, 2020, p. 41, 43). Greece, Japan, and China—the top three ship-owning countries—represent 40.3 per cent of the world's tonnage and 30 per cent of the value of the global fleet (UNCTAD, 2020, p. 37).

Among top 10 countries of ship registration by dollar value three were Asian countries—China, Hong Kong (Special Administrative Region of China), and Singapore.

Three Asian countries—China, Japan, and the Republic of Korea—hold world leadership in shipbuilding with each country specializes in different shipping sectors (see Table 2). China is the leading builder of bulk carriers (56%), offshore vessels (58%), and general cargo ships (35%). Japan is the leading builder of chemical tankers (54%). The Republic of Korea is the leading builder of gas carriers (63%), oil tankers (59%), and container ships (42%) (see Table 2).

3 The Transport Support of Europe-Asia Trade

European and Asian ports and regional shipping systems play a pivotal role in ensuring Europe-Asia trade. The EU and Asia are now leading trade partners, with $1.5 trillion of annual merchandise trade. The Europe-Asia trade accounts for around half of all world merchandise trade. Europe and Asia trade more between them than between any other regions in the world. Germany and China together are responsible for one quarter of the overall trade between Europe and Asia: about one third of European goods shipped to Asia come from Germany, with China as the largest customer; and over half of China's exports to Europe are delivered to Germany, the Netherlands, and the UK (Neves, Becker, Dominguez-Torreiro, Neves et al., 2019). In 2020, about 44% of EU imports came from Asia, while other European countries accounted for 31% and North America for 13%. The main destinations for EU exports were other European countries with 37% of the total exports, followed by Asia (30%) and North America (20%) (EUROSTAT, 2021a).

The specific feature of the trade between Europe and Asia—geographically distant from one another—is that it is supported primarily by maritime routes. For example, in 2011–2016, in the Europe-Asia trade, sea transport accounted for around 97% of cargo by their volume (in metric tonnes) and 70% of cargo by their value (Economic Commission for Europe, 2018, pp. 40–41). The share of air cargo in Europe-Asia freight traffic was less than 2% by volume, but some 30% by value. And the share of railway transport was 1% of cargo by volume and more than 2% by value (Economic Commission for Europe, 2018, pp. 40–41). The most significant in the system of Europe-Asia transport links is the volume of trade and the freight market between the EU and China.

In 2015, the biggest ports serving Europe-Asia trade by throughput were Rotterdam with an annual throughput of 12.2 million TEUs, Antwerp (9.7), and Hamburg (8.8). The biggest container seaports on the Baltic Sea serving trade flows from Asia were Saint-Petersburg (Russia), with an annual cargo throughput in 2016 of 1.7 million TEU, Gdansk (Poland)—1.3 million TEU, Gdynia (Poland)—0.7 million TEU, Khamina/Kotka (Finland)—0.6 million TEU,—1.7 million TEU, Klaipeda (Lithuania)—0.4 million TEU, Helsinki (Finland)—0.4 million TEU, Riga (Latvia)—0.4 million TEU (Economic Commission for Europe, 2018, p. 97). In the Mediterranean the biggest ports by throughput were Piraeus (Greece) with 3.3. million TEU (2015) and Mersin (Turkey) with 1.46 million TEU (2016). On the Pacific coast Chinese ports Shanghai, Shenzhen, Ningbo-Zhoushan, Guangzhou, Qingdao, Tianjin, Dalian, Xiamen, Hong Kong, and Busan (Republic of Korea) were the biggest ports with total annual throughput of 43.4 million TEU (2015) (Economic Commission for Europe, 2018, p. 97).

In the trade lane between Northern Europe and Asia, there are approximately 37 services provided by 12 alliances/carriers, with a total number of 241 container ships being employed on this route (Liu & Kronbak, 2010, p. 441).

The conventional sea route linking the Asian and European markets passes through the busy and narrow Malacca Strait in Southeast Asia, crosses Indian Ocean, and goes via the Suez Canal. This shipping route has some limitations and weak points. According to some experts, the Suez Canal passage is already suffering from growth of trade volumes, and the enhancement of traffic flows may hit the capacity of the canal. The Suez Canal incident in March 2021, when the Ever Given container ship unintentionally blocked the Canal for six consecutive days thus disrupting global trade, demonstrated the fragility of the traditional sea route between Europe and Asia through the Suez Canal. Moreover, a major concern for

European and Asian trading nations has become maritime piracy, specifically, in the Strait of Malacca and in the Gulf of Aden (Martínez-Zarzoso, 2013, p. 61). To avoid the increasing waiting time for the Suez Canal and reduce risk of piracy, ship owners have been considering alternative shipping routes and networks to serve the Europe-Asia trade flows, like, for example, transarctic routes or the Cape of Good Hope shipping route (Zhao, Hu, Lin, Zhao et al., 2016, p. 50). The high trading demand between Europe and Asia accentuates the need to explore alternative or supplementary maritime passageways. A viable option providing potentially shorter, time saving, and safer route with presumably lower shipping costs in comparison to traditional shipping routes between Europe and Asia might be the Northern Sea Route (the NSR).

4 Conclusion: The Implications of the Northern Sea Route on the Existing Europe-Asia Logistics

The NSR is the key part of the Northeast Passage between Northeast Asia (i.e., Japan, South Korea, and China) with Northwest Europe through the Arctic Ocean. Russia, which strongly promotes the NSR, expects that by 2035, the NSR will become a globally competitive national maritime transport corridor that will compete with the southern route via the Suez Canal. Recently, there has been a surge in shipments via the NSR: cargo traffic on the NSR has jumped from four million tons in 2014 to 32.97 million tons (including 1.28 transit cargo) in 2020. Russian authorities aim to increase cargo shipping volumes along the NSR to 80 million tons per year by 2024 (President of Russia, 2018).

However, so far, the most shipping activities on the NSR are domestic and destination shipping, while the number of international transits remains insignificant both in the number of transit voyages and their cargo volumes. In 2016, there were only eight transit voyages via the NSR, in 2017—12, in 2018—17, and in 2019—14. All transits except two—those were shipments of coal from Vancouver, Canada to Finland in 2016—have been between Northeast Asian ports (in China, Japan, and South Korea) and ports in Northwest Europe (in the five Nordic countries, Germany, UK, Netherlands, and France) (Gunnarsson, 2021, p. 6). Asian shipping companies are in the leading role, with the Chinese COSCO with 23 voyages or 45% of all transits during the 4 years, followed by German companies with 25% (Gunnarsson, 2021, p. 6).

In 2020 alone, 64 transit voyages were made, with the volume of transported cargo totaled to 1.28 million tons (Northern Sea Route Information Office, 2020). The main share of transported cargo belonged to iron ore concentrate—78% or one million tons. The rest of transit transportations were general cargo ships belonging to Chinese COSCO, which transported around 0.198 million tons of cargo (windmill equipment, wood pulp, fertilizer, and other general and bulk cargo). The ports of exit and destination in Europe were in Denmark, Finland, Lithuania, Germany, and

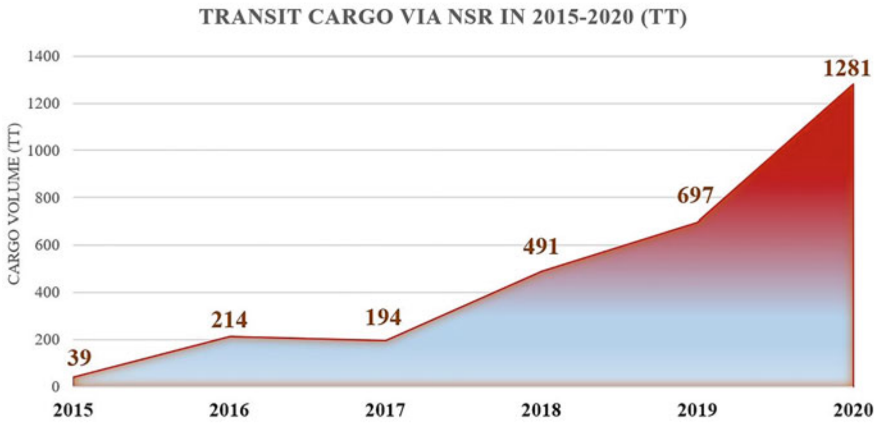

Fig. 2 Transit cargo through the Northern Sea Route, 2015–2020 (in tons) (Northern Sea Route Information Office, 2020)

Sweden (Northern Sea Route Information Office, 2020). Overall, over the last few years there has been the gradual and continuing growth in the number of transit voyages and their cargo volume on the NSR with a sharp increase in 2020 (see Fig. 2).

Yet, a sharp increase in overall shipments via the NSR during past several years has not resulted from transit voyages; it is mainly due to increased domestic shipping and destination shipping between the NSR and European ports. In 2016–2019, 76–92% of all voyages on the NSR were domestic shipping. And during the same period there were 1232 destination voyages on the NSR: 1108 between the NSR and European ports, and 124 between the NSR and Asian ports (Gunnarsson, 2021, p. 5). In 2016 and 2017, most of these voyages were deliveries of LNG modules and project cargo from outside Russia to locations within the NSR (mostly for the construction of the Yamal LNG plant at the port of Sabetta). Since 2018, shipments of LNG and gas condensate from the Yamal LNG plant to western European ports have greatly contributed to the increased traffic through the NSR.

According to Bjorn Gunnarsson, currently all international transit voyages on the NSR are largely exploratory in nature or demonstrations of intentions, aiming at evaluating commercial viability of the NSR as a possible trade route (Gunnarsson, 2021, p. 7). The emerging NSR represents change to the existing network for Europe-Asia trade shipping and will have important implications for leading maritime powers and ports—both in Asia, Europe and beyond. An increase in shipping along the NSR will benefit ports in Northwest Europe (first and foremost, for ports in the five Nordic countries, Germany, UK, Netherlands, and France) and Northeast Asia (in Japan, China, and South Korea). In terms of reducing sailing distance between the Atlantic and Pacific, of all Asian countries, Japan has the greatest potential to gain from use of the NSR due to its northerly location (Moe & Stokke, 2019, p. 29). In China, the major beneficiaries are expected to become ports in northeastern part of the country. In South Korea there appeared a competition among ports, such as Busan, Ulsan, and Kangwon, which have asked Korean central government to invest capital for the development and modernization of their ports, arguing that their ports are the best fit for the Arctic era (Park, 2014, p. 64).

Adversely, if shipping companies decide to use the NSR as the alternative route for transporting cargoes from and to Europe and Asia, the shipping activities at the Suez Canal and the Straits of Malacca will be affected (Rahman, Saharuddin, Rasdi, Rahman et al., 2014). The transformation of the NSR into a global SLOC may also result in the diversion of some traffic from the Singapore port, at present profiting from its status as world's major transshipment hub (Leksyutina, 2021, p. 7). It can also result in the redirection of sea traffic from Indian ports to other countries, although, according to Indian researcher Sinha, it will have limited impact on Indian harbors, since India is not a transshipment hub (Sinha, 2019, p. 122).

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Digitalization of the Northern Sea Route Based on Enterprise Architecture Approach

Igor Ilin, Olga Voronova, Alena Ershova, and Krasimir Kostenarov

Abstract Development of architectural solutions for the Northern Sea Route requires research and formalization of different activities performed by the whole range of industries, taking into consideration interests of all stakeholders involved. This study focuses on development of key aspects of motivation expansion for the Northern Sea Route based on business architecture design. Stakeholders that are largely engaged in digitalization were identified, classified, and characterized. As a result, the architecture of digital services required for informational support was suggested. Application of services and models presented in this study can potentially facilitate development of integration model for information systems architecture in the business architecture of the Northern Sea Route.

1 Introduction

Development of architectural solutions for the Northern Sea Route involves research and formalization of various activities of enterprises in numerous industries, taking into account interests of all stakeholders. Among other fundamental requirements, it is necessary to pay due attention to formation and improvement of mechanisms that enable interaction between constantly changing business requirements and IT services that support them. In its turn, commodity exchange market for the period up to 2024 and longer is expected to experience dynamic changes and require complex digital solutions that particularly refer to online data collecting on cargo transportation and tracking.

Taking these conditions into account, development of an aggregated model for motivational expansion will allow identifying key requirements and selection paths to be followed throughout the process of development of architectural models for the Northern Sea Route.

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2 Development of Key Aspects of Motivation Expansion for the Northern Sea Route Based on Business Architecture Design

Motivation expansion focuses on identifying driving transformation forces of enterprises involved in the implementation of the Northern Sea Transit Corridor. Thereby, designing a meta-model of motivational expansion demands consistent assessment of motives and intentions (goals, principles, requirements, and selection principles), as well as the sources of the above-mentioned motivations (stakeholders, drivers, and evaluation). It should be noted that motivation elements are related to basic elements through the concepts of "requirement" and "restriction."

Identification of stakeholders and their requirements for the digital architecture of the Northern Sea Route is the most important stage in any project, especially the one related to the development of information technology support. In order to identify the main stakeholders, that are parties directly interested in the formation of a reference architectural solution, this paper primarily focused on the organizational management structures of enterprises and organizations in various industries, taking into account the interests of all involved persons. It is particularly relevant because, undoubtedly, all stakeholders should be involved in the process of identifying requirements. Stakeholders can be both internal and external, thereby, it is important to take into account the opinions and requirements of all involved parties.

Based on the conducted analysis, a standard structure of stakeholders interested in building architectural solutions for the Northern Sea Route includes: administration of the Northern Sea Route: government and state bodies at the federal or regional level, shipowners, carriers of cargo, shippers, receivers of cargo, ship crews, transport intermediaries, insurance companies, financial organizations, third-party organizations. Each group of stakeholders sets, modifies, and pays special attention to goals in order to achieve their interests. At the same time, the driver acts as a condition that directly or indirectly creates and motivates changes in the organization, thereby initiating the transformation of goals.

Once the most significant stakeholders have been identified, it is possible to proceed to identification of requirements for the digital architecture of the Northern Sea Route for each selected group of stakeholders. A requirement should be understood as a statement of a need that must be implemented by the system. Requirements design properties of the elements needed to achieve the results, which are in turn modeled by the goals, so the requirement defines the property that applies to a particular system. In this regard, restriction should be understood as a limitation of the way in which the system is implemented. Restrictions do not prescribe implementation of some intended functionality of the system, but impose a constraint on the way in which the system can be implemented (as opposed to a requirement). This can be a selection principle on the implementation of the system (for example, use of a certain technology) or a selection principle on the implementation process (for example, time or financial restrictions). It should be noted that the requirements of

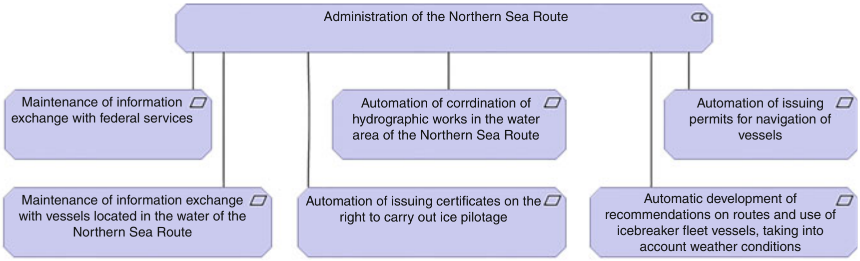

Fig. 1 Requirements of the Northern Sea Route Administration

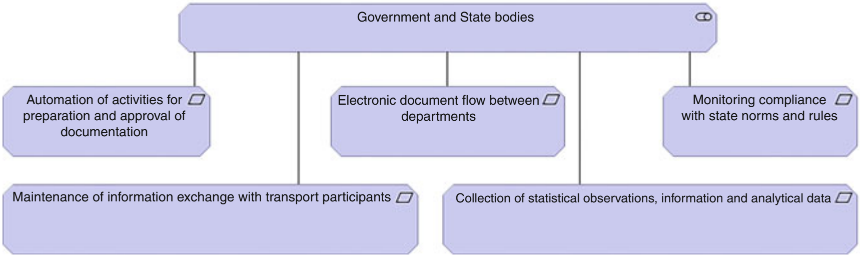

Fig. 2 Government requirements

stakeholders can manifest themselves in various forms: in the form of demands, requests, expectations, or restrictions.

When identifying specific requirements, it is important to start with the Administration of the Northern Sea Route. Based on the list of activities that the Administration performs, its main requirements for digital architecture were formed (Fig. 1).

According to Fig. 1, most of the requirements from the Administration are related to the automation of routine activities for formation, approval, and issuance of various documents, as well as to ensuring information exchange with participants of maritime transportation.

The next group of stakeholders is governmental and state bodies. Their requirements are reflected in Fig. 2.

Since the activities of state bodies are largely regulatory in nature, most of the requirements are related to ensuring this regulation. State authorities should be able to monitor the situation in the Northern Sea Route, track compliance with established national and international norms and regulations, collect various data for subsequent analysis, the results of which will allow identifying acute problems as well as opportunities for further development (Chueva et al., 2017). What is more, due to the fact that many state bodies of various profiles are involved in maritime transportation (the Federal Customs Service of the Russian Federation, the Federal Service for Supervision of Consumer Rights Protection and Human Welfare (Rospotrebnadzor), the Federal Service for Veterinary and Phytosanitary

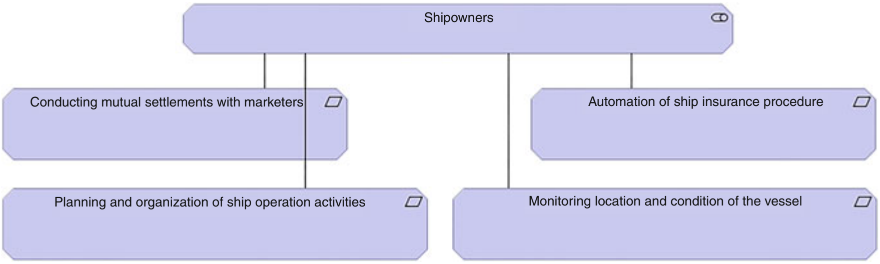

Fig. 3 Requirements of shipowners

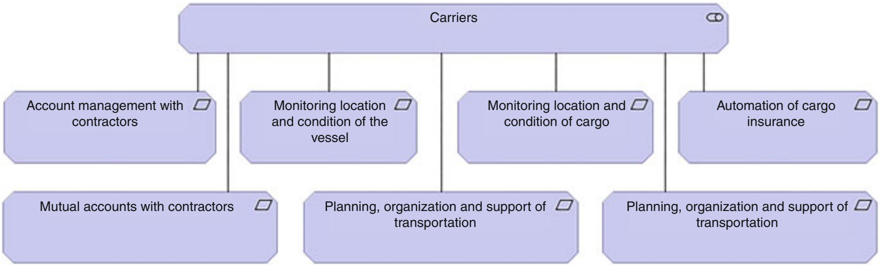

Fig. 4 Requirements of carriers

Surveillance, the Border Service of the Federal Security Service of the Russian Federation, etc.), it is necessary to ensure a smooth electronic document flow between departments, as well as to organize their unhindered data exchange with other participants.

Further on, we will consider the requirements for digital architecture of the Northern Sea Route that arise for ship owners (Fig. 3). In the context of identification of claims, in this case, shipowners are considered as persons/organizations that have the right of ownership of the ship, but are not engaged in its direct operation (transfer the right of operation under the contract to carriers).

Requirements of shipowners are primarily related to control of direct operation of the vessel. The owner of the vessel should be able to track its route, find out its current location, as well as check the condition of the vessel and the operability of its systems and plan activities for the inspection, testing of various mechanisms, devices, ship systems, and equipment. In addition, an important role for owners is played by the ability to automatically plan and organize activities for commissioning of ships to carriers in accordance with their requests. No less important for shipowners is the ship insurance procedure, and therefore there is a requirement for its automation, which implies the automatic collection of information necessary for the insurance company and the formation of a list of documents based on this data.

The next group of stakeholders is carriers that use vessels directly for transportation. Their requirements are clearly shown in Fig. 4. It should be noted that in reality, the owner of a vessel can also be engaged in its operation and, accordingly,

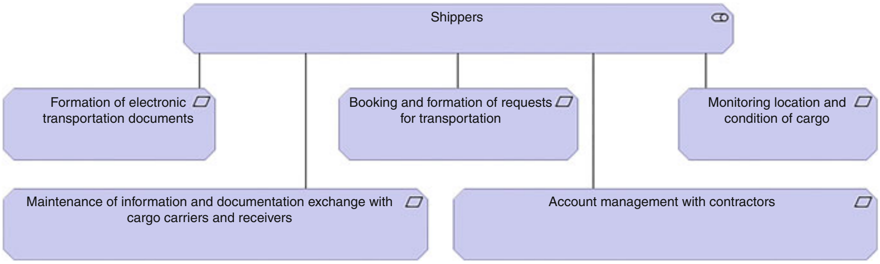

Fig. 5 Requirements of shippers

be the carrier, but for convenience of identifying the requirements, these two groups of stakeholders were separated.

Requirements of carriers partly overlap with the requirements of shipowners in terms of monitoring the location and condition of a vessel, since the carrier is responsible for it during operation. In addition, while transporting, the carrier is also responsible for the cargo on board from the moment it is accepted for carriage until it is issued, and therefore the carrier must be able to track the conditions under which the transport takes place and the condition of a particular cargo at a particular time. The cargo insurance procedure should also be automated as much as possible. Furthermore, carriers strive to automate planning, organization, and maintenance of transportation: for example, the automatic creation of cargo plans for ships in accordance with such parameters as destination, expected delivery time, type of cargo, capacity of ships. Among other things, given the large number of contractors with whom it is necessary to maintain communication, it is extremely important for carriers to create a single information space and establish electronic document management.

Of course, one of the most important categories of stakeholders is shippers (sellers). Their requirements are shown in Fig. 5.

For shippers, it is very important to automate the planning and coordination of transportation with other participants, namely: to create a request for transportation and book a seat with the carrier, to form the necessary package of documents for the carrier and the consignee, to conduct mutual settlements. Shippers should also be able to track the location and condition of the cargo. Despite the fact that from the moment of acceptance of the cargo, the responsibility passes to the carrier, there may be disputes as to when safety of the cargo was violated (damage or loss). In order for any of the parties to verify this, it is necessary to provide them with access to this kind of information.

Receivers of cargo (buyers) also have their own requirements for digital architecture. They are reflected in Fig. 6.

Requirements of receivers are determined by their main goal (to get the necessary cargo in the proper quality at a certain time) and largely repeat the requirements of other transport participants: the ability to track where and in what condition a

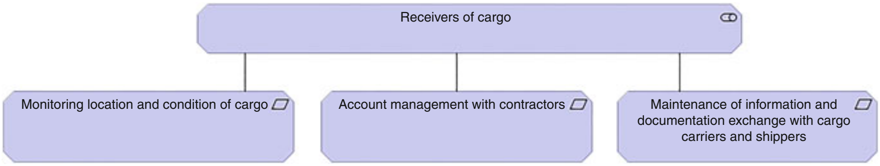

Fig. 6 Requirements of receivers

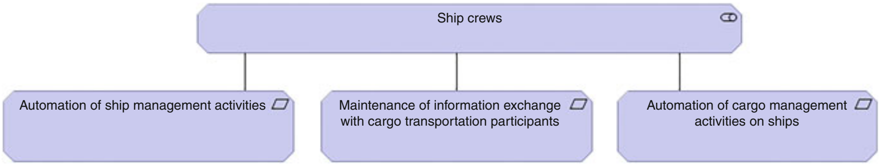

Fig. 7 Requirements of a ship crew

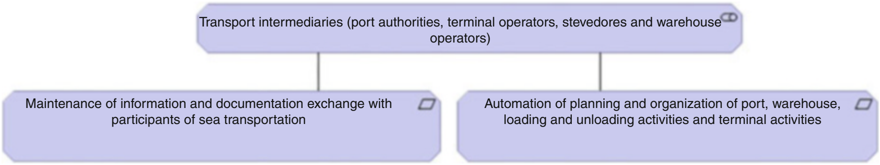

Fig. 8 Requirements of transport intermediaries

particular cargo is, maintaining information and documentation exchange with other transport participants, as well as conducting mutual settlements.

Ship crews also have some requirements for the digital provision of the NSR. These requirements are shown in Fig. 7.

It is expected that the requirements of ship crews are related to the automation of ship and cargo management activities on these ships. In addition, information should be transmitted not only to the persons directly involved in a particular transport, but also to coastal and meteorological services, as well as to port administrations, etc.

Transport intermediaries involved in transportation are also parties interested in digitalization. Such intermediaries primarily include port administrations, terminal operators, warehouse operators, and stevedores responsible for loading and unloading cargo. Their requirements are shown in Fig. 8.

First of all, due to the intermediary nature of the activity, ensuring the coordination of transport participants through the organization of unhindered information and documentation exchange is one of the key requirements. In addition, automation is required within the framework of the activities that each specific intermediary implements.

Since sea transportation is associated with a number of possible risks, insurance is necessary. In this regard, insurance companies also become stakeholders whose requirements must be taken into account (Fig. 9).

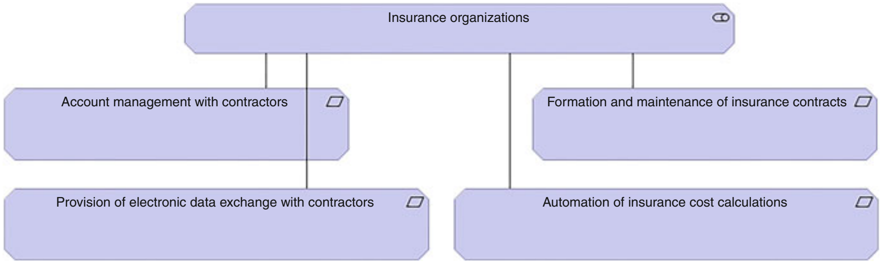

Fig. 9 Requirements of insurance organizations

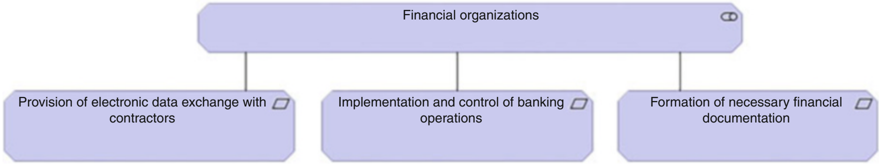

Fig. 10 Requirements of financial institutions

For insurance companies, it is important to automate the processes of forming and approving insurance contracts with customers, calculating the cost of insurance premiums, and conducting mutual settlements. Electronic document management is also necessary.

Financial organizations involved in the settlement processes between participants in maritime transport are also interested parties. Their requirements are reflected in Fig. 10.

Digital and information technologies planned for implementation should provide automation of various banking operations, including the formation of the necessary financial documents, and should also provide control over financial flows. Electronic data exchange should also be implemented.

Finally, the last group of stakeholders are organizations, associations, and associations of various profiles that do not directly participate in transportation activities, but can have an indirect influence on it. As a rule, such organizations carry out activities for monitoring safety, monitoring the environmental situation, collecting data for the formation of statistics, and other similar activities. Such organizations include, for example, the International Maritime Organization (IMO). For more information, the main requirements of such organizations are shown in Fig. 11.

Thus, the main groups of stakeholders that will be affected in one way or another by digitalization of the Northern Sea Route were identified, together with their key requirements for information and digital solutions.

It should be noted that identification of typical aspects of modern architectural solutions will allow us to develop an optimal architectural solution that will create new opportunities for the Northern Sea Route to optimize resources and acquire new professional knowledge for all involved persons, which, in turn, will significantly

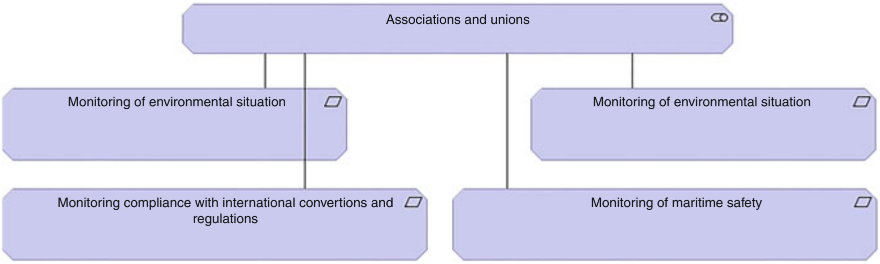

Fig. 11 Requirements of associations and unions

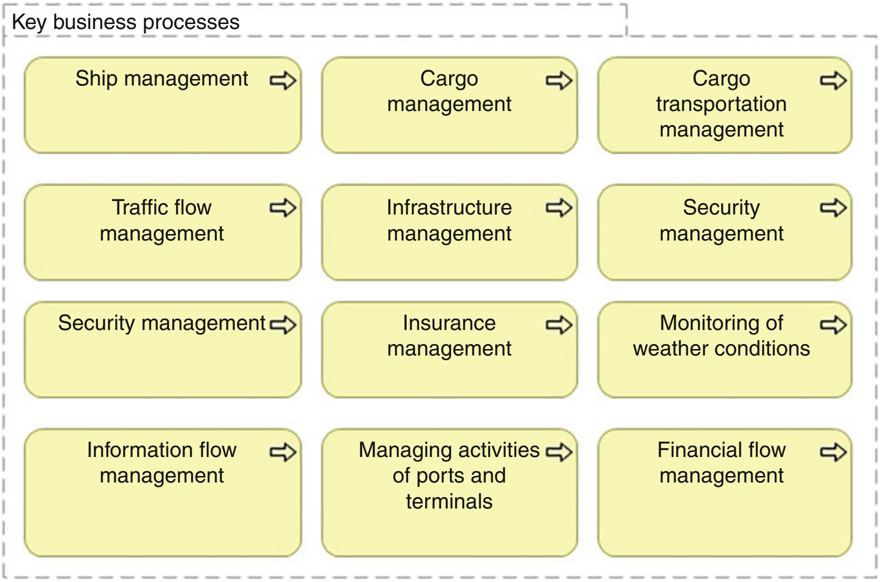

Fig. 12 Key business processes

increase profits, improve the quality of cargo transportation, and lead to a significant increase in the volume and conversion of the Northern Sea Transit Corridor. As mentioned earlier, development of digital architecture of the Northern Sea Route in this study will be carried out in accordance with the TOGAF. According to the Architecture Development Method (TOGAF ADM), the first step in the architecture creation process is the development of a business architecture.

Business architecture or business layer architecture is a description of the mechanics and structure of a business activity. At the same time, the basis of business architecture is a system of key business processes, which is formed on the basis of the functional structure of the business (Gurzhiy et al., 2021). Based on the requirements of stakeholders identified at the previous stage, a list of key business processes was determined (Fig. 12).

It is essential to consider each of the processes specified in the model in detail.

1. Ship Management Activities Include Functions Directly Related to their operation, namely:
   (a) shipboard systems and equipment management;
   (b) navigation management;
   (c) management ship operation;
   (d) ship safety management;
   (e) radio communication management;
   (f) management of administrative and economic activities on the ship;
   (g) managing day-to-day activities on the ship;
   (h) cargo management.
2. Cargo management includes the following main functions:
   (a) tracking location of cargo in transit;
   (b) preparation of cargo documentation;
   (c) cargo safety management;
   (d) cargo condition monitoring;
   (e) cargo insurance.
3. Cargo management activities also include a number of functions:
   (a) planning and organization of cargo transportation;
   (b) managing freight requests;
   (c) managing the accompanying documentation;
   (d) cargo transportation safety management;
   (e) cargo transportation control;
   (f) managing freight rates and calculations;
   (g) accounting and analysis of cargo transportation activities.
4. Port and terminal management includes the following functions:
   (a) management of cargo handling activities;
   (b) ship maintenance;
   (c) management of technical facilities and infrastructure of the terminal/port;
   (d) management of administrative and economic activities of the port;
   (e) port/terminal production management;
   (f) terminal and port security management;
   (g) warehouse management;
   (h) analysis and forecasting of terminal/port congestion.
5. Traffic management activities are mainly related to the dispatching and routing of ships. In addition, this also includes the preparation of a schedule of ships.
6. Infrastructure management involves activities of monitoring condition, maintenance and repair of various infrastructure facilities, and structures that are located in the waters of the Northern Sea Route.

7. Security management includes measures to monitor and prevent potential threats and hazards.
8. Document management involves creation and exchange of documentation between stakeholders.
9. Information flow management includes the functions of organizing and coordinating the exchange of data between various participants in the maritime transport process.
10. Financial flow management activities include the implementation and control of mutual settlements.
11. Monitoring weather conditions in the context of transport along the Northern Sea Route is necessary due to the severity and unpredictability of the Arctic climate.
12. Insurance management includes functions of cargo and ship insurance.

These processes and functions were included in the business architecture model of the Northern Sea Route. In addition, this model represents business actors—individuals, organizations, or structural units with which a particular process is associated. They can be the executors of the process or its participants. In addition to the stakeholders mentioned earlier, the model includes additional organizational units: the NSR Situation Center, the Center for Hydrometeorological and Ice Conditions, and the NSR Control Center.

It is assumed that the situation center will monitor various parameters in the waters of the Northern Sea Route in real time, dispatch vessels, predict situations, and manage crisis situations. The Center for Hydrometeorological and Ice Conditions will carry out forecasting and monitoring of natural conditions. The SMP Control Center will carry out coordination activities, manage the flow of information and documentation. These centers can be implemented as separate structural units, or they can be incorporated into existing organizational units (Figs. 13, 14, and 15).

Based on the developed models of motivational expansion, key business processes, and a function-oriented organizational structure, it is possible to present a top-level model of the business architecture of the Northern Sea Route. The next step after forming a business architecture in accordance with TOGAF ADM is to develop an application architecture.

Application architecture describes the IT services that provide information support for the elements of the business architecture, as well as the application components that these services implement.

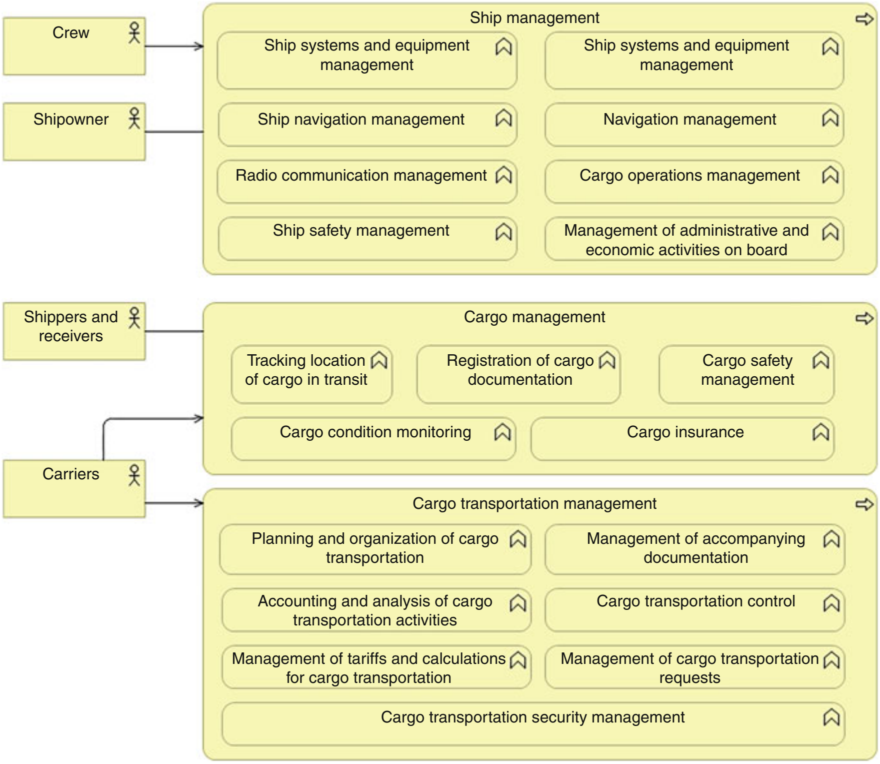

Fig. 13 Function-oriented organizational structure of the Northern Sea Route (part 1)

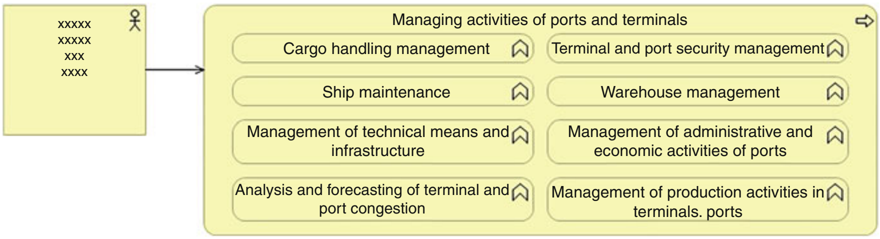

Fig. 14 Function-oriented organizational structure of the Northern Sea Route (part 2)

3 Architecture Development of Digital Services for the Northern Sea Route

Formation of a system of requirements for the architecture of services is an extremely important stage in the development of the architecture of the Northern Sea Route. This stage should be carried out already at the initial stage of project development, since the results obtained will depend on the results obtained.

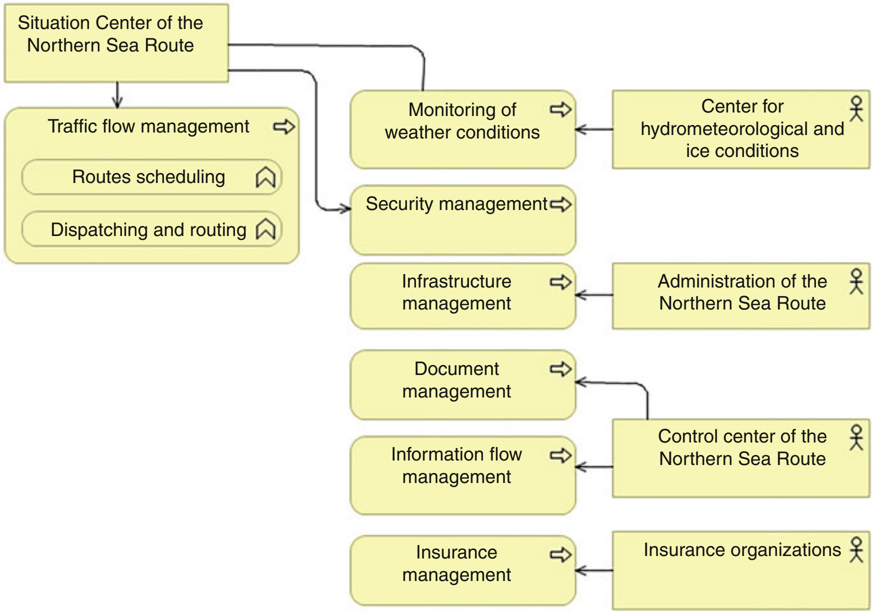

Fig. 15 Function-oriented organizational structure of the Northern Sea Route (part 3)

When forming a system of requirements for the architecture of services, you should adhere to the following principles, shown in Figs. 16 and 17.

It is important to pay attention to the classification shown in the figure in more detail. Business requirements are a justification for the needs of stakeholders. It should be noted that depending on the development goals, the following two groups of requirements can be distinguished: requirements of the Northern Sea Route Administration and requirements of direct customers of specific software of various services (owners of business processes: shipowners; carriers; shippers; consignees; ship crews; transport intermediaries involved in the physical movement of goods).

User requirements are a description of specific functions performed by the services. Collecting this information is quite time-consuming. When systematizing these requirements, business architects often face such problems as the lack of clarity in the presentation of information by the performers of various business processes, mixing (contradiction) and combining requirements (Pirogova et al., 2020).

System requirements are a much more detailed description of user requirements, including a functional specification that describes system functions and constraints. Functional requirements, in turn, determine the functionality of the software required to meet the business requirements of the main stakeholders. Non-functional requirements are intended to describe the characteristics of the system and its environment, not the behavior of the system. In some ways, non-functional requirements reflect user requirements (taking into account the restrictions on the financing of specific projects, legislative aspects, and the company's security policy) (Milaković et al.,

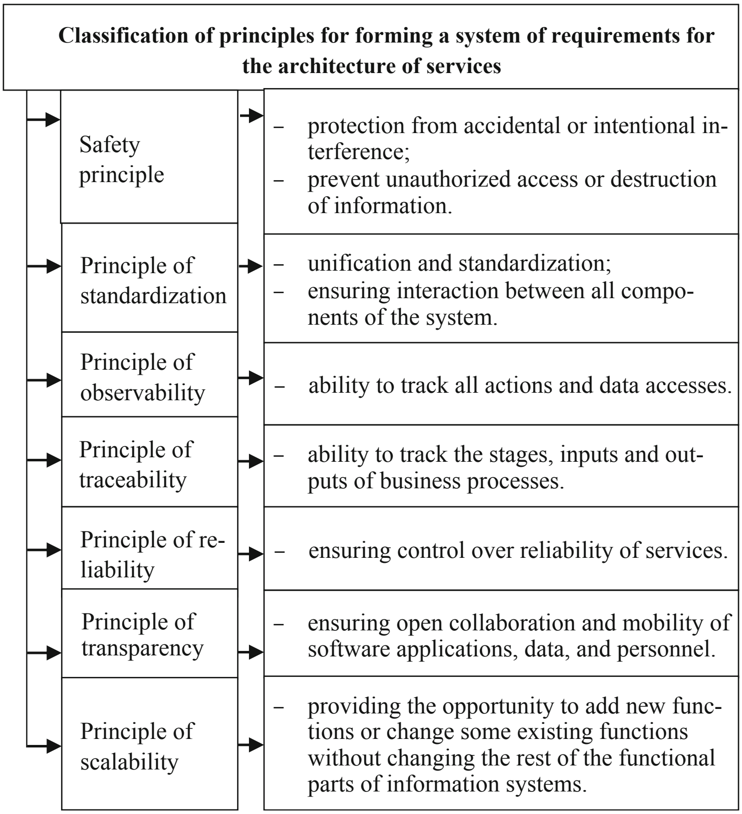

Fig. 16 Classification of principles for forming a system of architectural requirements

2018). Requirements of the subject area characterize the subject area of business services, and, depending on the content, they can be attributed to both functional and non-functional requirements. Product requirements are a set of requirements for the performance of services and the convenience of their operation. Organizational requirements include software implementation requirements, design methods, and output requirements. Integration requirements make it possible to formalize the choice of the service integration method, and describe the interface of interaction between the developed services and the existing systems (Fig. 18) (Fadeev et al., 2021).

It should be noted that special methods of analyzing end-to-end service architecture are used to determine the relationship between business, application, and infrastructure services (Fig. 19).

It is vital to observe interconnection between business, application (information system services), and infrastructure services presented in the figure in more detail. Business services are the services of the participants of the Northern Sea Route which ensure the interaction of internal and external clients of business

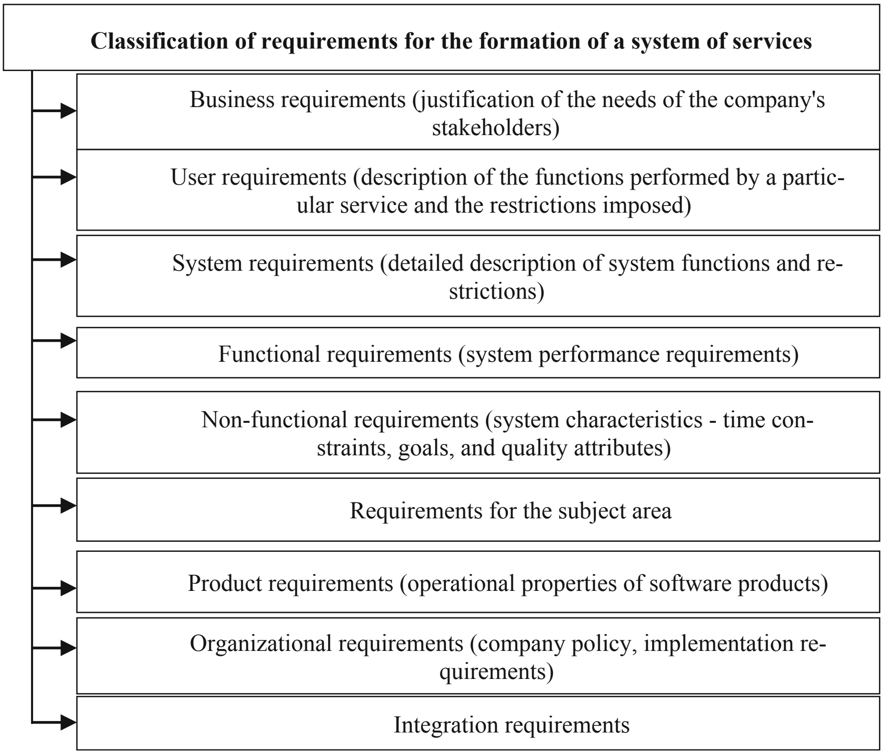

Fig. 17 Classification of requirements for formation of a system of services

processes (Ilin et al., 2020b). These services provide direct interaction between internal customers and/or departments, as well as interaction with shippers, consignees, partners, and other third-party organizations. Business services implement certain business processes, and the implementation can be carried out through any channel of interaction, not necessarily related to automation. Business services can fully and/or partially consist of non-automated operations and operate with any type of resources (labor, financial, material, information) (Ilin et al., 2020c).

It should be noted that the functions of composite applications for implementing business services must meet certain business goals (Zaychenko et al., 2018a). Therefore, in order to map a business service to the application services of an information system, it is necessary to go to the assessment of the business process implementing this service and select the totality of automated actions of a particular performer. At this stage, it is necessary to identify the functions performed by the computer part of information systems in the automated user actions and determine how to perform these functions.

Infrastructure services, in turn, are used for the functioning of the IT infrastructure (Iliinsky et al., 2020). Examples of infrastructure services include a data archiving service, a backup service, and so on (Fig. 20).

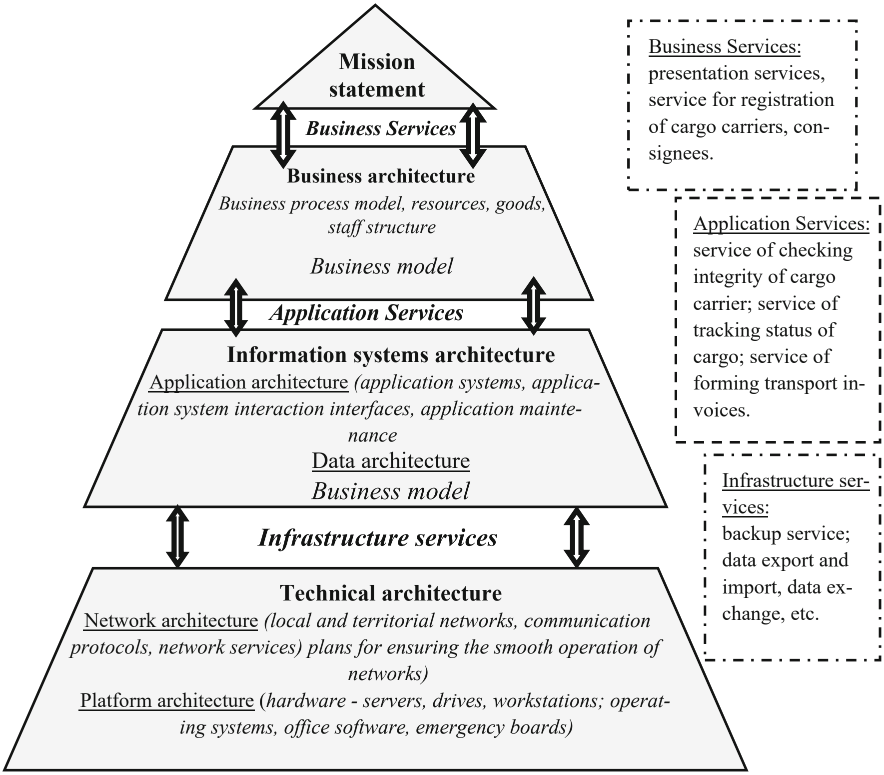

Fig. 18 Representation of the Northern Sea Route architecture

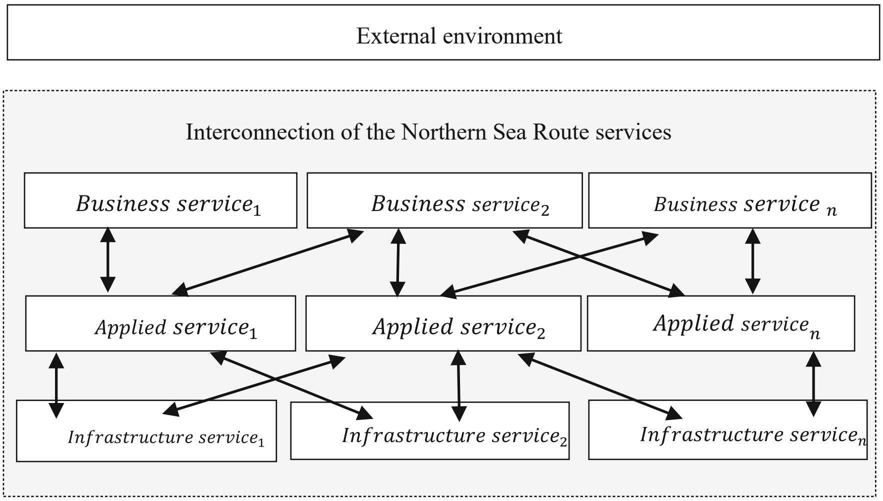

Fig. 19 Interconnection between business, application, and infrastructure services

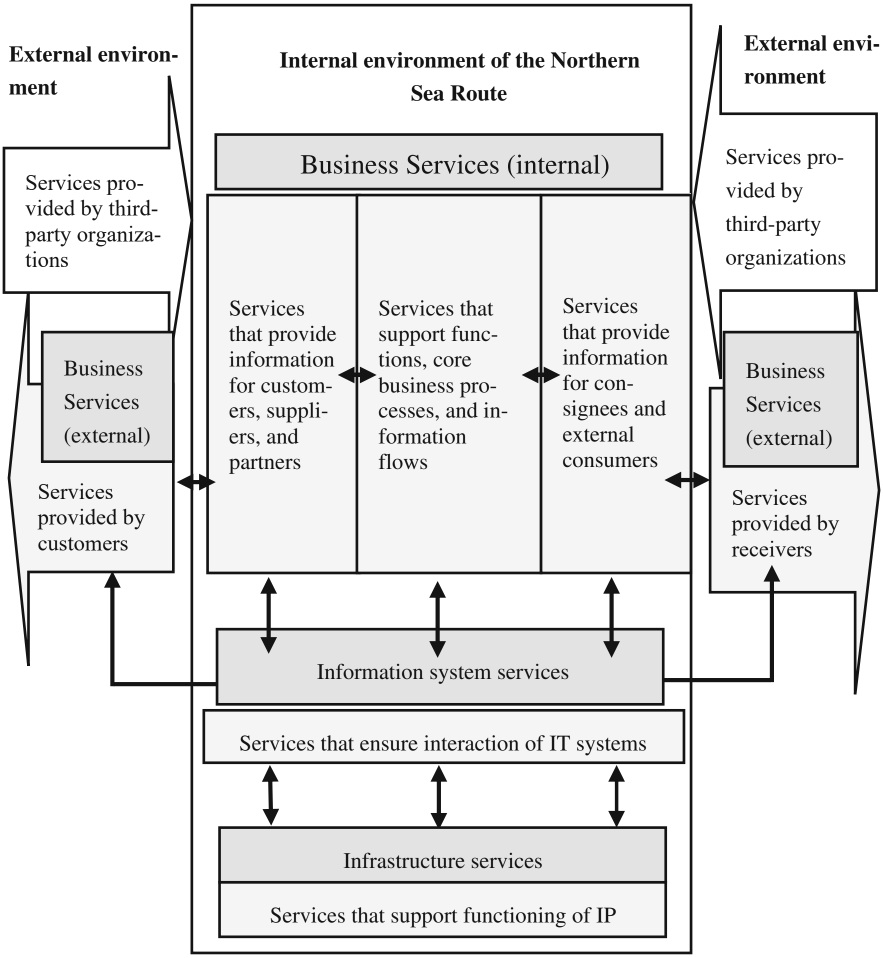

Fig. 20 Structure of the Northern Sea Route services

When developing reference architectural solutions for the Northern Sea Route, it is advisable to take into account a clear functional orientation of the subdomains, reflecting the operational business models of enterprises in various industries, taking into account the interests of all involved persons (Fig. 21).

These requirements are general and are subject to specification and implementation in the final product during the development process. Based on the results of the previous stage, it is necessary to analyze the information received. This will allow you to identify the optimal requirements for the system based on functional and non-functional needs.

Currently, under the influence of various factors, information technologies are changing so quickly that it becomes almost impossible to predict where and in what form the next breakthrough will occur. Modern information technologies are

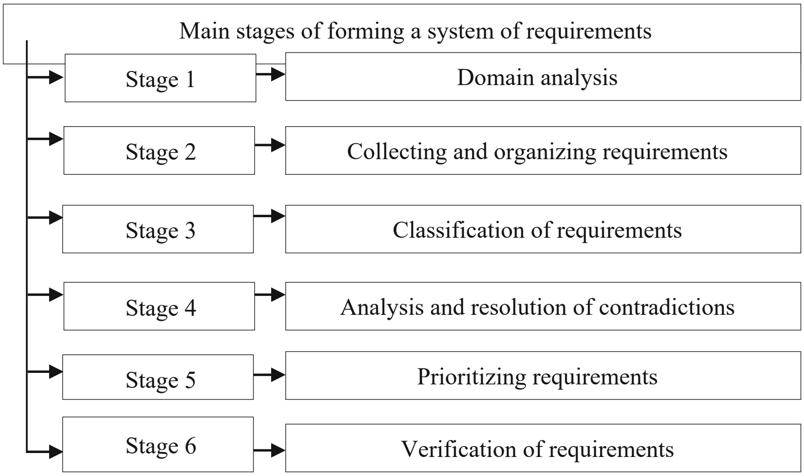

Fig. 21 Major stages in forming a system of requirements for the services architecture

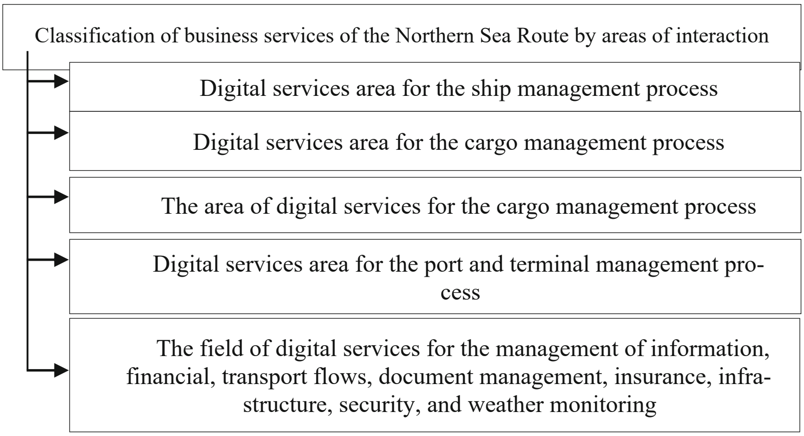

Fig. 22 Classification of business services of the Northern Sea Route by areas of interaction

increasingly penetrating into the very essence of doing business, which naturally leads to a significant expansion of the range of specific business solutions. At the same time, specific tasks become the driver of the development of business services, and the trends of their development are aimed at the real solution of emerging problems (Voronova, 2020).

When developing reference architectural solutions for the Northern Sea Route, it is advisable to take into account a clear functional orientation of the subdomains that reflect the operational business models of enterprises in various industries, taking into account the interests of all involved persons (Sergeev et al., 2021). The figure shows the classification of business services by interaction areas (Fig. 22).

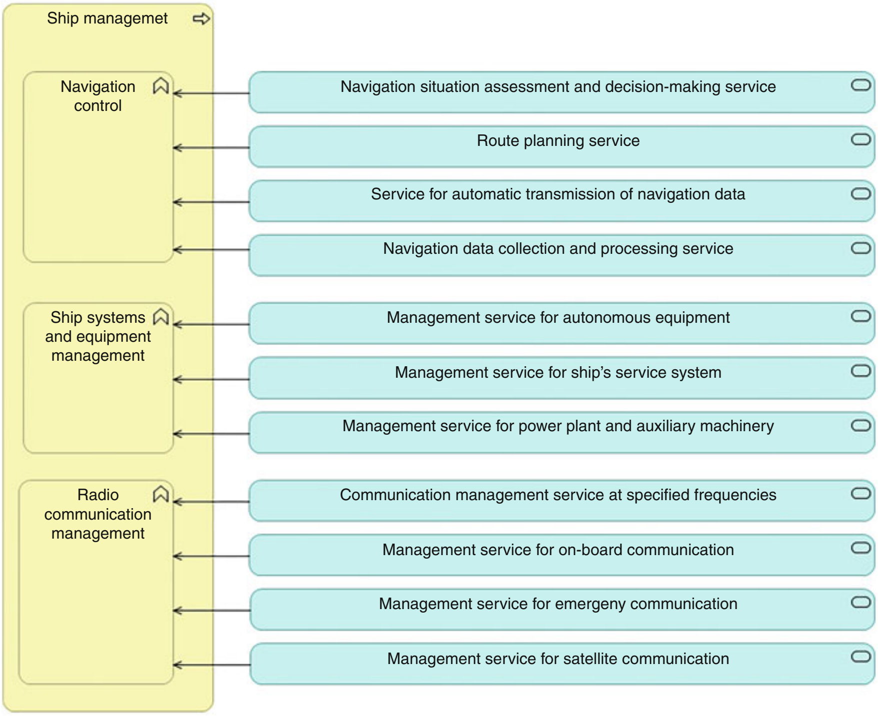

Fig. 23 Digital services architecture for the ship management process (part 1)

Fig. 24 Digital services architecture for the ship management process (part 2)

It is important to look at the classification of business services in more detail (Figs. 23, 24, 25, 26, 27, 28, and 29).

In order to further evaluate the architecture of business services, it is important to consider the basic service-oriented architecture shown in Fig. 30.

Based on the presented service-oriented architecture, it follows that the service provider represents various services, the service consumer consumes services that

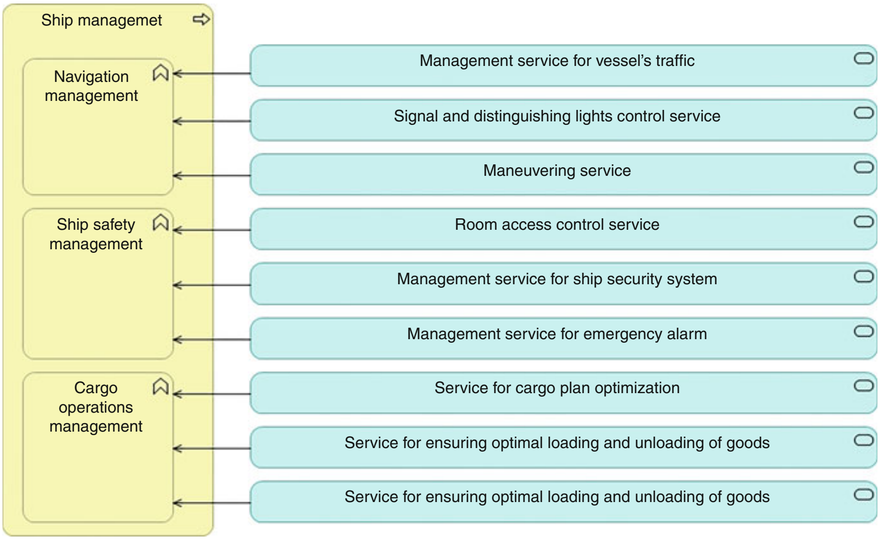

Fig. 25 Digital services architecture for the ship management process (part 3)

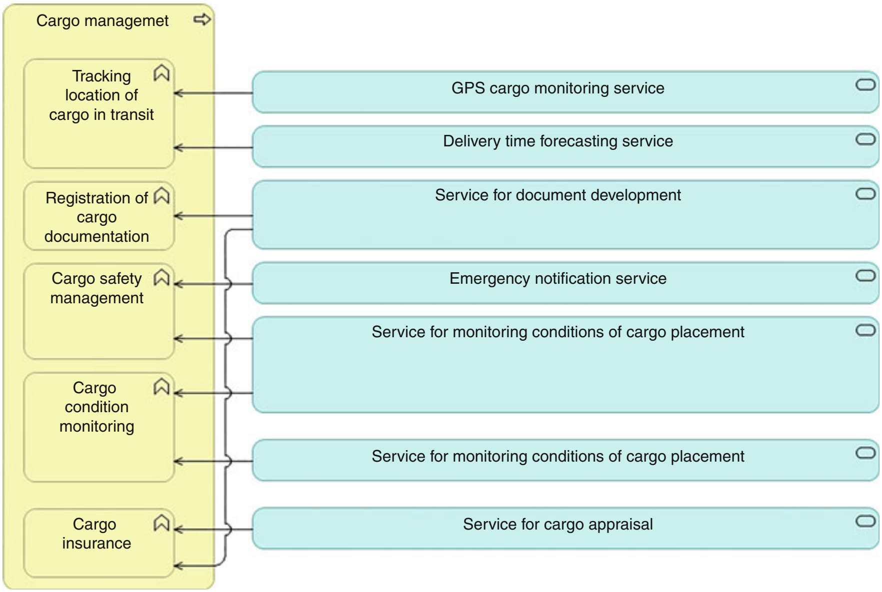

Fig. 26 Digital services architecture for the cargo management process

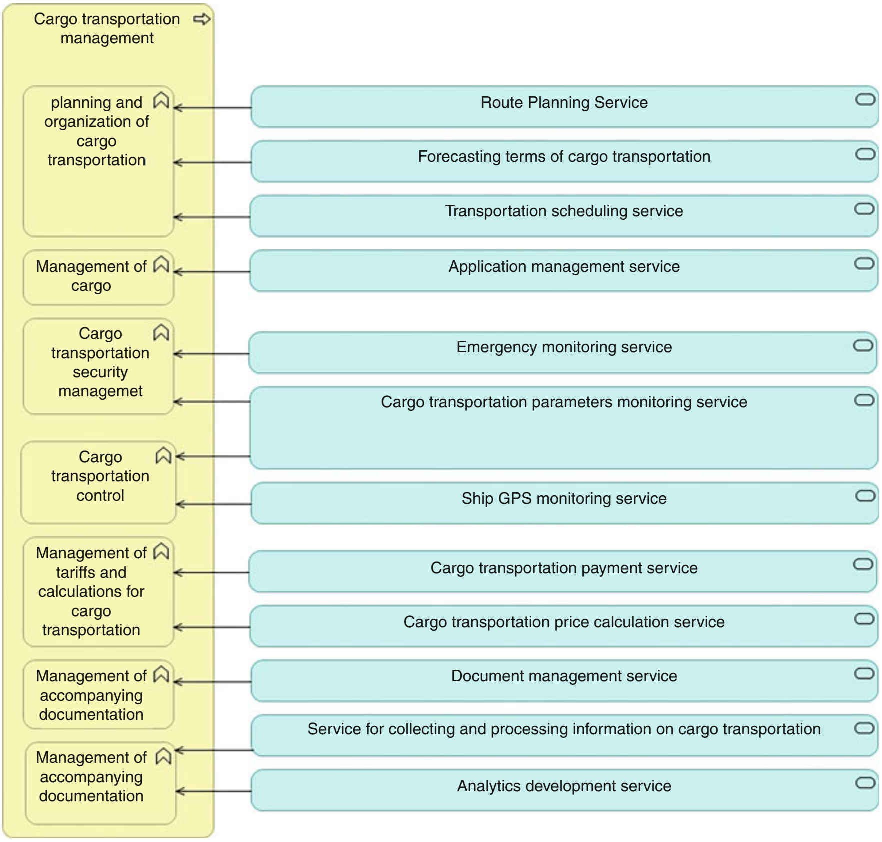

Fig. 27 Digital service architecture for the freight management process

meet its business needs and are found in the catalog of services, the catalog of services serves to publish and maintain a list of services available to consumers. When evaluating the lifecycle of business services, consider the following steps (Didenko & Cherenkov, 2018):

- designing a business service;
- business service development;
- implementation of the business service;
- operation;
- business service analysis;
- optimization of the business service.

Thus, the service architecture can be represented in the following form (Fig. 31).

The practical use of this architectural model in the design and development of new business services will allow a smoother adaptation of this area of business to the

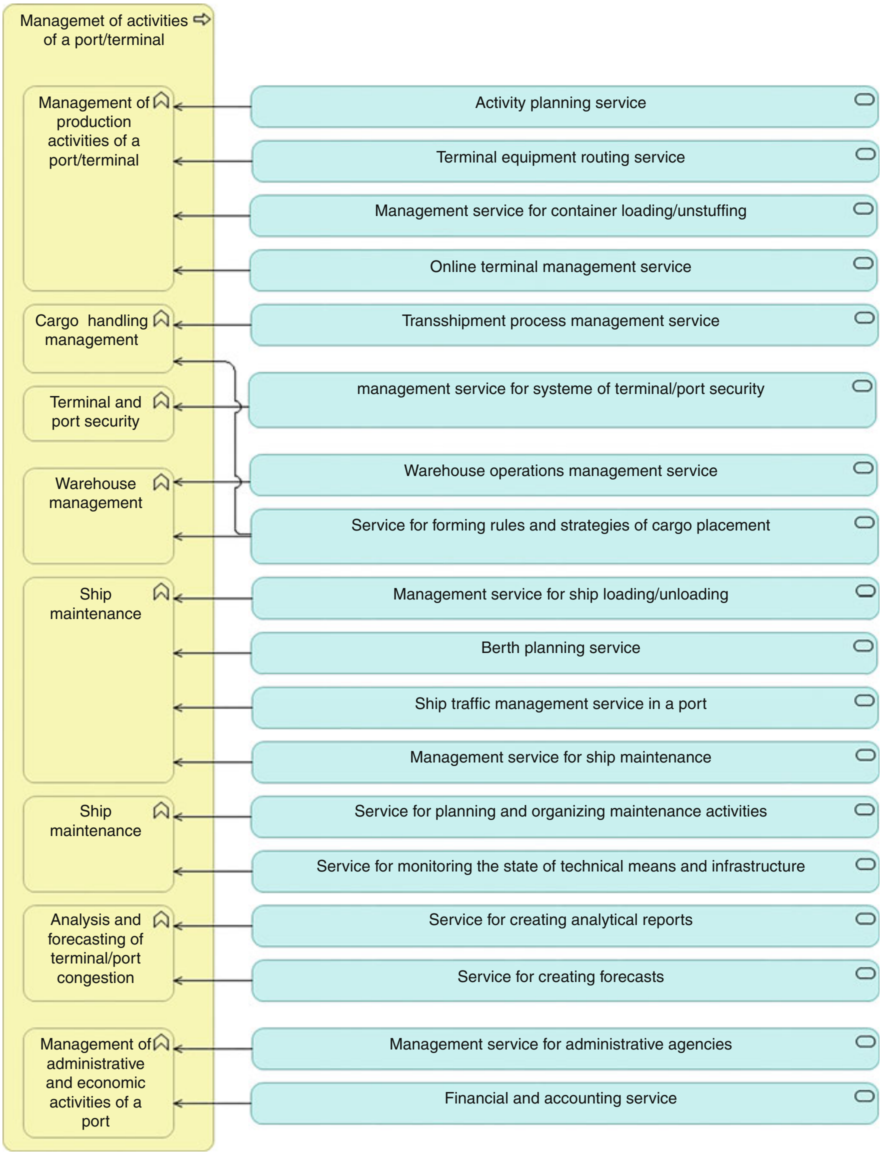

Fig. 28 Digital service architecture for the port and terminal management process

environment, since digitalization has already significantly changed and continues to change the field of cargo transportation (Iceberg, Central Design Bureau, 2019).

The digitalization of the economy and the flourishing of information technologies inevitably lead to the fusion of digital and classical technologies, and therefore only the timely introduction of new popular business services based on information

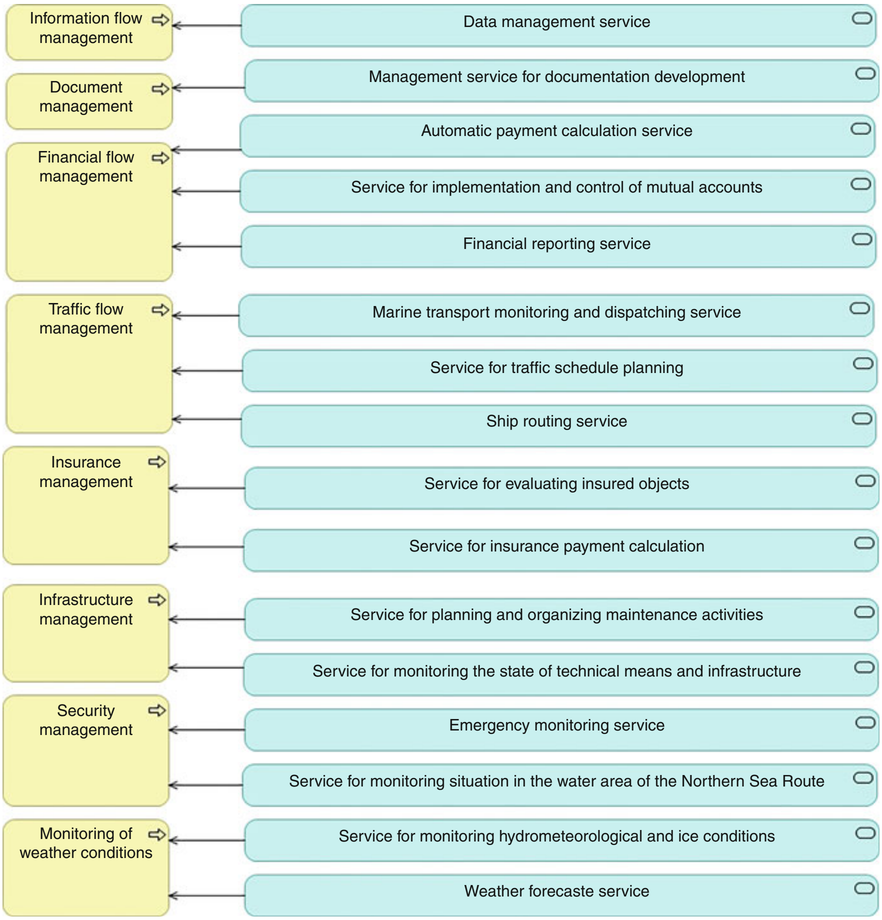

Fig. 29 Digital service architecture for information, financial, transport, document management, insurance, infrastructure, security, and weather monitoring processes

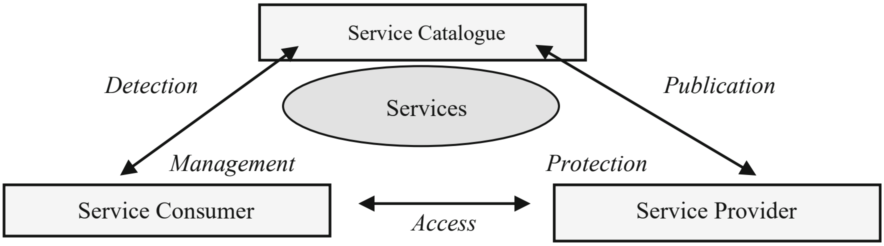

Fig. 30 Basic service-oriented architecture

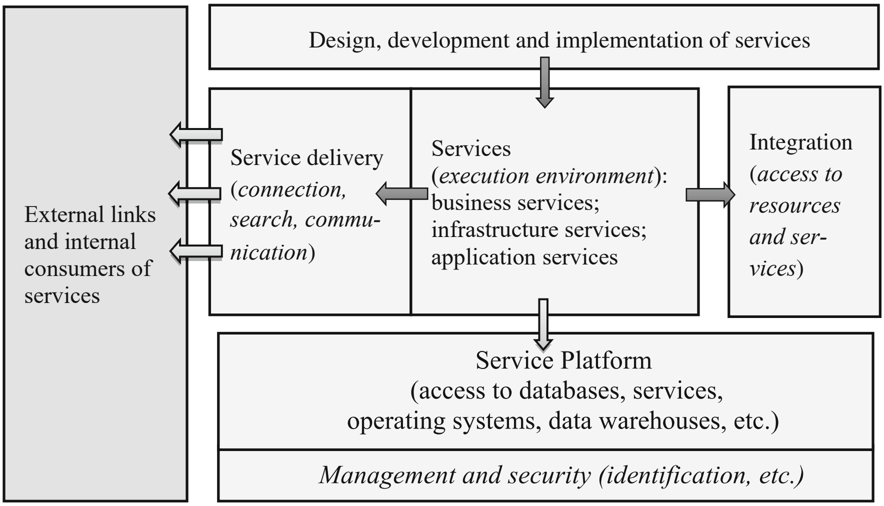

Fig. 31 Architectural model of business services of the Northern Sea Route

technology tools will allow you to achieve your goals, increase efficiency, master new channels and significantly increase the volume of cargo transportation (Zaychenko et al., 2018b).

The implementation of these digital services is supposed to be carried out using a digital platform. To date, the platform approach has become one of the stable global trends in the field of digitalization. And it is this approach that is most appropriate for the digitalization of the Northern Sea Route. In addition, the use of the platform was indicated in the provisions of the Northern Sea Route infrastructure development plan for the period up to 2035, approved by the Government of the Russian Federation, discussed earlier (Liu & Kronbak, 2010).

There are many different definitions of a digital platform, but most authors understand a digital platform as a system of both formalized and unspoken rules and algorithms for user network interaction, based on various architectural standards of software and hardware used for storing, analyzing, and transmitting data about participants in this interaction (Ilin et al., 2020a).

The main advantage of the platform is an increase in the speed of exchange of value between different groups of users (Egorov et al., 2020). Among other things, the operation of the platform allows you to ensure control and establish a process for evaluating the result, and it is also possible to use the technology to resolve disputes between suppliers and buyers. Within the framework of the platform, it is planned to create a transparent system for monetizing services that does not cause additional difficulties for users (Blunden, 2012).

The functional component of the platform is implemented by a complex of various subsystems and solutions (Aslam et al., 2020). Figure 32 shows a model of the proposed architecture of the Northern Sea Route platform, which presents the

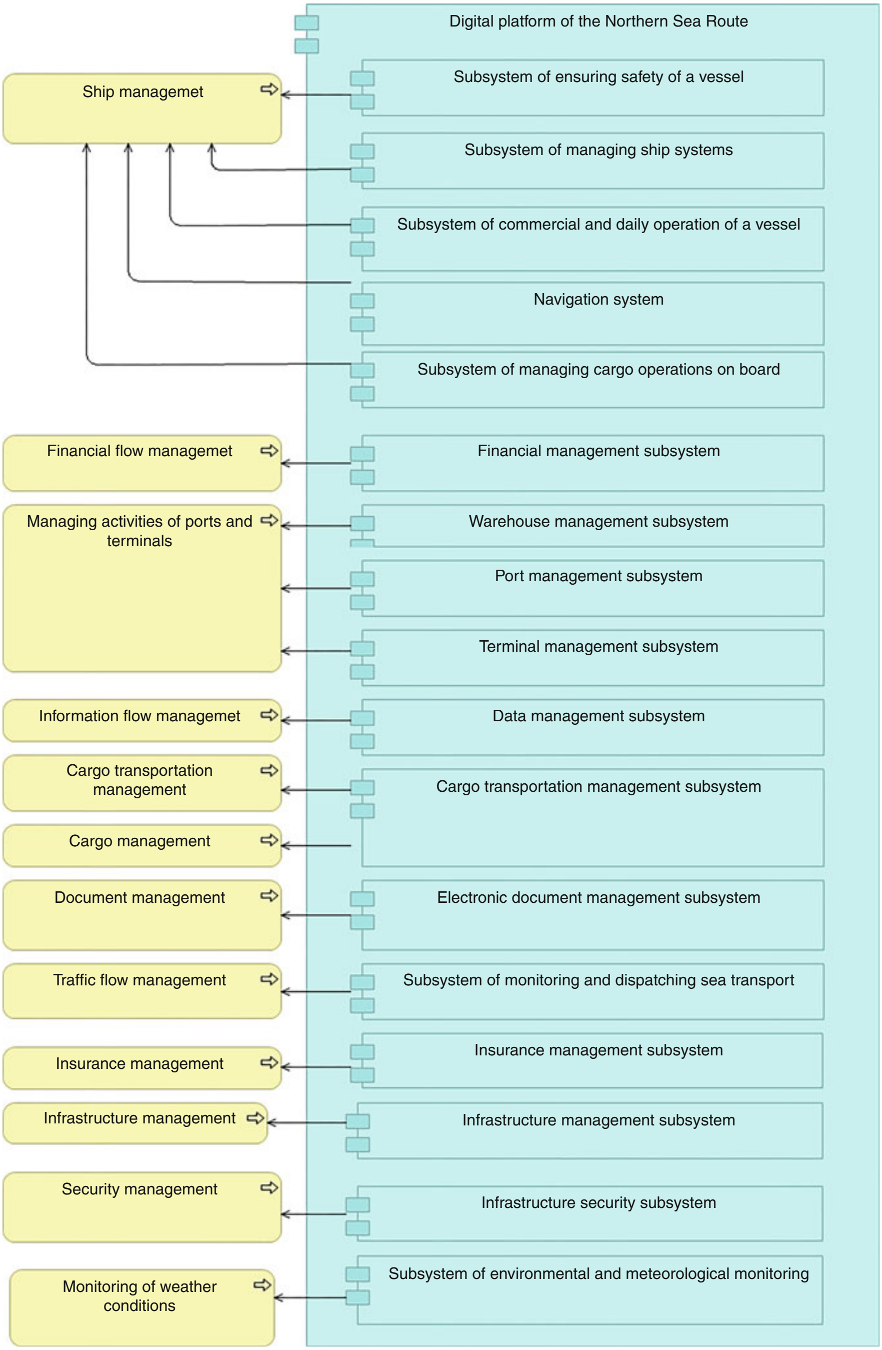

Fig. 32 Architecture of the Northern Sea Route platform

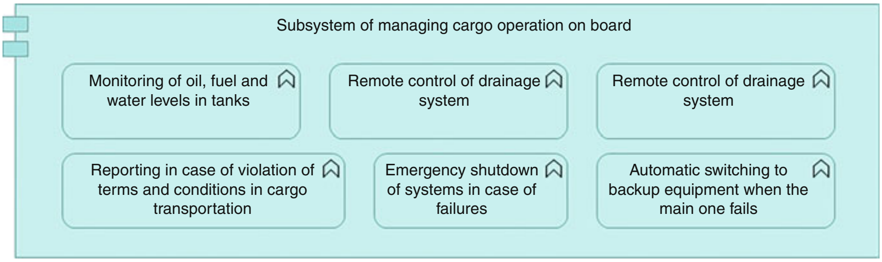

Fig. 33 Main functions of the cargo operations management subsystem

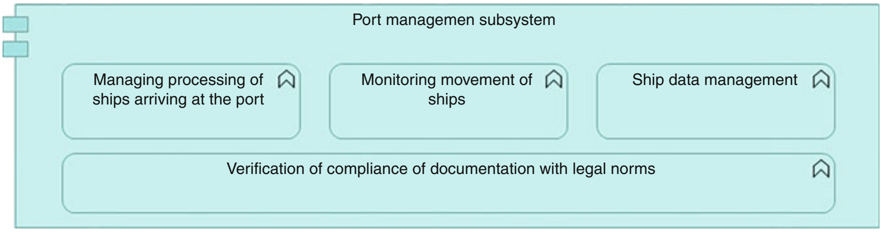

Fig. 34 Main functions of the port management subsystem

main functional subsystems of the platform, as well as their relationship to business processes.

Each of the subsystems shown in the figure performs a whole list of functions that ensure the correct operation of the platform. Next, we will take a detailed look at each subsystem and its functions.

The first such subsystem is the cargo operations management subsystem. This system implements a whole list of functions that ensure the correct execution of any cargo operations, including the transportation of various goods, as well as improving the stability of the vessel. This, in turn, involves monitoring the level of oil, fuel, and water in tanks, remote control of the ballast system, remote control of the drainage system, monitoring the fulfillment of cargo transportation conditions, notification in case of violation of transportation conditions, emergency shutdown of systems in case of failures, automatic switching to backup equipment in case of failure of the main one. Figure 33 schematically presents these functions of the cargo operations management subsystem.

The platform also contains a port management subsystem. This subsystem implements the functions of managing the processing of ships arriving at the port, monitoring the movement of ships. Ship data management functions and automatic verification of compliance with local and international legislation are also extremely important. The figure schematically shows the functions of this subsystem (Fig. 34).

Furthermore, it is important to consider the terminal management subsystem. First of all, this system implements the functions of managing various areas of the terminal: berthing, inspection, container storage area, and repair area. One of the main functions of the terminal management subsystem is the organization of loading

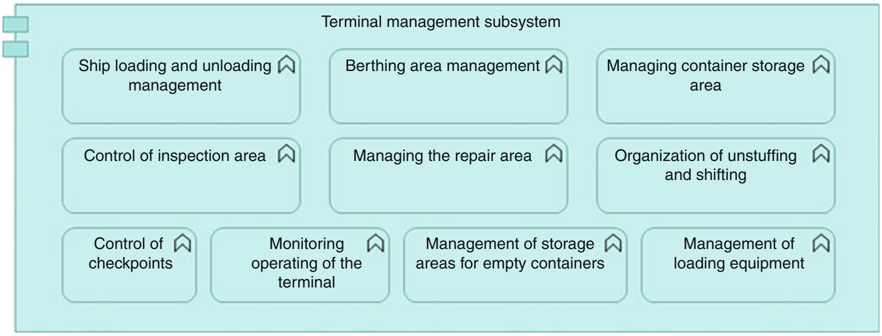

Fig. 35 Main functions of the terminal management subsystem

and unloading of ships and the management of loading equipment. These functions allow you to develop a loading/unloading plan and implement it using the necessary equipment. Among other things, the functionality of this system allows organizing loading and unloading containers. Container unloading consists of removing cargo from the container for further transportation or reloading. Reloading involves moving cargo from one vehicle to another without placing the cargo in a long-term storage warehouse. The management of these processes is often complicated by the weight and other dimensions of the cargo, and the subsystem under consideration can significantly facilitate the process and minimize time costs. Among other things, the subsystem provides the functionality of managing the depot of empty containers. An equally important function is the management of checkpoints on the territory of the terminal to ensure the safety of personnel and infrastructure of the terminal. Also, the terminal management subsystem implements the function of monitoring the operation of the terminal. The functions performed by the terminal control subsystem are schematically shown in Fig. 35.

The next subsystem that we will consider is the warehouse management subsystem. This subsystem has the functions of managing the loading and unloading of incoming cargo. Among the functions of this group are receiving goods and identifying them by scanning barcodes and other identification labels, and monitoring the compliance of the parameters of the received cargo with the parameters declared at the time of shipment. This block of functions also involves the movement of goods from the vehicles of the senders to the vehicles of the recipients. The warehouse management subsystem also includes functions for managing the placement, storage, and internal movement of received goods. Also, the subsystem implements the functions of planning warehouse operations, which allow you to create a list of parameters that determine the order of planning the use of warehouse space, specify the boundary time for the implementation of warehouse operations, as well as ensure that the plans being built correspond to current tasks and plan inventory activities in the least busy periods. Inventory management and reservation functions allow you to combine inventory data for several warehouses, create an inventory schedule, and control the storage time of goods. Among other things, this

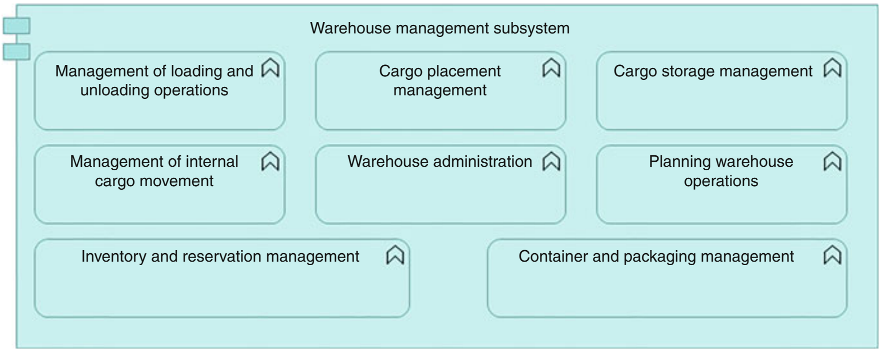

Fig. 36 Main functions of the warehouse management subsystem

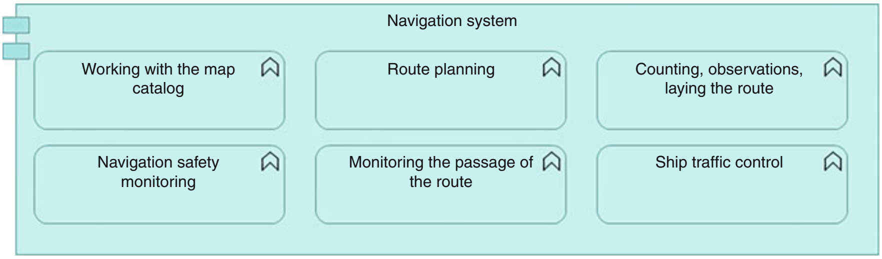

Fig. 37 Basic functions of the navigation system

subsystem implements the functions of container and packaging management, as well as warehouse administration. Tare and packaging management functions allow you to track the availability of tare and packaging material stocks, monitor the recycling processes of used materials, and organize the storage of unused materials. Warehouse administration functions include, but are not limited to, reporting and statistical data analysis, documentation verification, and warehouse security. The figure schematically shows the functions of the warehouse management subsystem (Fig. 36).

The next system to consider is navigation. This system implements the functions of planning the ship's path. To do this, you can use both a tool for building a new route, and selecting an existing one in the database with the ability to adjust it. The navigation system makes it possible to work with various types of maps, providing users with such functions as displaying the map in true or relative motion mode, changing the color palette of the map to facilitate its perception. The system also implements the functions of counting, observation, and path laying. This function block allows you to determine the true position of the vessel and its speed, make sure of its course, and predict the position of the vessel as it passes through the path. Also, the functionality of this subsystem provides for monitoring the passage of the route and monitoring navigation safety. These functions allow you to quickly change the route in case of emergency situations, notify the authorized personnel about the entry

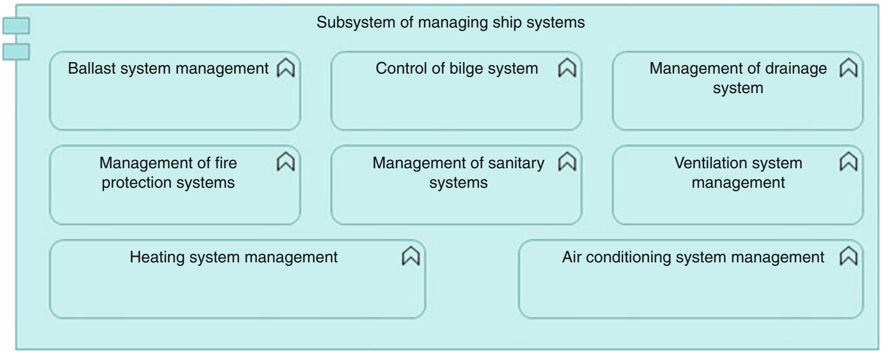

Fig. 38 Main functions of the general ship systems management subsystem

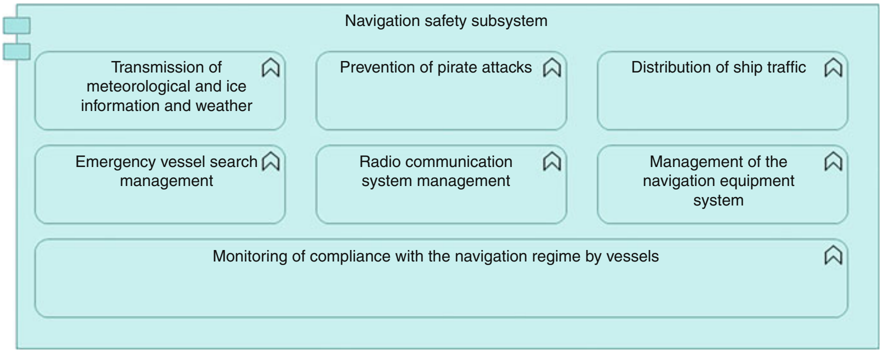

Fig. 39 Main functions of the navigation safety subsystem

of the vessel into the region with specific navigation conditions. The navigation system also provides a functional ability to control the movement of the vessel. This functionality is implemented using the so-called autoroute, which automatically controls the movement of the vessel along a given route. The listed functions are shown schematically in Fig. 37.

The platform also provides a subsystem for managing general court systems. Ship-wide systems are systems whose functioning is necessary for the correct operation of the vessel. Ship-wide systems include bilge, fire-fighting, sanitary and comfort systems. Bilge systems are generally called ballast, drainage, and drainage systems. Comfort systems are ventilation, heating and air conditioning systems (Fig. 38).

The next part of the platform is the navigation safety management subsystem. The main functions implemented by this subsystem include the management of ship traffic, monitoring the position of ships, and monitoring the compliance of all participants of the sea traffic with the navigation regime. Also, the navigation safety management subsystem implements the functions of controlling the navigation equipment system. This subsystem also implements the functions of transmitting

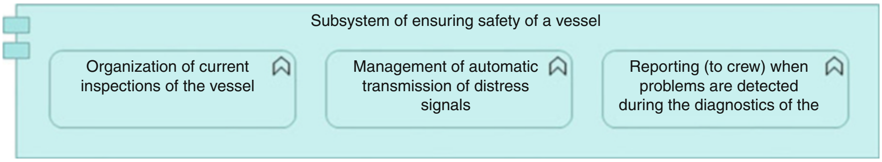

Fig. 40 Main functions of the ship safety subsystem

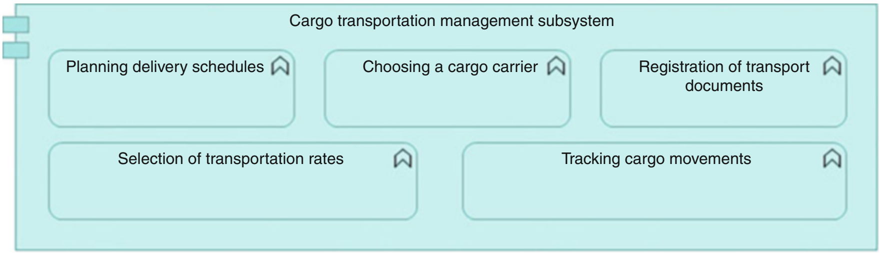

Fig. 41 Main functions of the cargo transportation management subsystem

meteorological and ice information to ships in order to avoid emergencies. Among the functions of the subsystem are also the prevention of pirate attacks, the management of the radio communication system, and the management of the search for emergency ships. The figure schematically shows the functions of this subsystem (Fig. 39).

The ship safety subsystem is designed to diagnose the condition of the ship and maintain the functioning of its systems. This is achieved through the functions of organizing inspections and inspections of the vessel, as well as alerting personnel when problems are detected during diagnostics. Among other things, the functionality of this subsystem provides for automatic transmission of distress signals in case of emergencies (Bianco et al., 2021). The figure schematically shows the functions of the ship's safety subsystem (Fig. 40).

Cargo transportation management subsystem performs the functions of planning the delivery schedules of the transported goods, allows you to choose the carrier and the transportation tariff. This subsystem allows you to track the movement of cargo along the delivery route. Among other things, the functionality of this system allows you to issue all transport documents in accordance with the requirements imposed on them. The figure schematically shows the functions of the cargo transportation management subsystem (Fig. 41).

The subsystem of environmental and meteorological monitoring implements the functions of monitoring meteorological conditions and assessing the ice situation on the routes of ships. Also, the functionality of this system involves forecasting weather conditions and monitoring the emissions of pollutants. The figure schematically shows the functions of the subsystem (Fig. 42).

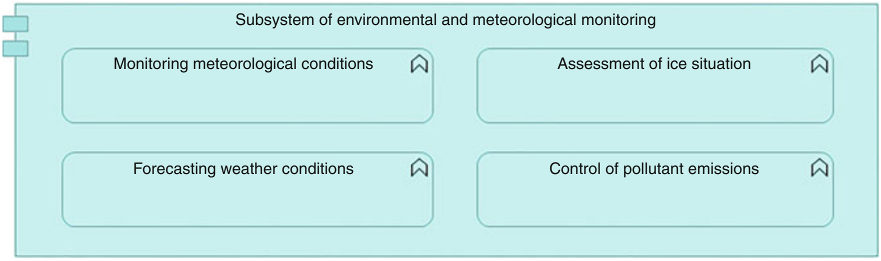

Fig. 42 Main functions of the environmental and meteorological monitoring subsystem

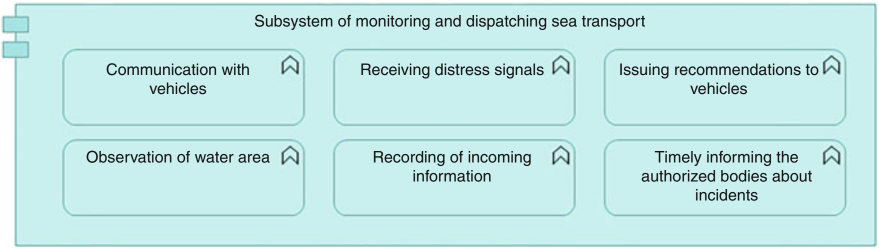

Fig. 43 Main functions of the marine transport monitoring and dispatching subsystem

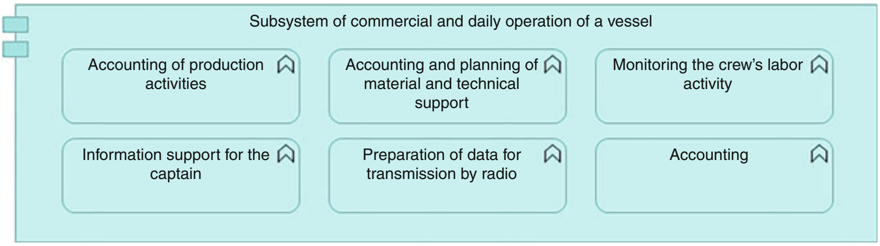

Fig. 44 Main functions of the subsystem for commercial and daily operation of the vessel

The subsystem of monitoring and dispatching of sea transport provides implementation of support of communication with vessels. This subsystem is used to receive disaster signals from ships in case of emergency situations and notify the authorized response authorities. The functionality allows you to monitor the water area and keep records of incoming information. One of the main functions of the subsystem is to issue recommendations to vehicles. The functions of the marine transport monitoring and dispatching subsystem are schematically presented in Fig. 43.

The subsystem of commercial and daily operation of the vessel regulates issues related to daily activities on the ship. The functionality of this subsystem allows you to monitor production activities, predict the needs for logistics, plan the activities of the ship's crew, and provide the captain with all the necessary data for work, as well

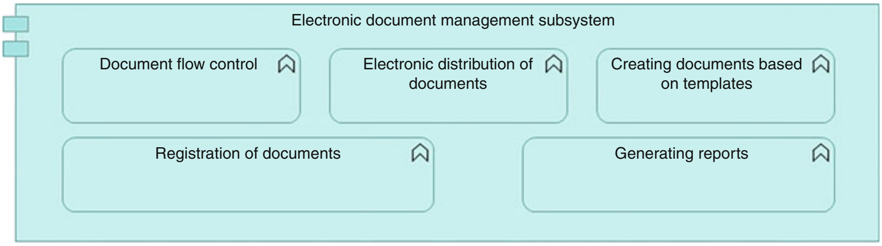

Fig. 45 Main functions of the electronic document management subsystem

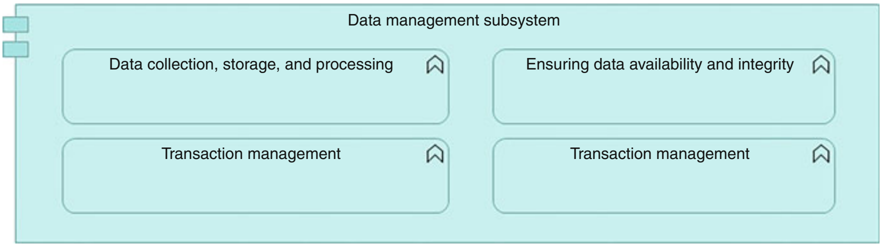

Fig. 46 Main functions of the data management subsystem

as prepare data for transmission by radio. Among other things, this system has the functionality of accounting. The functions of the subsystem for commercial and day-to-day operation of the vessel are schematically presented in Fig. 44.

Each of the subsystems shown in the figure performs a whole list of functions that ensure the correct operation of the platform. Next, we will take a detailed look at each subsystem and its functions. Functionality of the electronic document management subsystem allows you to automate activities related to the formation and exchange of documentation. In particular, the functions of this subsystem allow you to automatically register incoming documentation, control the movement of document flow, and exchange documents within the system itself. It also supports the creation of documents based on the developed templates and the formation of reports. The figure schematically shows the functions of the electronic document management subsystem (Fig. 45).

Functionality of the data management subsystem allows you to collect, process, and store various types of data. The functions of this subsystem also include ensuring the integrity, availability, security, and confidentiality of data, as well as transaction management. The figure schematically shows the functions of the data management subsystem (Fig. 46).

The insurance management subsystem also allows you to perform a number of functions. Among them are the development of profit and expense plans for all types of insurance, the formation of reports, accounting and storage of legal acts for all types of insurance activities, as well as the calculation of tariff rates for types of property and personal insurance (Fig. 47).

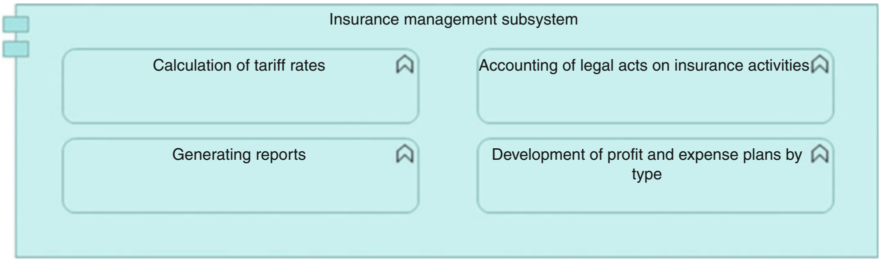

Fig. 47 Main functions of the insurance management subsystem

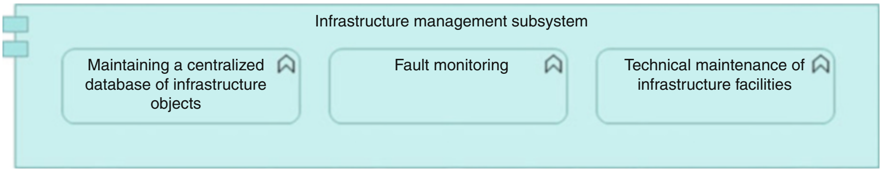

Fig. 48 Main functions of the infrastructure management subsystem

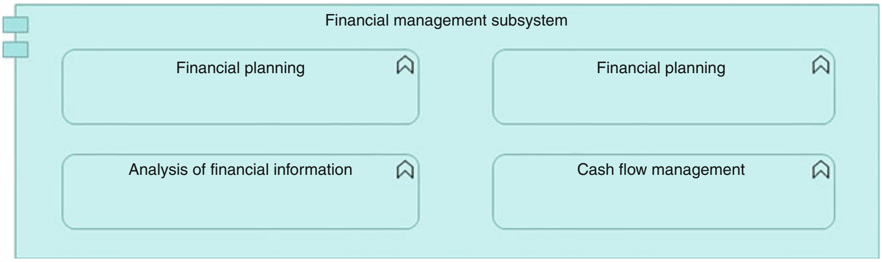

Fig. 49 Main functions of the financial management subsystem

The next system under consideration is the infrastructure management subsystem. The functionality of this subsystem allows you to create a centralized database of infrastructure objects, monitor malfunctions in the operation of the infrastructure, and organize measures to maintain infrastructure objects in working order. The functions of the infrastructure management subsystem are schematically presented in Fig. 48.

The last subsystem considered in this section is the financial management subsystem. The functionality of this system allows you to carry out financial planning activities, manage cash flows, analyze financial information, and monitor investments and investments. The functions of the financial management subsystem are schematically presented in Fig. 49.

Within the framework of this section, a system of models for the architecture of the digital platform of the Northern Sea Route was developed, which in turn allows us to present a meta-model for integrating the architecture of information systems into the business architecture of the Northern Sea Route.

4 Conclusion

Thus, in the course of this study, the circle of key stakeholders who will be most involved in the digitalization of the Northern Sea Route was identified. For each group of stakeholders, a list of the main requirements for the digital architecture of the Northern Sea Route is defined. Taking into account the identified requirements, as well as taking into account the analysis of the Northern Sea Route, architectural models were developed. First of all, a reference model of key business processes and a functional-oriented organizational structure of the Northern Sea Route were developed. On the basis of which the business architecture of the Northern Sea Route was developed, which reflects the main processes and key functions, as well as their performers. Using digital modeling, you can create meta-models at the strategic level that model the markets and ecosystem of new products, allow you to evaluate the cross-industry and cross-country effects of the created product, as well as model the requirements of future standards for competitiveness in the global market.

As a result of the research, the architecture of digital services is proposed, the implementation of which is necessary for the implementation of information support for business activities. Digital services are described for each key business process. The architecture of the application layer is built, which reflects the set of subsystems necessary for the implementation of previously identified digital services. The minimum required functionality was also described for each subsystem. Overall, a metamodel of integration of information systems architecture into the business architecture of the Northern Sea Route has been developed.

Further application of developed models will contribute to facilitated design of integration model for information system architecture in business architecture of the Northern Sea Route.

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The Northern Sea Route as a Factor of Sustainable Development of the Arctic Zone

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Abstract The socio-economic development of the Arctic region of the Russian Federation is an object of close attention of the state and the scientific community. The most important factors in the development of the Northern Sea Route (NSR), such as permanent presence in the Arctic, the infrastructure development of the NSR, and cooperation with different countries are considered in this chapter. Geopolitical and transnational factors play strategically important roles in the expansion of maritime traffic in the Arctic zone. These factors include control over the territory rich in natural resources, the high value of the NSR transit factor, because its path connects the northwestern and far eastern regions of Russia. Also an important factor is the potential for growth in transnational transit traffic along the Northern Sea Route between European and Pacific ports. High-quality development of the Arctic territories is impossible without the successful implementation of infrastructure projects. The formation of the Arctic transport system is the most important task for the development of the region. The limited transport system seriously hinders the development of the northern regions. The Northern Sea Route is the basis of the economic stability of the North of Russia and the most important element of the Russian and international transport system. Therefore, it is necessary to follow the key factors, reconstruct the current and develop new paths.

1 Introduction

1.1 Motivation

The socio-economic development of the Arctic region of the Russian federation has become the object of close attention of both the government and the scientific

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community. A number of regulatory documents in the Russian Federation have been adopted, the main purpose of which was the regulation of certain aspects of the political, industrial, economic, and social development of this region (Consultant, 2020; RG.RU, 2014; Ruyga & Zyubanova, 2016). The characteristics of the Arctic territories that determine the need for special approaches to their development and development are (Diakov & Kotiev, 2018):

- extreme climatic conditions;
- focal nature of the development of these regions;
- low population density with an insufficient labor force and outflow of the population;
- remoteness from major industrial centers and inaccessibility of regional facilities;
- high resource intensity with a high dependence on the supply of resources from other regions;
- low sustainability of ecosystems with a high presence of waste and pollution from human activities;

Currently the Arctic is in the focus of attention from both Arctic and non-Arctic states due to the presence of both reserves found and reserves estimated of natural resources. Russia, whose history is connected with the Arctic more than other countries, after several years in which there was only a marginal interest in this region, is beginning to pay more and more attention to its Arctic regions. The network of meteorological stations and military bases is being restored, new ice-breakers are built, and new oil fields on the Arctic shelf are developed. But all this is impossible without a developed infrastructure, the basis of which in the Russian Arctic sector is the Northern Sea Route (NSR).

The NSR not only forms the base of the transport infrastructure of the Russian Arctic, since it connects the main northern ports and river transport systems into a single transport corridor and thus the NSR is the only means of supplying some Arctic regions with food and goods (Alekseeva et al., 2019).

In addition, the importance of the NSR as the basis of the Arctic transport infrastructure is emphasized by the need to use it for the export of natural mineral resources (for example, oil and gas) produced in the Arctic. The NSR route (from the Bering Strait to the Novaya Zemlya archipelago) is characterized by severe climatic conditions, which complicates the safe navigation of ships in these waters.

1.2 Outline

Within the framework of the chapter, it is planned to analyze the current state of the Northern Sea Route. It is necessary to define the NSR and indicate its key ports with a short history of its development. The second part of the work analyzes other international projects which improve transport and logistic and their impact on regional developments. The results of the study are a description of the role of the

NSR in the social, economic, and environmental components of the Russian Federation.

2 Basics

2.1 Definition of the Northern Sea Route

The Northern Sea Route is a navigable seaway passing along the northern shores of Russia along the seas of the Arctic Ocean (Barents, Kara, Laptev, East Siberian, Chukotskoe, and Beringovo), connecting the European and Far Eastern Russian ports, as well as the mouths of navigable Siberian rivers into a single the all-union transport system. The Northern Sea Route is limited by the western entrances to the Novaya Zemlya straits, that is, by the meridian running north from Cape Zhelaniya, and in the east in the Bering Strait by the parallel of 66°N and 168° 58′37″W. The length of the Northern Sea Route from the Kara Gates to Provideniya Bay is about 3030 NM (Northern Sea Route Information Office, 2021).

Thus, the Northern Sea Route is a seaway passing through the Arctic Ocean, from the Novaya Zemlya archipelago to the Bering Strait, which separates the Pacific Ocean and the Arctic Ocean.

2.1.1 The Main Ports of the NSR

The main ports of the Northern Sea Route include the following key ports (Fig. 1): Sabetta, Dikson, Dudinka, Khatanga, Tiksi, Pevek.

The listed objects of the shipping infrastructure, which are located at the mouths of large rivers (Lena, Ob, Jenissei), serve as transshipment points for cargo ships. The Northern Sea Route is a seaway along which timber, engineering products, coal, building materials, food, and furs are transported. The ports on the Northern Sea Route are adapted to receive large icebreaking ships.

Currently there is an economic project implemented which aims to re-equip the port of Petropavlovsk-Kamchatsky into a port-hub for the NSR. It is located at a very favorable position, which could allow the city to become an important transport hub between Northern Europe and the Pacific region. In addition, the Petropavlovsko-Kamchatsky port, as a component of the NSR, has additional advantages as year-round navigation, non-freezing bay, and possibility of accumulation, storage, and sorting of goods (Pegin, 2017).

2.1.2 Brief History of Development

In the eleventh century, the people of Novgorod reached the Frozen Sea. Dvinsky mayor—Uleb—in 1032 mastered the first NSR, stretching from the Kara Gates to

Fig. 1 Map of NSR ports. Source: Østreng, (2010)

Novaya Zemlya. In search of new goods for Novgorod, the explorers moved further and further northward. They opened a sea route to Kolguev, Vaigach, Novaya Zemlya, and other islands (Johannessen, 2017).

In the second half of the sixteenth century, British explorers tried to find a way out to the coast of South and East Asia in the north and tried to go through the Pacific Ocean to the Arctic. The first two expeditions reached Novaya Zemlya Island, the third reached the Kara Bay. Because of the active movement of the ice masses, the sailors did not advance and abandoned this project by moving back to Great Britain. In 1594, Dutch explorers reached Yamal, and a year later they went to the Kara Sea and like their predecessors, they were forced to return. The third Dutch expedition was able to reach Svalbard, the Bear Island, the island of Novaya Zemlya and entered the Kara Sea.

For the first time, the practical significance of the NSR as a transport route was mentioned by the Russian diplomat and politician Dmitry Gerasimov in 1525. The Russian polymaths Dimitri Mendeleev and Mikhail Lomonosov both have been working on the role and use of the NSR.

In 1732, Empress Anna issued a decree according to which Vitus Bering was to go to Kamchatka to explore new lands in Siberia. This expedition was named the Great Northern. As a result, the entire Russian northern coast was mapped.

The results of subsequent Russian expeditions questioned the possibility of navigation in the Kara Sea, but already in the 1990s of the nineteenth century this myth was refuted. For the first time, the entire route of the NSR was covered by a Swedish expedition led by the famous explorer Nordenskjold in 1879 (NERSC, 2021).

The invention of icebreakers, the radio, and the emergence of the steam fleet led to a further development of the NSR as a transport route. Since the 1920s, the Kara expeditions were resumed and shipping voyages from Vladivostok to Kolyma became a regular practice. During the Second World War, the Northern Sea Route was extremely important for the Soviet Union—warships were conducted along it, the fleet received coal, and the Soviet industry received timber, nickel, and copper. December 17, 1932 is considered the date of the official opening of the NSR as a transport highway (Østreng et al., 2013).

After the end of the Cold War the first foreign ships entered the NSR in 1991. However, this did not become an impetus for the active use of the transport route in international trade. The NSR is characterized by a number of straits with shallow waters which makes navigation for large vessels challenging.

In addition, the NSR is notable for unstable ice conditions, which also negatively affects the "popularity" of this seaway (Highnorthnews, 2021).

2.2 *Defining Sustainability*

The concept of sustainable development involves the harmonious development of three areas: economics, ecology, and social. Thus, the sustainable development of the Arctic zone and, in particular, the shelf development system, suggests an effective balance between economic growth, environmental protection, and social relations. Existing Arctic shelf development projects are often distinguished by a single-criterion decision-making—economic growth to the detriment of other components.

The main directions of sustainable development and strategic priorities in accordance with the draft of the Arctic Doctrine of the Russian Federation for the development and rational use of natural resources are (Zhuravel, 2020):

1. The final establishment and consolidation in international legal acts, including bilateral and multilateral treaties, of the boundaries of the exclusive economic zone and the economic sovereignty of Russia in the Arctic.
2. Improving the structure of production in the Arctic in accordance with the natural, climatic, and socio-economic conditions and the ecological capacity of each specific region on the basis of differentiated principles of regulation of economic activities and with the priority development of industries of national importance.
3. Reconstruction in tax and financial legislation of the current system of rent payments from the use of raw materials in order to increase the self-sufficiency of the Arctic territories, including through the creation of stabilization funds of the heritage.
4. Orientation of the branch of traditional economic activity towards life support, protection of economic rights, and full employment of the indigenous small-numbered peoples of the North.

5. Restructuring of the fuel and energy complex with a focus not only on imported raw materials, but also local energy sources, traditional and non-traditional (renewable).
6. Development and implementation of investment projects for the exploration and development of mineral and hydrocarbon resources of the shelf and coastal areas, the development of aquaculture in the seas of the Western Arctic.

The economic prerequisites for sustainable development of the Arctic are:

- natural resource potential, primarily hydrocarbons. The natural resources of the Arctic shelf are estimated at 100 billion tons of coal equivalent (tce) of which 4 billion are tons of fuel equivalent ready for production;
- the presence of large industrial centers and settlements (Murmansk, Naryan-Mar, Vorkuta, Salekhard, Norilsk, Khatanga, Tiksi, Pevek, Anadyr, etc.);
- relatively developed transport infrastructure, primarily in the European North and Western Siberia;
- it is possible to expand the use of the Northern Sea Route, including for international transport, and unconventional energy sources;
- external economic factors, which include the military-strategic and geopolitical position of the Russian Arctic, its importance as a global ecological reserve.

For example, StatOil has a limited operational activity in the Arctic and sub-Arctic. This activity is currently focused on the relatively ice-free areas in the Norwegian Barents Sea and offshore Newfoundland, Canada. They have taken long-term positions in other Arctic basins and these are being matured for future exploration.

Despite the leading company StatOil, there are problems with spills and oil in the arctic. This is due to the extremely cold, ice-covered waters, the darkness of winter, and limited access to cleaning resources. Oil spill response challenges in the Arctic are related to extreme cold, ice-covered waters, the darkness of winter, and limited access to clean-up resources.

An important place in the state policy of the Russian Federation in the Arctic belongs to the social development of the Arctic zones of the Russian Federation. This policy is aimed at improving the quality of life of the population, including those belonging to the indigenous people. From the social prerequisites point of view for the sustainable development of the Arctic, one can single out (Zaychenko et al., 2019):

- ensuring the availability of primary health care, quality preschool, primary general and basic general education, secondary vocational and higher education, services in the field of culture, physical culture, and sports in settlements located in remote areas, including in places of traditional residence and traditional economic activities of indigenous peoples;
- providing citizens with affordable, modern, and high-quality housing, improving the quality of housing and communal services, improving the living conditions of persons leading a nomadic and semi-nomadic lifestyle, related to indigenous peoples;

- the accelerated development of the social infrastructure of settlements in which the bodies and organizations are located which perform functions in the field of ensuring national security and (or) the functions of a base for the development of mineral resource centers, the implementation of economic and (or) infrastructural projects in the Arctic;
- creation of a system of state support for delivery to settlements located in remote localities, fuel, food, and other essential goods in order to ensure affordable prices for such goods for citizens and business entities;
- provision of year-round main, interregional, and local (regional) air transportation by affordable prices;
- ensuring that the state fulfills its obligations to provide housing subsidies to citizens leaving the Far North and equivalent areas;
- preservation of the culture of indigenous people, their language, and traditions.

2.3 Current State and Development Prospects

The development of the Northern Sea Route in the past 6 years has been unprecedented, the volume of traffic has increased eightfold in 6 years. It is planned to increase the volume of traffic to 80 million tons in 2024. According to the report at the end of 2020, the volume is 33 million tons. However, the strategic task is to transform the Northern sea route to the international universal transport corridor, which will allow realizing advantages in distance and timing. According to some experts, the prospects for the development of the NSR are largely related to the fact that it can become a full-fledged competitor to the Suez Canal (Fedorov & Medvedev, 2020).

Analysts have come to the conclusion that the NSR is capable of handling about 50 million tons of cargo per year at this moment. Seafarers share this point of view, since they believe that every year the Northern Sea Route will become more and more in demand, especially given the growing activity of gas and oil companies in the Arctic and Yamal regions (Zhuravel & Nazarov, 2020).

The Northern Sea Route, as one of the future key routes of international transport, has many advantages, given the piracy that flourishes along the Horn of Africa. The development of the Northern Sea Route in Russia may also be due to the fact that the country has created the world's largest icebreaker fleet. It is planned to add at least 20 more to the operating nuclear-powered ships. The latter should be financed by resource-extracting organizations.

In other words, the Northern Sea Route has a huge potential to, if not completely replace other transport arteries, then become highly demanded in terms of delivery of certain types of freight. The fact of global warming also promises great advantages for the use of the NSR, since the routes, which were previously covered with a significant layer of ice, today become navigable without icebreakers.

The history of the development of the routes of the Arctic Ocean goes back several centuries. A powerful impetus to the development of seaways was given by the creation of nuclear icebreakers, as a result of which navigation became possible throughout the year. In the 1990s, the activity on the NSR fell sharply due to the collapse of the Soviet Union. Only large transport facilities were supported by large resource-producing corporations, since they were needed for their smooth operation.

Today, the development of the Northern Sea Route is again among the priority tasks, not only in our country, but throughout the world (Highnorthnews, 2021). Basically, the increased attention to this region is associated with the deposits of the Arctic shelf. And the issue of transportation is key here.

In 2013, the concept of the Maritime Silk Road also known as One Belt One Road or Belt Road Initiative (BRI) was formed in China. The Chinese government proposed routes that can connect the ports of Australia, Indonesia, Singapore, and Malaysia as well as ports in Africa and Europe with the People's Republic of China. If this corridor is combined with the routes of the Northern Sea Route, such a global network will bring many advantages to countries around the world. From an economic point of view, this is very beneficial, since the delivery of goods will be faster, and transport costs will decrease. In the future, it will be possible to reorient all trade routes of the Asia-Pacific region in the direction of the Northern Sea Route (Kozlov et al., 2019).

Traditional routes using the Suez Canal and the Horn of Africa area are becoming increasingly unsafe due to the active activities of pirates, but actually over the last years they became safer due to Operation ATALANTA (Eunavfor, 2021). Therefore, the risks of sea carriers are growing. In this regard, the development of the Northern Sea Route for international trade could become a profitable project.

For Russia, efficient operation and development of transport infrastructure on the northern coast could mean dynamic economic growth. In general, a number of main goals for the development of the transport component for the Northern European part of Russia can be named:

1. Creation of a common transport space.
2. Provision of affordable and fair services in the field of transport logistics of cargo transportation.
3. Provision of affordable transport services for the population at the level of quality standards.
4. Entering the world transport space and maximizing the possibility of transit traffic.
5. Increase in transport safety indicators.
6. Reducing harm to the environment.

2.4 Problems of the NSR Development

A serious obstacle hindering the development of the Northern Sea Route for shipping are the difficult climatic and ice conditions. Most of the NSR passes through zones of thick multiyear ice. Due to this safe navigation for most of the Northern Sea Route is only possible for a few months usually from July to October.

On some routes where nuclear ice breakers are used a longer navigation period is possible. In the next 10 years, Russia intends to increase the icebreaker fleet and bring navigation along the Northern Sea Route year-round. Russian experts believe that modernizing the infrastructure of the Russian Arctic will require significant financial and labor investments (Ilyinsky et al., 2020). It will be necessary to improve the work of hydrography and meteorology services, to establish a system of aerial reconnaissance of ice movement, to create state structures responsible for environmental control. It is necessary to increase the resources of the Ministry of Emergency Situations, to improve the infrastructure of ports.

Another challenge is communication. Foreign ships that have conducted test voyages state that satellite communications of the operators Inmarsat, Thuraya, GlobalStar do not work above 70°N to 75°N.

3 Analysis

3.1 Analysis of International Experiences of Regional Development by Means of Development of the Transport and Logistic Systems Development

3.1.1 Trans-Siberian Railway

This is a railway across Eurasia connecting Moscow with the largest East Siberian and Far Eastern industrial cities of Russia. The length of the tracks is 9288 km and this makes the Trans-Siberian Railway the longest railway in the world (TravelReal-Russia, 2021).

It passes on the original route through Ryazan, Samara, Ufa, Zlatoust, Miass, Chelyabinsk, Kurgan, Petropavlovsk, Omsk, Novosibirsk, Krasnoyarsk, and Vladivostok and thus connects the western, northern, and southern ports of Russia. The railway has further connections to St. Petersburg, Murmansk, Novorossiysk, and to the Pacific ports Vladivostok, Nakhodka, Zabaikalsk.

Today TransSib consists of four branches (Wikivoyage, 2021):

- The original route (red line on the map)—with the above cities.
- Baikal–Amur Mainline (green line): Taishet—Bratsk—Ust-Kut—Severobaikalsk—Tynda—Komsomolsk-on-Amur—Sovetskaya Gavan.
- Northern route (blue line): Moscow—Yaroslavl—Kirov—Perm—Tyumen—Krasnoyarsk—Taishet—and then the transition to the Baikal–Amur mainline.
- Southern Route (the black line shows the section of the Southern Route where it differs from the other routes): Tyumen—Omsk—Barnaul—Novokuznetsk—Abakan—Taishet (Fig. 2).

The decision to build the Siberian railway at the expense of the treasury was made by the tsarist government back in the 1880s. In 1887, three expeditions were organized to find places for laying the route for the South Ussuriysk, West Baikal,

Fig. 2 Map of Trans-Siberian Railway. Authors' Creation

and Central Siberian lines. The construction of the Trans-Siberian Railway began in the 1890s of the last century. The decision to carry out work on the construction of the Great Siberian Route was made in the winter of 1891. Construction began on both sides—from Vladivostok to Chelyabinsk (TripSib, 2021).

The following shows some milestones of the construction of the Trans-Siberian Railway:

- 1893—the construction of a road from the Ob to Irkutsk;
- 1894—the beginning of the construction of the Northern Ussuriyskaya road;
- 1897—the beginning of the construction of the CER. 1898—the section from Ob to Krasnoyarsk was accepted;
- 1900—a decision was made to build the Circum-Baikal Railway;
- 1906—surveys were carried out for the laying of the Amur Mainline;
- 1911—laying of the section from Kerak station to the Burey river with a branch to Blagoveshchensk;
- 1916—commissioning of the bridge across the Amur.

The construction of the railway was significantly influenced by the demographic situation in the region. The flow of immigrants to Siberia has noticeably increased with the Trans-Siberian Railway. With the construction of the rail, the principle of settlement began to change. In earlier times the population settled along the river Ob, its tributaries and along the Moscow highway, now it began to concentrate along the main railway line and along the railway branches built on the eve of the First World War.

At the turn of the nineteenth and twentieth centuries, the industrialization of Siberia accelerated due to the Trans-Siberian Railway.

The inflow of capital and labor from the European part of Russia increased, and foreign capital began to flow into the region.

By the beginning of the twentieth century, Siberia was a supplier of raw materials. In the second half of the nineteenth and early twentieth centuries, the main goal of the Russian government was the production of agricultural products. The agricultural sector employed up to 90% of the population at this time.

The railway provided access for settlers to agricultural areas and the chance to transport the output of agricultural products to the sales markets. This influenced not only the growth rate of agricultural production, but also the change in the structure of which crops would be cultivated.

Structural changes have also taken place in the industry of Siberia. The mining industry, which was previously dominant, began to give way to the manufacturing industry. In 1900, the mining industry produced 65% of the value of all products in Siberia and the Far East of Russia, but in Western Siberia the manufacturing industry already gained a foothold.

With the construction of the railway, the demand for bricks, cement, and woodworking products, which were supplied mainly by local enterprises, increased sharply. The sales market for these industries also expanded in connection with the development of construction in cities and rural areas.

The Trans-Siberian Railway became the main transport artery connecting Siberia with the center of the Russia as well as with the eastern parts. Machines, equipment, metal, and manufactured goods were imported from the European part of the country and from the Urals. At the beginning of the twentieth century, the railway network of Siberia was significantly expanded. On the eve of World War I, the Altai railway was built (from Novonikolaevsk to Barnaul), and the construction of the Kolchuginskaya and Achinsk-Minusinskaya roads began. Although the latter passed through the territory of the Yenisei province, partial logging for its construction was carried out in the Mariinsky district.

The construction of the railway gave a powerful impetus to the economic modernization of the region and contributed significantly to the development of education and culture, for example, the number of primary educational institutions in Siberia increased by 167.2% from 1894 to 1911 (TheTransSiberianExpress, 2020).

The economic modernization of the region, in turn, entailed profound changes in the social structure and composition of the population. The formation of new classes and groups (the bourgeoisie, the proletariat, the intelligentsia) began, whose representatives were increasingly involved in the social movement in its various forms. A network of educational institutions and libraries began to take shape in the region, education, and culture developed. The Trans-Siberian Railway influenced all spheres of public life in Kuzbass, and workers and employees of the road took an active part in the social and political life of the region (Goarctic, 2019).

The main role is that the Transsib connects the European part, the Urals, Siberia and the Far East of Russia, the Russian western, northern and southern ports, as well as rail links to Europe, on the one hand, to Pacific ports and rail links to Asia. TransSib electrified double-track line, fully equipped with modern communication and information facilities. The technical equipment of the railway allows transporting more than 100 million tons of cargo per year at a maximum permissible speed of 90 km/h. The advantages of the line, among other things, include the absence of the need to cross any state borders.

As for One Belt One Road, it is providing sales markets for Chinese products and expanding the routes of supplying these products abroad. Moreover, this is the formation of a space within the Eurasian continent, in the economic and financial sense tied to China.

3.2 Trans-European Transport Network (TEN-T) in Europe

The Trans-European Transport Network (TEN-T) was initiated by the European Commission to facilitate more trade within Europe by easing the transport of goods (TEN-T, 2020).

TEN-T is a policy which targets the creation of a logistical network consisting of railway, roads, inland waterways, and sea routes as well as the sea ports, rail terminals, and airports to improving economic but as well social and geographic cohesion in the European Union (TEN-T, 2020).

The development of TEN-T as an economic and social policy dates back to the Treaty of Rome in 1957 but the implementation was so slow that the Treaty of Maastricht in 1992 included the need for the European Commission to prepare guidelines to implement this (Vallecillo, 2018).

So in 2011, the European Commission changed the program from voluntary to mandatory for the EU member states and TEN-T got a multiyear budget and also this budget was increased significantly (Butcher, 2012).

The TEN-T policy as a whole can be accessed in the Regulation (EU) No. 1315/2013 (EU, 2013). TEN-T should not only help to improve the real infrastructure of the member states of the EU but also help in the development of improved and innovative ways to transport goods within the EU using new technologies and digitization (Weenen et al., 2016).

This means that the networks of all EU member states should be contributing to the TEN-T according to the EU treaty and finally become one integrated European Network (Steer Davies Gleave, 2011).

The TEN-T program consists of two parts: the core network and the comprehensive network. The first one is set to be finished by 2030 [28] and includes the projects with the highest priority which brings the highest benefit to TEN-T like, e.g., the cross-border sections of TEN-T (Khúlová & Šprochová, 2016).

The budget for this program was planned at 26 billion EUR for the years 2014–2020 by the EU (TEN-T, 2020).

TEN-T consists of nine corridors: the Atlantic corridor, the Baltic Adriatic corridor, the Mediterranean corridor, the North Sea Baltic corridor, the North Sea—Mediterranean corridor, the Orient/East-Mediterranean corridor, the Rhine–Alpine corridor, the Rhine–Danube corridor, and the Scandinavian Mediterranean corridor (TEN-T, 2020).

The following figure shows the geographical distribution of these corridors on the European map (Fig. 3).

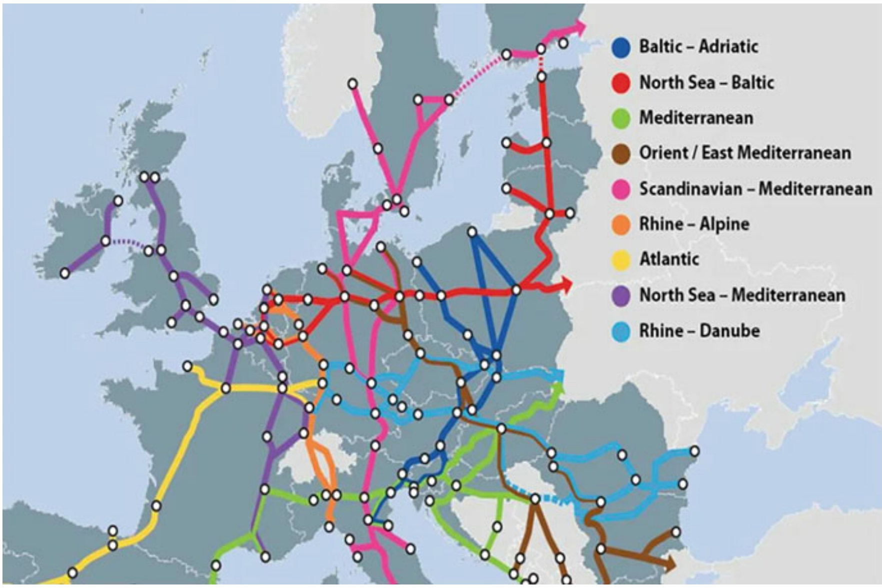

Fig. 3 The Core Network Corridors of TEN-T. Source: TEN-T (2020)

The following example shows some of the measures which are done by the Port of Hamburg within the TEN-T framework: there is extension of the tracks at the railways yard at Maschen, where more than 3000 train cars are handled every single day set to be finished by 2025 as well as several smaller projects (Biermann & Wedemeier, 2016).

Gutiérrez et al. did a study where they discuss the European value added value which was generated by infrastructure projects by using the TEN-T projects and verified this approach by the TEN-T priority project 25 (Gutiérrez et al., 2011). The authors also state that: “projects or project sections that generate intense spillovers would have high European added-value, so they would be contributing to the goal of improving the network interconnection, particularly in the case of border sections” (Öberg et al., 2018). They also state that another goal of the TEN-T project is to promote territorial cohesion within the EU. This means to balance the different development within the EU.

Cross-border projects like TEN-T can transform areas at the edge of a particular country into a centralized area (Öberg et al., 2018) and thus strengthen the economic capabilities of these areas.

Khúlova and Šprochová show this notion at the example of the Visegrad countries (Poland, Slovakia, Hungary, and the Czech Republic) (TEN-T, 2020). Of these four countries only Poland has direct access to the ocean whereas the other three are landlocked. Of the nine corridors, five are crossing the aforementioned countries directly and consist of different transport modes (rail, road, inland waterways, seaways, and air) (TEN-T, 2020).

Regarding the sustainable factor of TEN-T, Öberg et al. did a study where stakeholder of TEN-T projects was interviewed (Öberg et al., 2018). Here the authors came to the result after analyzing the interviews and reasoned that interviewees who gave a positive answer to if the corridor approach can promote sustainability “that a corridor approach combine resources and long-term planning effort, and provide opportunities for more effective and environmentally friendly transportations” (Öberg et al., 2018).

TEN-T will transform the logistics networks in Europe, especially in the periphery of the EU in a positive way.

3.3 Belt and Road Initiative (BRI)

Another very important project which will have a big impact on logistics and societies worldwide is the Belt and Road Initiative (BRI) or One Belt One Road by the government of the People’s Republic of China (Dunmore et al., 2019). The primary goal is to connect the People’s Republic of China via South East Asia, the Central Asian states and the Middle East with Europe (Hilger, 2018).

This initiative was launched in 2013 by the president of the People’s Republic of China Xi Jinping and is a thoroughly ambitious project. It consists of the construction of transport connections via land between Asia and Europe, the development of a belt of economic integration between China and other countries and additionally maritime routes between China and all other continents (Hilger, 2018).

There is currently not a defined framework but the concept is rather fluid. Currently there is also not an official database nor a list of which countries are participating but according the government of the People’s Republic of China 65 countries with 60% of the world’s population and 30% of global economic output are involved (The Belt and Road Initiative, 2020).

The following maps show the BRI (Fig. 4).

Within the scope of the BRI the Russian government proposed and the Chinese government promoted a Silk Road on ice which should be developed by the two countries jointly. It should start in the Sea of Japan, entering the Arctic Ocean via the Okhotsk Sea and the Bering Sea and then follow the NSR to the ports of Northwestern Europe (Lin, 2021). Lin (2021) describes how a big data infrastructure is built up in the Ice Silk Road to gain more insights and thus makes it easier to acquire, store, and process the necessary data of this seaway (Yang et al., 2018).

The BRI will have an impact on logistics in Europe and also the shipping lines for Europe. The New Eurasia Land Bridge is connecting Chinese cities by rail with Europe through Kazakhstan, Russia, Belarus, and Poland. For example, there is already a direct train service between Chongqing, PR China and Duisburg, Germany (Stamouli, 2016).

The Port of Piraeus, Greece is considered a gateway port to Europe. COSCO will operate the Port of Piraeus and will invest 552 million Euros in the port (WSJ, 2016) “to make Piraeus the biggest transit port in South Europe” (Zhuravel & Nazarov,

Fig. 4 Map of the BRI. Source: The Belt and Road Initiative (2020)

2020). This will lead to new transport routes by rail from Southern to Central and Northern Europe by rail, e.g. from Piraeus, Greece to Budapest, Hungary (WSJ, 2016).

It is assumed that the trade between East Asia and the European Union will grow by 80% between 2016 and 2040, meaning roughly 2.5% per year. Some of these cargos (ca. 6%) will be transported by using the train (Hilger, 2018).

The BRI will thus have a global impact on the transport networks will lead to the economic improvement of a number of countries.

3.4 Analysis of NSR Development Plans According to the Official Sources

According to the infrastructure development plan for the Northern Sea Route (NSR), at the first stage (until 2024), it is required to increase the volume of cargo transportation, which will mainly be carried out in the western direction of the NSR. Large foreign and Russian companies are already working in this direction (Topwar, 2019).

To increase the volume of cargo traffic, it is necessary to modernize and expand the production capacities of a number of ports, and somewhere to build new ones. The development of the Port of Murmansk is planned. After modernization, its capacity will increase by 18 million tons. Not far from Murmansk, in the Ura Bay, NOVATEK company will build a liquefied natural gas (LNG) transshipment complex (Garant, 2020). The total investment is estimated at 70 billion rubles, of which the federal budget will provide only 0.9 billion. The number of facilities will also include federal property.

The modernization of the Arkhangelsk seaport has begun. Reconstruction of the Arkhangelsk approach channel is planned. It is planned to build a deep-water area of the seaport of Arkhangelsk. The project will include two specialized (for mineral fertilizers, oil cargo, and gas condensate) and four universal (for metal, bulk, timber, and container cargo) sea terminals with a total capacity of up to 38 million tons, access roads and railways (RG.RU, 2020). The construction cost is estimated at 149.8 billion rubles. The project is planned to be implemented in two stages: 2018–2023 and 2026–2028 (expansion of infrastructure and reaching design capacity).

In the future, the NSR will make it possible to deliver hydrocarbons to the markets of the Atlantic and Pacific Ocean.

Reconstruction of eight Arctic airfields is envisaged: Amderma, Murmansk, Arkhangelsk, Naryan-Mar, Dikson, Pevek, Tiksi, and Chokurdakh. In the coming years, most of the airfields in the Arctic will become all-season and will be able to receive aircraft of all types. Also, 40 Far Eastern airports have been included in the Comprehensive Modernization Plan. The terms of modernization are shifted due to a decrease in funding. To increase freight traffic, a large project is being implemented: the construction of the Northern Latitudinal Railway (SSH). The construction of the SSH is planned to be carried out until 2023 (Thebarentsobserver, 2019). The planned traffic volume will be 23.9 million tons per year (mainly gas condensate and oil cargo). A combined railway and road bridge will be built across the Ob River with a total length of about 40 km with approaches (up to 60 billion rubles). The SSH will connect the towns of Salekhard and Nadym, the village of Pangody with the central part of Russia by rail. The USS will reduce the length of transport routes from Western Siberia to the ports of the Baltic, White, and Kara Seas.

4 Results

4.1 Social

The development of the Arctic regions depends on the availability of resources, existing industry, transport, energy and other infrastructure, and population. GDP per capita of the Murmansk Region and Kamchatka Territory is second only to the oil and gas producing regions, Moscow (21.407 USD) and St. Petersburg (13.081 USD) and exceeds the indicators of a number of the main investment-intensive regions—Moscow (556.4 rubles), Leningrad regions (603.2 rubles), the Republic of Tatarstan (633.8 rubles) (Faikov & Faikova, 2021). This indicates the increased volumes of the economies of the northern regions, which is largely due to the development of the NSR. At the same time, it is in these regions, as well as in the Arkhangelsk region, that the trend towards a decrease in the number of the population persists. Despite the implementation of large projects, people are leaving, which indicates a decrease in the quality of life, insufficient social development of the regions. In the resource regions, the population is either constant or slightly increasing, but the total number and density of the population in the northern parts of these regions is low.

4.2 Economic

Currently gas, oil, timber, copper, and nickel produced in the north are transported on the NSR, the strategic importance of this seaway is thus high. The importance of the NSR as a unique transport artery is determined by the need for an industrial development of the Arctic region. This is an important factor to ensure the economic security of Russia. The NSR plays a role in the development of a number of Russian regions connected with the Arctic Ocean by large rivers (Ob, Indigirka, Yenisei, Kolyma). In addition, the Northern Sea Route affects the economy, transport links of the northeastern part of Russia, i.e. the Republic of Sakha (Yakutia), Chukotka, and Magadan.

The role of export markets can hardly be overestimated for the development of the economy and economic growth of any state. The development of the economy only at the expense of the domestic market does not allow it to develop dynamically outside the limits of domestic demand and consumption of goods. Export markets remove restrictions on the quantitative demand for goods due to limited domestic demand and provide essentially unlimited opportunities for obtaining additional resources from outside for the development of their own economy. An increase in the produced national income and economic growth lead to an improvement in the well-being of the population. Small and medium-sized businesses make a huge contribution to the development of foreign economic activity of the state. Since the development of this particular sector of the economy is a way to increase the competitiveness of the state economy as a whole.

The volume of total exports is an indicator characterizing the involvement of a state in the world economy; it should be noted that in most developed countries the share of small and medium-sized businesses in this indicator is about 30–40%. As mentioned above, with the introduction of sanctions against Russia and the closure of traditional European markets, the domestic economy is experiencing an urgent need to search for new markets. Over the past 15 years China and India are developing at high speed. It can be noticed by the value of GDP per capita, which tends to the value of the United States and Europe. In China, the GDP of capita is around 10.500 USD. For instance, USA has 63.000 USD. Asian markets are unlimited in terms of possible export of products. An important feature that contributes to the development of exports and dynamic trade cooperation of the Russian Federation with India and China is the similarity of the models of cross-cultural communication (Arapova & Mujumdar, 2020).

So, the NSR is a strategic sea transport artery that plays an important role in the development of the economy of the Russian Federation. This is a waterway that allows international trade, ensures the security of the state, and fully develops the Arctic region.

4.3 Ecological

Environmental threats are one of the main problems in the Arctic. Some opponents of the NSR are arguing that a year-round navigation of the NSR would be dangerous for wildlife there due to a lack of measures to protect the Arctic ecosystems. The implementation of northern maritime logistics should be based on ensuring environmental requirements, and thus green logistics can become the basis of a competitive advantage.

The highest value of which is considered to be the provision of green shipping, the introduction by Arctic maritime logistics into the world economy of technologies that multiply or eliminate greenhouse gas emissions into the earth's atmosphere, especially in its most sensitive zone of the clean ecological Arctic (Glomsrød & Aslaksen, 2006). Taking into account the special environmental pressure when choosing the NSR as a route for shipping, including within the framework of the competition between global carriers, environmental requirements for sea transportation with competitive power plants, for example, nuclear power plants, LNG in the future on hydrogen, with modern digital ship systems and complexes are the most important strategic aspect in the creation of a national Arctic cargo fleet. Therefore, it is an important task to present the NSR as the most environmentally friendly route for the transportation of goods that can bring a synergistic effect to the development of industry in the countries of the Arctic Council and the indigenous population of the Arctic region, to help reduce the global anthropogenic load and emissions as a result of using a shorter route between Europe and Asia, which will also contribute to realizing the goals and objectives of the Paris Climate Agreement. It should be emphasized once again that fuel costs are the most sensitive and critical criterion in the shipping business and an increase in the cost of fuel can provoke a global crisis in the shipping business. In connection with the impending in the period 2022–2025 crisis associated with the IMO 2020 problem, the project for the development of northern maritime logistics based on the NSR using ships with nuclear power plants has its own advantages (Nticenter, 2020). The use of nuclear power plants, on the one hand, increases capital costs in the construction of a ship, on the other hand, we obtain indisputable operational advantages in terms of fuel of the "fill and forget" type, fuel loading once every 5–7 years, unlimited autonomy possibilities, operating costs for nuclear fuel are significantly lower in relation to the annual cost of LNG or conventional diesel. This gives a return on costs within 10–15 years of operation. In particular, it should be taken into account that it is not necessary to create a special infrastructure for servicing ships with nuclear power plants, since it has already been created, like the regulatory framework, but for LNG, such an infrastructure will still have to be built. Due to the fact that the IMO 2020 problem will affect the instability of fuel prices and will lead to a twofold increase in the cost of fuel costs, the use of nuclear power plants will allow, among other things, to give consumers the stability of the cost of transport/transit services for a long period of up to 10 years (International Approaches to Carbon Pricing, 2021). Also, in terms of their impact on the environment, ships with nuclear power plants have zero CO_2 emissions. That is, it is a 100% vessel with no carbon footprint.

5 Conclusion and Outlook

The socio-economic development of the Arctic region of the Russian federation has become the object of close attention of both the government and the scientific community. A number of regulatory documents in the Russian Federation have been adopted, the main purpose of which was the regulation of certain aspects of the political, industrial, economic, and social development of this region.

This chapter examines the most important factors in the development of the Northern Sea Route. Among their permanent presence in the Arctic, development of the infrastructure of the Northern Sea Route, cooperation with other countries.

An important role is played by strategic factors related to geopolitical and transnational importance of maritime shipping in the Arctic zone. Such factors are control over sea areas, potentially rich in natural resources, the transit value of the Northern Sea Route as an internal route between northwestern and far eastern regions of Russia. Also an important factor is potential growth opportunities for transnational transit traffic along the highway Northern Sea Route between European and Pacific ports.

High-quality development of the Arctic territories is impossible without successful implementation of infrastructure projects. The formation of the Arctic transport system is the most important task for the development of the region. The limited transport system seriously hinders development of the northern regions. It is necessary to connect the routes of our great Siberian rivers to the Northern Sea Route, reconstruct old and build new branches of railways, highways, and also massively use aviation, then it will be powerful transport and logistics system.

The Northern Sea Route is the basis of the economic stability of the North of Russia and the most important element of the Russian and international transport system. Study The Northern Sea Route is a prospect of interesting and important work.

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The Northern Sea Route Development: The Russian Perspective

Vasilii Erokhin, Valery Konyshev, Alexander Sergunin, and Gao Tianming

Abstract This study aims to examine what the Russian concept of the Northern Sea Route's development is and how it evolved during the post-Soviet period. The authors conclude that despite some legal inconsistencies, the lack of a proper infrastructure, and residual environmental problems, the NSR will remain an important priority for the Russian future strategy in the Arctic region. The NSR is viewed by Moscow as an effective instrument to develop the Russian Arctic both domestically and internationally. However, Moscow still faces a dilemma: On the one hand, it wants to keep its control over the NSR and support Russian shipbuilding industry and shipping companies. On the other hand, the Kremlin is willing to open up this passage for international cooperation and integrate it to the global transportation system.

1 Introduction

The Northern Sea Route (NSR) is a crucial element of Moscow's national strategy in the Arctic Zone of the Russian Federation (AZRF). In addition to Russian economic interests, there are some geopolitical and security factors which affect the NSR's development and should be paid attention by the Russian decision-makers (Sergunin & Gjørv, 2020). The Kremlin points out the importance of the NSR's economic and environmental security aspects and the role it plays in ensuring AZRF transport and social cohesiveness.

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According to Russia's vision, the NSR missions include supplying everything needed to the remote AZRF regions and local communities (the so-called Northern supply—supply of foodstuff, consumer goods, and fuel to the northernmost Russian settlements), including the so-called new points of economic growth; export of the products originated from the Russian Arctic to other regions of Russia and abroad; becoming an energy superhighway for export of hydrocarbons and other natural resources of the Russian Arctic; assurance of smooth international transit of cargo; organization of search and rescue (SAR) operations system along the Arctic Ocean's coastline; securing border control over the vast area which became more accessible in view of melting polar ice; guaranteeing quick redeployment of the Northern Fleet forces to various parts of the Arctic Ocean and adjacent seas.

Given the importance of the NSR for Russia, Moscow is constantly adjusting its strategy for this sea route, including the improvements in its legal regulations, decision-making system, icebreaker and pilot services, port infrastructure, navigation and SAR systems, telecommunications, and so on.

This study aims to examine what the Russian NSR development concept is and how it evolved during the post-Soviet period. The chapter starts from an analysis of the NSR physical and economic geography, including its competitive advantages and shortcomings. The next section is devoted to the analysis of the current NSR management system. The special section describes the evolution of Russian policies on the NSR over the last three decades, including legal regulations on Arctic shipping. Finally, Russia's NSR development strategies—past and present—are explored.

2 The Physical and Economic Geography of the NSR

Russia views the NSR as Russia's historically existing national unified transport route which always have been under Moscow's exclusive jurisdiction. According to Russia's normative documents, the NSR lies between the Kara Gate, at the western entry of the Novaya Zemlya straits, and Provideniya Bay, which is a part of the Bering Strait. Its total length is 5600 km (see Fig. 1). In contrast with some common perceptions, the Barents and White Seas, where the Murmansk and Arkhangelsk ports are located, are not integral parts of the NSR legal regime. The NSR includes about 60 straits, the Vilkitski, Shokalski, Dmitri Laptev, and Sannikov Straits are among the main ones. The NSR runs through three large archipelagos such as Novaya Zemlya, Severnaya Zemlya, and the New Siberian Islands. It is difficult to define the NSR legal status because this sea route does not consist of a single shipping channel; rather, there are multiple lanes depending on whether the vessel navigates close to the Russian coastline or chooses to bypass the three above-mentioned archipelagos (see Fig. 2). For this reason, the NSR water area includes waters of different legal status: internal, territorial, and adjacent waters, and exclusive economic zone.

Fig. 1 Northern Sea Route water area and ports

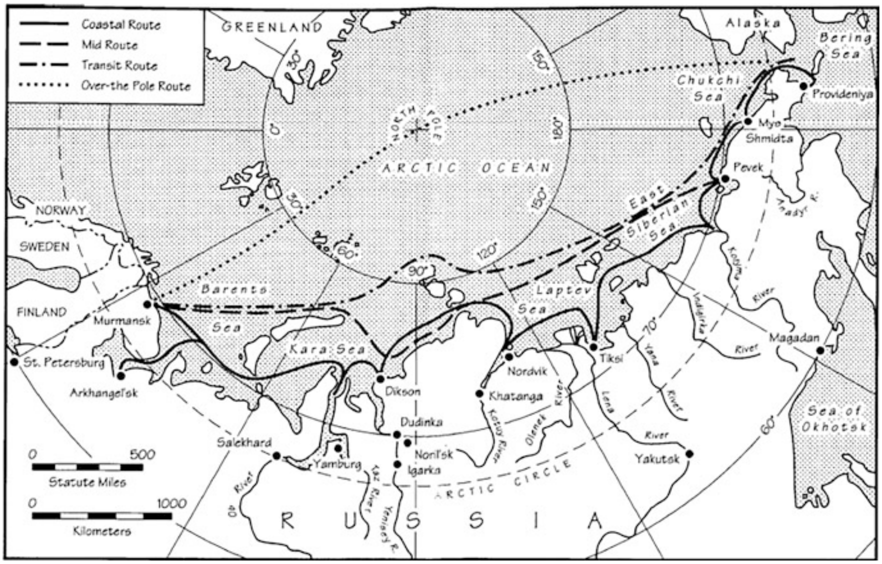

Fig. 2 The alternative “versions” of the Northern Sea Route. Source: http://www.globalsecurity.org/military/world/russia/images/north-sea-route-map1.gif

Since the Soviet time the NSR is of vital importance for Russia both economically and socially. The NSR is now actively used by “Norilsky Nikel,” “Lukoil,” “Gazprom,” “Rosneft,” “Rosshelf,” “Novatek,” and other Russian companies to ship products and supplies to and from their plants, mines, oil, and gas fields.

In the Soviet time, the Northern Sea Route was a purely domestic seaway where international shipping was not allowed. However, with the Arctic ice melting, the NSR becomes more accessible for navigation and Russia expresses its genuine interest in making the NSR an international transport corridor. Moreover, Moscow hopes that revenues from icebreaker and pilot escort will be helpful in maintaining its icebreaker fleet and NSR port infrastructure which are extremely costly.

2.1 The NSR’s Competitive Advantages

It is widely acknowledged that an ice-free Arctic could significantly reduce transportation costs by making shorter the way from Europe to China and Japan by 20–40% (see Fig. 3). In principle, for many vessels traveling from East Asian ports (China, Japan, and South Korea) to Western and Northern Europe the way through the NSR is shorter than through the southern routes, including the Suez Canal. For example, the distance from Yokohama to Hamburg via the NSR is only 11,100 km while the route via the Suez Canal is 18,350 km. This could reduce the sailing time from 22 to 15 days (i.e., the 40% reduction). The way from Shanghai to Rotterdam could be shortened from 22,200 km (through the Cape of Good Hope) to 14,000 through the NSR. The growing piracy in the Horn of Africa, the overburdening of the Suez Canal (or its obstruction similar to what happened in March 2021), regular

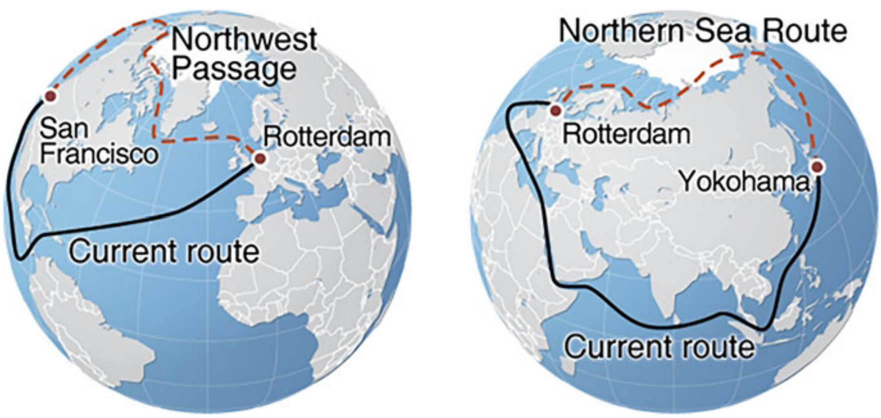

Fig. 3 The Northwest Passage and Northern Sea Route (as compared to the southern routes). Source: http://maps.grida.no/go/graphic/northern-sea-route-and-the-northwest-passage-compared-with-currently-used-shipping-routes

tensions in the Hormuz Strait, all shift attention of shipping companies to the search of new alternatives, including the NSR.

Trip from northern Russia to North America (especially to Canada) would also be faster by using the Arctic seaways. Vancouver is 9600 km from Murmansk through the Bering Strait, but is 16,000 km through the Panama Canal. In 2007, Moscow and Ottawa tried to launch a project “Arctic bridge” connecting Murmansk to the port of Churchill located in the Canadian Province of Manitoba. The Canadian railroad operator OmniTRAX (the owner of the Churchill port) even started negotiations with the Murmansk Shipping Company on this issue. In 2007 and 2008, the experimental shipments of Russian cargo arrived in Churchill from Murmansk.

2.2 The NSR’s Weak Points

In contrast with the above optimistic expectations, some international experts (Antrim, 2010; Laruelle 2014; Smith & Giles, 2007) point out that navigating through the NSR is still a serious challenge. Firstly, the significant reduction or full disappearance of polar ice during the summer season does not make the NSR water area completely ice-free. Ice can suddenly emerge on the way of a ship. There could be a plenty of icebergs as a result of glacier melt-down. In other words, the possibility of collision and shipwreck will still be considerable; the trip via the NSR will still be quite risky and unpredictable.

Secondly, navigating polar waters is (and will be) difficult in technical terms: ships need ice-strengthening and—depending on a season—icebreaking capabilities, as well as proper training for captains and crews to sail via the NSR.

Thirdly, international shipping companies complain that Russian fees for ice-breaker and pilot escort and getting weather and ice reports are too high and sometimes unnecessary.

Fourthly, international insurance companies tend to introduce high insurance fees for shipping cargo via the NSR because of its unpredictability in terms of time of shipping, maritime safety, and other risks.

Fifthly, currently, the NSR has no 100% reliable operational rescue system and not all Russian Arctic ports would be able to host vessels in need of repairs. The Russian government builds ten SAR centers along the Russian Arctic coastline but the question whether these plans would come true or not and whether these centers would be helpful in the NSR development remains open to discussion.

Sixthly, the environmental consequences of the NSR’s increased traffic can be controversial because of pollution from ships and the risk of accidents. The 2013 international agreement on prevention and fighting oil spills in the Arctic Ocean signed at the Arctic Council’s ministerial meeting in Kiruna is helpful in coping with this environmental threat but still insufficient to solve the whole problem.

The above concerns, however, do not preclude both Russia and potential NSR users from the ambitious plans to develop this important Arctic route.

3 The NSR Management System

The NSR was officially opened to international use in 1991. The legislative/normative basis for the NSR use included the Regulations for Navigation on the Seaways of the NSR (1991), the Guide for Navigation through the NSR, the Regulations for the Design, Equipment, and Supply of Vessels Navigation in the NSR (1995), the Federal Law on the Northern Sea Route (Putin, 2012), and the Ministry of Transport's Regulations on Navigation through the NSR (2013).

To effectively control Arctic shipping, the Ministry of Transport reestablished its NSR Administration (NSRA) in March 2013. This agency was responsible for processing Russian and foreign ships' applications for the navigation through the NSR and ensuring the navigation safety. Later, along with the Russian Maritime Register (national classification society), the NSRA was charged with implementation of the International Maritime Organization's (IMO) Polar Code (2014–2015) which entered into force in 2017 (NSRA, 2021; Sergunin & Konyshev, 2019, p. 79).

However, given the growing traffic via the NSR and the need to quickly develop its infrastructure, the Kremlin started to doubt whether the NSRA and Ministry of Transport at large would be able to effectively cope with the existing and future challenges (Humpert, 2018; Sergunin & Konyshev, 2019, pp. 79–81).

The Kremlin even started to discuss an idea of establishing a "superagency" that could solve all the NSR-related managerial and infrastructural problems by coordinating the icebreaker, rescue and research fleets' activities, maintain the port, navigation, and communication infrastructures, issuing permissions for ships to travel through the NSR, developing international cooperation, and so on (Marinin et al., 2018). However, this idea met a cold shoulder from various executive agencies managing the NSR as well as from private companies which did not want to deal with a new bureaucratic "monster" looking like Joseph Stalin's Glavsevmorput' (the Main Directorate of the Northern Sea Route).

Finally, the Kremlin opted for a compromise variant: President Vladimir Putin approved a new version of the NSR law (27 December 2018) which introduced a NSR management system based on shared responsibility (the so-called two-key principle) of the Russian Nuclear Power Agency (Rosatom) with its fleet of nuclear icebreakers and Ministry of Transport, including the NSRA (Putin, 2018b). Rosatom was charged with the development and operation of the NSR, as well as with maintaining and improving the infrastructure and seaports along Russia's Arctic coast. A special department on the NSR was organized within Rosatom. At the same time, the NSRA, being an integral part of the Ministry of Transport, kept its prerogatives to issue regulations on Arctic shipping, give or refuse permissions to navigate the NSR, and develop international cooperation, including the Polar Code implementation. Obviously, this reorganization aimed to make the NSR management system more efficient and carry out President Putin's ambitious plan to annually ship 80 million tons of cargo through this polar route by the year 2024 (Putin, 2018a).

To illustrate the central role of Rosatom in decision-making on the NSR it should be noted that the 2019 Government's plan to develop the NSR infrastructure up to 2035 was in fact drafted by the Rosatom (Golubkova & Stolyarov, 2019).

Besides the two above agencies (Rosatom and Ministry of Transport), several other governmental bodies are involved in the NSR decision-making. The Federal Service for Hydrometeorology and Environmental Monitoring and its research institutions, including the Arctic and Antarctic Research Institute in St. Petersburg, as well as the State Space Corporation provide governmental bodies and vessels navigating through the NSR with information on ice and weather conditions in the Arctic.

The Ministry for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters is in charge with SAR and oil spill prevention and response activities in the NSR water area. As mentioned above, this ministry develops a network of SAR centers along Russia's Arctic coastline.

The Ministry of Defense is one of the key players in the NSR decision-making system as well. Civil agencies should coordinate concrete shipping routes with the Defense Ministry to bypass the Arctic islands hosting Russian naval and air force bases (Yeltsin, 1998, Articles 14–15; Pokrovsky, 2019). In addition, the Rosatom and NSRA should take into account military exercises in the NSR water area. The Russian military is supposed to assist the civilian rescue agencies with SAR operations, if necessary.

The Border Guard Service (BGS) and its structural component—Coast Guard—play an important role in organizing border controls, ensuring economic security and preventing illegal activities in Russia's exclusive economic zone (EEZ), including poaching, smuggling, illegal migration, attacks on critical industrial and infrastructural objects and terrorism. According to the NSR navigation rules, ships crossing Russian maritime borders (sometimes repeatedly) should notify the BGS (through the Russian system of ship identification) on the proposed route of navigation and systematically report on their position (Government of the Russian Federation, 2014). This is required for both exercising control over shipping and maritime safety reasons because the Coast Guard vessels potentially can be used in SAR operations.

The Ministry of Interior and the Russian National Guard are responsible for preventing illegal migration along the Russian Arctic coastline and helping the Ministry of Emergencies' SAR operations on the land.

Given the multiplicity of decision-makers (see Fig. 4), there is a problem of coordinating their activities. However, this coordination function is not performed by such governmental bodies as the Ministry for the Development of the Far East and the Arctic and the State Commission on the Arctic Development, because they are engaged in the development of the AZRF as a whole, and not the NSR. The absence of such a coordination mechanism leads to inconsistency in the actions of various departments responsible for the NSR, and, as a result, to a decrease in the effectiveness of the NSR's functioning and the dissatisfaction of its Russian and foreign users. Unfortunately, the creation of an effective decision-making system for the NSR and the management of Arctic shipping remain an unsolved problem.

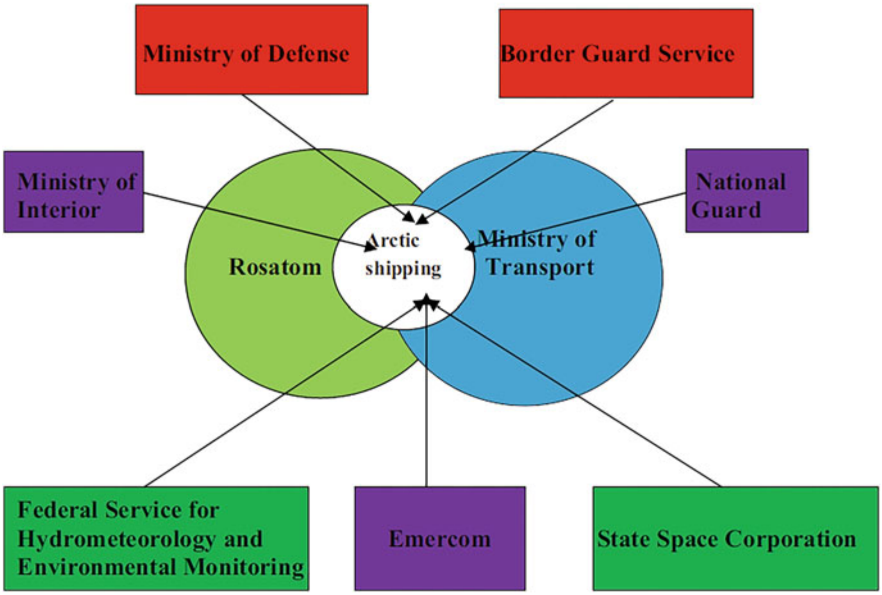

Fig. 4 NSR management system

4 Russia's Policies on the NSR

Moscow faces the following dilemma with regard to the organization of Arctic shipping: On the one hand, Russia wants to make the NSR an international transport corridor and attract foreign customers to actively use this seaway. On the other hand, the Kremlin would like to promote Arctic shipping under Russian flag and restore Russian shipbuilding industries, including shipyards that produce vessels for navigation in ice conditions (Gavrilov, 2020). It is worth of remembering that about 5–7 years ago the Novatek company was unable to find a Russian shipyard capable of building ice-class LNG tankers to ship the Yamal LNG plant's products from Sabetta port to Russian and foreign customers. The Novatek had to order 15 LNG tankers of Arc7 class to the South Korean Daewoo Shipbuilding Marine Engineering (DSME) company. Such Moscow's ambivalent line was reflected in the recent Russian regulations on the NSR navigation.

The first legislative initiatives to limit the use of foreign tonnage on the NSR were undertaken in 2015 when Russia started to feel the effects of Western economic sanctions, including its Arctic sector of economy (Moe, 2020). However, it took another 2 years to materialize them in the form of a new federal legislation.

On 29 December 2017, the new Federal Law No. 460-FZ "On Amending the Merchant Shipping Code (MSC) of the Russian Federation and Invalidating Specific Provisions of Legislative Acts of the Russian Federation" was signed into law by President Vladimir Putin (2017). Its main objective was to create conditions for increasing the participation of vessels sailing under the Russian state flag in shipping activities between Russian seaports, as well as between Russian ports and any other locations under Russian national jurisdiction (for example, artificial islands, installations and structures within the Russian EEZ or on the Russian continental shelf). That objective has been achieved by expanding the term “cabotage” and by establishing the rule that icebreaking services and pilotage assistance in the NSR water area can only be performed by ships under the Russian flag.

At the same time, the law made it easier to re-register to Russian flag which was important for those Russian ships which used flags of convenience.

The Article 4 of the MSC has also been amended to provide that oil, natural gas (including LNG), and gas condensate extracted on Russia’s territory or its continental shelf and loaded onto ships in the NSR water area can also be transported, until the first point of unloading or in cases of transhipment, solely by vessels flying the Russian flag. The aim of the law was “to create favorable social and economic conditions for cabotage by finding balance between the interests of state, carriers and consumers, as well as to increase the competitiveness of sea carriers engaged in the transportation and towing on vessels flying the State flag of the Russian Federation” (Poyasnitel’naya Zapiska, 2016).

Since some Russian and foreign customers might be discontent with the Russian requirement to pay not only for the goods themselves but also for their shipment by Russian vessels via the NSR, the law admitted some exceptions. For example, paragraph 4 of Article 4 of the MSC provided that Russian Government is entitled to issue special permits for the transportation of the above goods by ships sailing under foreign flags “if it does not contradict generally recognized principles and norms of international law and international treaties of the Russian Federation” (Putin, 2017). The law allowed for an exception to the above restrictions for the vessels of certain countries, depending on the current economic or political situation and on the willingness of these countries to develop friendly bilateral relations with Russia.

The first such permit was issued by the Russian Government decree No. 435-r on 14 March 2019 (Government of the Russian Federation, 2019). Twenty-eight foreign ships have been given the opportunity to transport natural gas and gas condensate from Sabetta up to the first unloading or transhipment point. This decision has been made in the interests of the Novatek company, which used the fleet of tankers built in South Korea and flying both Russian and foreign flags.

As some experts believed, the Novatek experience could encourage other shipping companies to apply for similar exceptions (Gavrilov, 2020, p. 279). On the other hand, the Russian business community tended to believe that the problem of increasing the competitiveness of Russian sea carriers should be resolved by adopting a special law to support Russian shipbuilding and providing large-scale state support to this industry rather than by introducing legislative bans and exceptions therefrom (“Gazprom” poprosil isklyucheniy, 2019).

However, given the fact that increasing capabilities of Russia’s shipbuilding industries to a sufficient level takes some time, Moscow continued to expand the list of exceptions. On 1 March 2020, a Federal Law “On Amendments to Article 4 of the Merchant Shipping Code of the Russian Federation” was adopted which introduced an additional paragraph 5 to the MSC Article 4 permitting the Russian Government to grant ships under foreign flags the right to engage in cabotage, icebreaker assistance, search and rescue operations, marine resource research, and some other marine activities in the NSR water area (Putin, 2020). Foreign ships can get such a permission in accordance with Russia's international treaties and/or in other cases determined by the Russian Government.

At the same time, the Kremlin did not abandon the idea of transporting hydrocarbons out of the AZRF by vessels built only in Russia. The initiative was launched by the Ministry of Industry and Trade and endorsed by the Energy and Transport Ministries (Moe, 2020, p. 213). The aim of this initiative was to support further development of the Russian shipbuilding industry, particularly its sector responsible for building ice-class vessels, including the new shipyard "Zvezda" (Star) nearby Vladivostok (Solski et al., 2020). In September 2018, vice prime minister Yuri Borisov said in an interview to the Russian TV that the new rules were to take effect on 1 January 2019 (Rossiya vvodit ogranicheniye, 2018). At the same time, Borisov admitted that for some time foreign-built vessels still could operate in the NSR water area because the Russian shipbuilders were unable to satisfy soon the growing needs of Russian hydrocarbon producers in transporting LNG and oil products via the NSR.

The proposal to reserve hydrocarbon shipping only for Russian-built vessels has again provoked an open dispute with Novatek and other Russian energy companies, which argued that the Russian shipyards were unable to produce ice-class vessels by the moment when the Arctic LNG 2 plant and other projects will be operational and, hence, implementation of the law might put further LNG and other hydrocarbon projects in jeopardy.

As mentioned above, in March 2019, the Russian government confirmed and extended the solution for Novatek by permitting the use of the 15 South Korea-built icebreaking Arc7 LNG carriers plus 13 other conventional LNG tankers under foreign flag, all individually listed, until 2043. It was decided that the Arc7 carriers will transport the LNG from the production sites of both Yamal LNG and Arctic LNG 2 plants to reloading terminals to be constructed nearby Murmansk and on Kamchatka. The conventional LNG tankers, which are less expensive to build and operate, will bring the gas further, to the customers both in the West and Asia Pacific.

Moreover, in early 2020, Novatek got permission to order ten Arc7 LNG tankers from abroad, on the argument that Zvezda would not have capacity to deliver vessels in time for all Novatek projects which included not only Yamal LNG, Arctic LNG 2 but also Ob' LNG and Arctic LNG 1 (Vedeneeva, 2020). However, since the introduction of the Ob' LNG plant was postponed, Novatek decided to limit itself to six Arc7 LNG tankers. The Russian shipping company Sovkomflot and Sino-Japanese MOL ordered three carriers each to the DSME to be delivered by the end of 2023 (Dyatel, 2020).

However, the Russian government stood firm regarding the restriction on foreign-built vessels for the next LNG projects. As a result of the government's pressure, at the end of 2018, Novatek had to agree to order 15 Arc 7 icebreaking carriers from Zvezda, for delivery between 2023 and 2025. Later the company also announced it would order five more carriers from Zvezda for the Ob' LNG project before 2025 and planned ordering additional 15–17 carriers from the yard before 2030, for the projects Arctic LNG-1 and Arctic LNG-3. Thus, total orders at Zvezda will amount to 35–37 Arc7 carriers before 2030 (Moe, 2020, p. 217).

All in all, the above new regulations definitely signify a trend that Russia embarks on increased shipping in the NSR water area of vessels which are built in Russia and sailing under the Russian flag.

The establishment of a new NSR management system and entering into force of the IMO Polar Code necessitated the introduction of a revised Rules of Navigation via the NSR in September 2020 (The Government of the Russian Federation, 2020). The document underlined that in contrast with the Rules-2013 Rosatom is now responsible for the organization of navigation through the NSR. To coordinate this work Rosatom established the Marine Operations Headquarters (MOH) which is responsible for (1) icebreaker assistance and escort of ships on the NSR navigation routes and (2) development of routes for navigation and arranging the icebreaker ships along the NSR water area.

The Rules-2020 retained the permission system for vessels willing to use the NSR. The permissions are issued by the Federal Agency of Maritime and River Transport (part of the Ministry of Transport) or its subordinate organization (NSRA) in agreement with the MOH. In contrast with the Rules-2013, the new rules require from the applicants a copy of the Polar Ship Certificate, envisaged by the Polar Code.

To obtain a permission, an application in electronic form (pdf file) shall be submitted to the NSRA by the shipowner, a representative of the shipowner, or the master of the ship, in Russian and/or English. The application shall contain information about applicant with indication of the full name and identification number of the ship assigned by the IMO, as well as surname, first name, patronymic (if any) of the head of the applicant—legal entity, contact phone and fax numbers, e-mail address (for a legal entity) or surname, first name, patronymic (if any) of the applicant, contact phone and fax numbers, e-mail address (for physical person who applied with a statement on his own behalf).

The following documents should be attached to the application in electronic form (pdf file), in Russian and/or English:

- information on the ship and the voyage;
- a copy of the Classification Certificate, issued by an organization, authorized for classification and survey of ships;
- a copy of the Tonnage Certificate;
- a copy of a Certificate of insurance or other financial security of civil liability for pollution damage from ships, issued in accordance with the International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001, International Convention on Civil Liability for Oil Pollution Damage, 1969;
- a copy of the Certificate issued by an organization, authorized for classification and survey of ships that has approved the Project of a one-time passage (a ferry), confirming the possibility of implementation of a passage with an indication of

the conditions for its completion (for a ship passing outside its designated areas and sailing seasons);

- a copy of the standard towing Manual or towing Project, approved by an organization authorized for the classification and survey of ships (for towed floating objects in their designated navigating area, including towed floating drilling rigs);
- a copy of the Polar Ship Certificate, required by the Polar Code (for ships to which this Code applies);
- a copy of the Certificate of Ownership of the ship (Certificate of Registry) (or other document confirming such ownership);
- a copy of the Contract for Icebreaker Escort Services (for ships for which such escort is mandatory according to the criteria for the admission of ships to the NSR water area, provided for in the Rules' appendix).

This application (with the documents attached) shall be sent by the applicant not earlier than 120 calendar days and not later than 15 working days before the estimated date of the ship's entry to the NSR water area. The NSRA should take decision on the application within ten working days; it takes five working days to get response from the MOH.

The grounds for refusal from the MOH are as follows:

- non-compliance of the ship with the admission criteria;
- non-submission by the applicant of a copy of the Contract for Icebreaker Escort Services, if such assistance is mandatory according to the admission criteria.

The NSRA can refuse to issue a permission if one or more of the following grounds are present:

- the MOH refusal;
- providing of incomplete or unreliable information in the application or its attachments;
- the documents are presented in an unreadable format;
- incomplete set of required documents or invalid documents have been submitted;
- the application is not signed by the applicant;
- ship's planned navigation route or area of work in the NSR water area and/or the period of navigation are outside the areas and/or seasons of operation of the ship, established by the organization authorized for the classification and survey of ships.

Any vessel allowed to travel via the NSR should notify the MOH 48 hours prior to entering the NSR water area. It also should submit to the MOH the following information: (1) the ship's name; (2) Ship Identification Number (if any); (3) the port of departure, actual date and time (Moscow time) of the departure; (4) the port of destination, estimated date and time (Moscow time) of arrival; (5) the maximum draft of the ship (in meters); (6) type and quantity (in metric tons) of the transported cargo (information on the floating object being towed); (7) class and quantity (in metric tons) of the transported dangerous cargo (if any); (8) fuel oil bunker with indication of the type of fuel oil (in metric tons) and the number of days during which the ship can proceed without bunkering; (9) fresh water supply taking into account fresh water replenishment from the ship's desalination plant (if any) and indicate the number of days during which the ship can proceed without replenishment of the fresh water supply; (10) provisions and other ship's stores and the number of days during which the ship can proceed without replenishment of the provisions and other ship's stores; (11) the number of crew members and passengers on board; (12) information on damage to the ship's hull, malfunctions of ship's engines, machineries, and/or technical facilities (if any); (13) the names, Ship Identification Numbers of towed ships (if any), other floating objects, type and quantity of cargo, number of crew members and passengers on their board (if any); (14) estimated date and time (Moscow time) of the ship's entry to the NSR water area, indicating the geographical coordinates of the planned crossing point of the NSR border.

The captain of a vessel traveling via the NSR should be in touch with the MOH on the daily basis and inform it on ship's standing as well as on arrival in the port of destination within the NSR water area or Russia's internal waters or leaving the NSR water area.

The Rules-2020 explained which vessels traveling through the NSR needed icebreaker and pilot escort and referred to the 2014 regulations on escort tariffs.

The document also reminded to the NSR potential customers about maritime safety rules and measures to prevent pollution from ships in accordance with the IMO Polar Code.

It should be noted that the whole procedure of getting permission for navigation via the NSR and ship's travel through this seaway did not become more complicated. It was slightly changed because of the introduction of the "two-key principle" (NSRA/MOH) and some new documents (e.g., the Polar Ship Certificate) and safety and ecological requirements stipulated by the Polar Code.

5 Russia's NSR Developmental Strategies: Past and Present

In the 2000s, discussions on the draft Concept for the Development of the Northern Sea Route, designed for the period up to 2015, unfolded in Russia. In the draft, it was indicated that the Concept's basic idea was that in the process of integrated development of the NSR and its use on a commercial basis, a self-supporting, cost-effective Arctic Sea Transport System under state control will be created by 2015 (Goldin, 2018). The discussions lasted for several years but did not lead to the adoption of the Concept. No real measures to develop the NSR were taken.

On November 22, 2008, the Russian government approved the Transport Strategy of Russia for the period up to 2030. Among its goals was integration into the world transport space and the realization of the country's transit potential, which fully related to the NSR. It was planned to reconstruct and build terminals that ensure

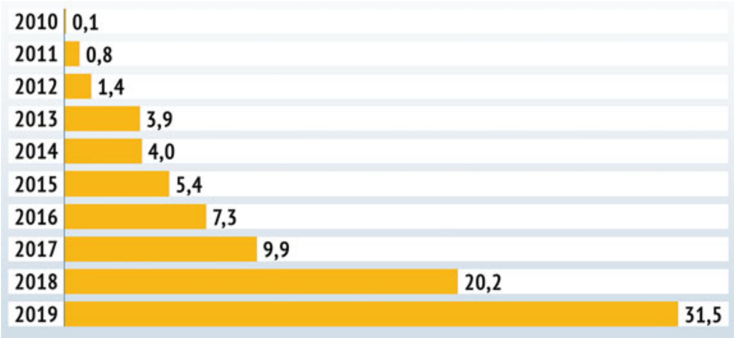

Fig. 5 The NSR cargo traffic (2010–2019), million ton. Source: https://www.vetandlife.ru/vizh/rynki/infografika-vizh-dinamika-perevozki-gruz/

the NSR operation, as well as the development of a number of ports (The Government of the Russian Federation, 2008).

The situation started to gradually change in 2011–2012 when the Kremlin decided to support internationalization of the NSR by launching a number of investment projects to modernize the NSR infrastructure. In 2011, the then Prime Minister Vladimir Putin said that 38 billion rubles would be allocated to increase the icebreaker fleet by 2014, and three universal nuclear icebreakers and six diesel-electric ones would be built by 2020. He also recalled the state decision on the creation of 10 integrated emergency rescue centers in the Russian Arctic (Zhernov, 2011). To this end in 2012–2014, over 21 billion rubles were allocated to the construction and modernization of maritime infrastructure in the Arctic (The Government of the Russian Federation, 2012).

The launch of the Novatek's Yamal LNG plant in late 2017 created a principally new situation in the region by requiring organization of all-year-round LNG shipments to East Asian and European customers. The volume of cargo traffic along the NSR has grown sharply over the past decade from 0.1 million ton in 2010 to 31.5 million ton in 2019 (see Fig. 5). In 2020, the cargo volume reached 32 million ton (Rosatom, 2021, p. 3).

Responding to the growth of the NSR cargo traffic a detailed plan of practical measures to develop the NSR infrastructure up to 2035 was adopted by the Russian Government in December 2019. It provided, inter alia, for renovation of ports along the NSR; building of SAR and auxiliary fleets; expansion of navigational and hydrographic services; development of a satellite group servicing the NSR communications and navigation; building new icebreakers; stimulating cargo shipments and international transit; boosting local energy supply, staff education, encouraging domestic shipbuilding, and assuring environmental safety (Medvedev, 2019).

The plan's main goal was to create by 2023 all the necessary conditions for ensuring all-year-round transportation of goods and passengers via the NSR. The document consisted of 84 points divided into 11 categories and listed concrete

Fig. 6 High-altitude routes in the NSR water area. Source: http://www.hydro-state.ru/kage.html

measures to be implemented by federal authorities, regional governments, and largest state corporations operating in the AZRF (Medvedev, 2019).

According to Alexey Likhachev, the head of Rosatom, this plan requires 735 billion roubles ($11.7 billion) in investments, with the state budget to provide a third and the rest to come from companies, such as Rosatom itself, Rosneft, Novatek, Gazpromneft, Gazprom, Nornickel, and banks (Golubkova & Stolyarov, 2019).

As to the infrastructural aspects of the NSR development the Russian Ministry of Transport plans to develop a high-altitude version of the NSR for large-capacity vessels. The first phase of the project aims to establishing 2-mile wide main and alternative lanes; at the second phase, 20-mile wide routes will be laid out (see Fig. 6). To this end, the MT's Federal State Unitary Hydrographic Department charts the routes with the help of three hydrological ships.

To increase the NSR's safety, Russia should complete the creation of ten federal SAR centers along the NSR. Currently, seven federal SAR centers are already operational in the AZRF (Murmansk Directorate of the Ministry for Emergency Situations, 2021). Moreover, there are four regional SAR and fire units, two maritime SAR coordination centers (Murmansk and Dikson), three maritime SAR stations (Arkhangelsk, Tiksi, and Pevek), and four storages for equipment for oil spill response (Dikson, Tiksi, Pevek, and Providence) (Vasilyev et al., 2015, p. 29) (see Fig. 7).

To further develop the NSR and bring it to international standards, some Russian experts suggest establishing an international consortium with the participation of *Rosatomflot* (nuclear icebreakers), *Sovkomflot* (tanker, gas, and cargo fleet), *Rosmorport* (port and navigation infrastructure), and international shipping companies (tanker and container fleet) (Semenikhin & Novosel'tsev, 2015, p. 9). The Russian government, however, opted for the Rosatom's leadership in managing the NSR.

To increase safety of the maritime traffic via the NSR Russia should further develop SafetyNET and Navtex systems in the NSR area. Particularly, in addition to

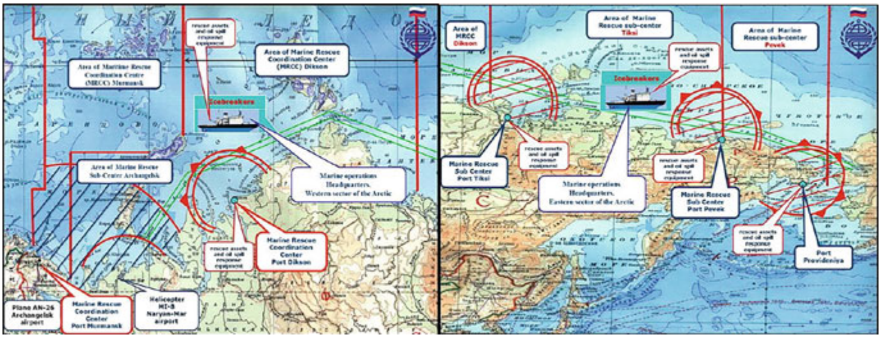

Fig. 7 Search and rescue centers on the Arctic Ocean's coastline and their zones of responsibility. Source: http://www.arctic-lio.com/nsr_searchandrescue

Fig. 8 SafetyNET and Navtex coverage zones in the NSR water area. Source: http://www.hydro-state.ru/tsibm.html

the existing Navtex station in Tiksi, a new Navtex station will be built on the Andrew Island (see Fig. 8).

As for technical aspects of the PC implementation many Russian and Western experts believe that a greater attention should be given to a proper equipping of ice-class ships for navigating in the polar areas. For example, Russia's Norilsk Nickel company uses Jeppesen's dKart Ice Navigator on their ice-class vessels, which helps them to significantly save costs for icebreaker assistance. New ice detection options for high-resolution radars in the form of an ice radar overlay on an ECDIS can also contribute to safer and more efficient navigation in ice fields (Oechslin, 2014).

Another concern for many NSR users is ionospheric interference: electromagnetic fields affecting radio signals on particular frequencies. These can affect positioning systems, as well as communications in general. Recent research by the International Association of Lighthouse Authorities (IALA) and the IMO confirmed that modern e-Navigation requires a more resilient positioning system. The Russian Arctic is fully covered by long-range RNS "Chaika"—the Russian version of LoranC—which is considered as a reliable backup to GPS/GLONASS and included in the global radio navigation plan of the IMO (Oechslin, 2014).

It is interesting to note that Russian and foreign experts suggest some specific proposals for bilateral cooperation in the PC's context. For example, some specialists propose a number of the U.S.-Russian bilateral initiatives:

- Commit resources to improve hydrographic information and update nautical charts.
- Improve navigation safety information sharing between the two countries.
- Improve emergency response capability, such as stationing a rescue tug near areas of high risk or high value.
- Conduct oil spill response exercises to test the effectiveness of the 2013 Arctic Oil Spill Agreement.
- Institute communication and reporting requirements to better monitor vessel traffic, reduce risk, and ensure vessel compliance with appropriate Arctic guidelines for safe navigation.
- Cooperate on establishing voluntary navigation safety measures in the Bering Strait (Rufe & Huntington, 2014).

6 Conclusions

It is clear that the NSR will retain its strategic importance for Moscow although there is a lack of clarity in its legal status, developed infrastructure, and reliable SAR system. Russia views this Arctic seaway as an effective tool to further develop the AZRF and engage the latter in international cooperation. The Kremlin is serious about the NSR development and has ambitious plans to attract both domestic and foreign investments to make this route more efficient and attractive for international customers. However, Moscow still has to cope with the old challenge: how to keep its control over the passage and help its shipbuilding industry with new orders, on the one hand, and make the NSR an international maritime transport corridor, on the other.

To transform the NSR from the domestically-oriented and insufficiently reliable sea route to an attractive platform for international maritime cooperation, Moscow still has to solve current legal, managerial, infrastructural, and environmental problems. First of all, Moscow should establish clear and transparent rules of shipping through the NSR water area. The Russian governmental agencies responsible for managing the NSR should establish a clearer division of labor between themselves and better coordinate their activities. The Russian authorities should significantly improve the NSR's port, SAR, communication, and other infrastructures. They should also clearly define safer and faster lanes within the NSR water area—depending on ice and weather conditions. Moscow should systematically modernize its icebreaker, rescue and research fleets operating in the Arctic Ocean. Russia should also establish reasonable and transparent icebreaker and pilot escort fees to make them affordable for all NSR potential customers.

If Moscow's ambitious program of the NSR development (launched in 2019) to be executed and legal aspects of Arctic shipping to be clarified, Russia could have a real opportunity to transform this Arctic seaway into a popular transport corridor connecting not only Russian northern ports and regions but also Europe and East Asia. Along with gaining economic benefits, Moscow's could demonstrate to the world community that it is interested in de-securitization of the Arctic region and making it a region of peace and cooperation, as declared in Russia's strategic documents on the High North.

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