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

Igor Ilin, Anastasia Levina, Anastasia Gurzhiy, and Alexandra Borremans

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

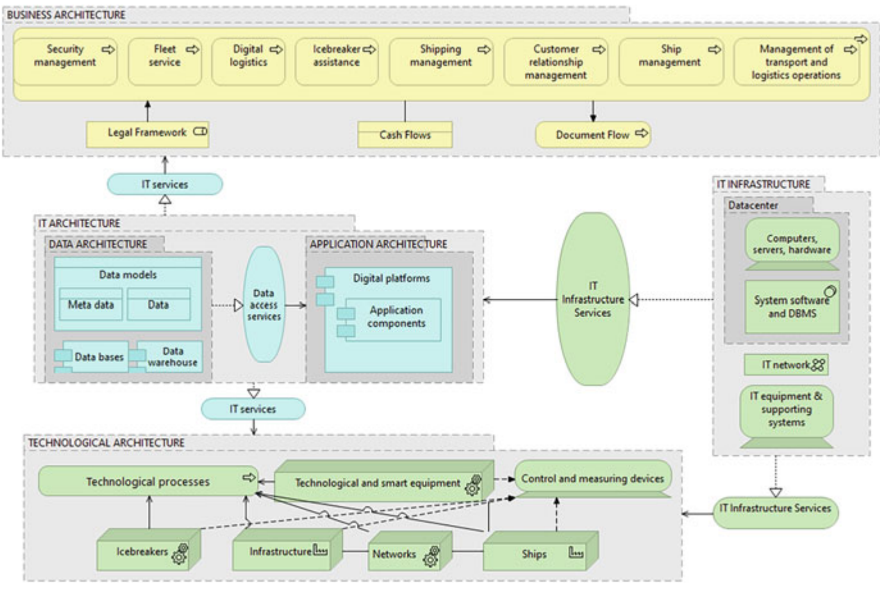

Fig. 1 Architecture "to be" of the Northern Sea Route

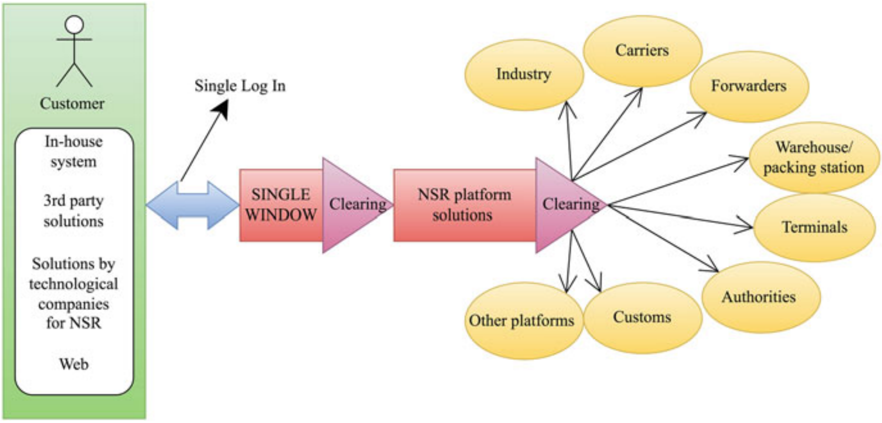

Fig. 2 Business digital ecosystem for the Northern Sea Route (UN Recommendation No 33, 2005)

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)

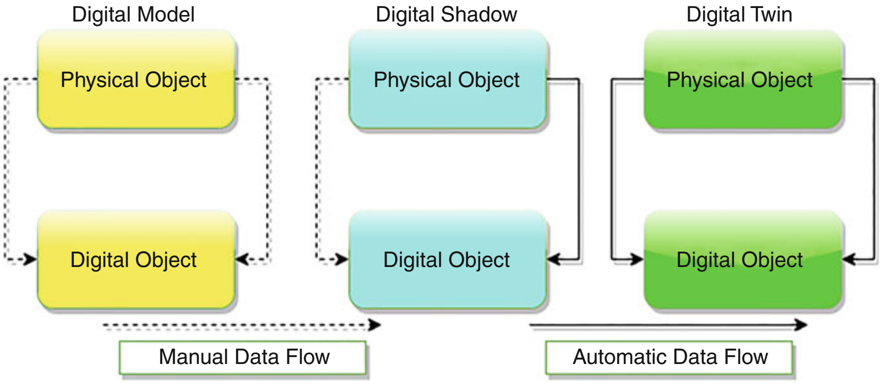

Fig. 3 Digital twin and digital shadow model

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."

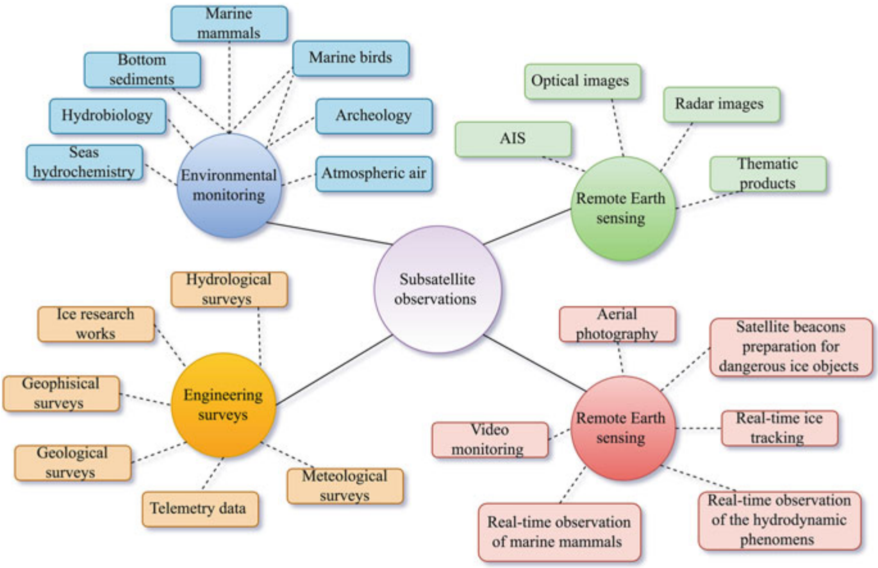

Fig. 4 Used satellite technologies for the NSR

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

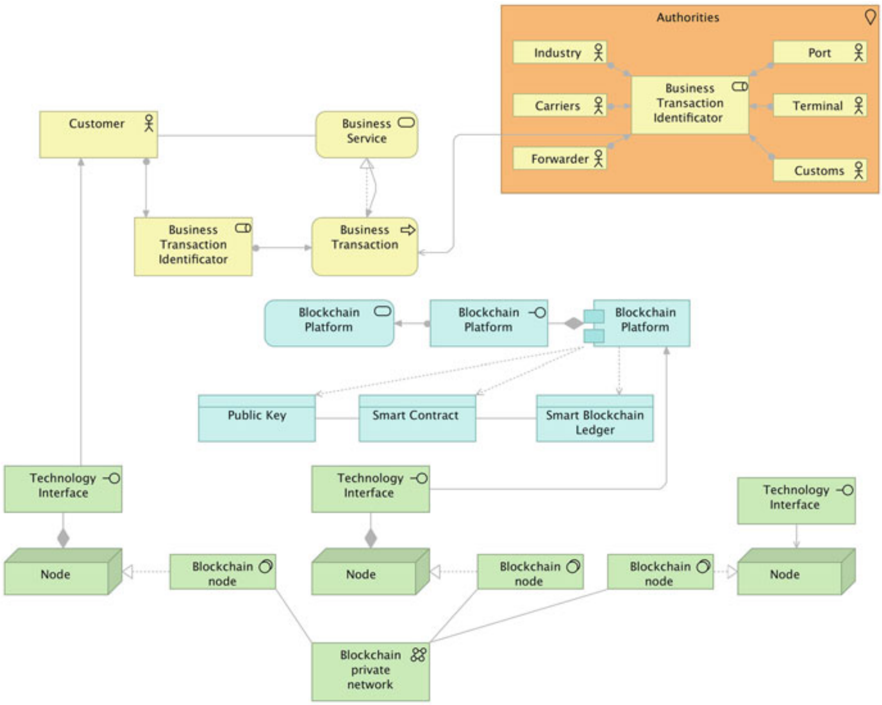

Fig. 5 Blockchain for NSR

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.

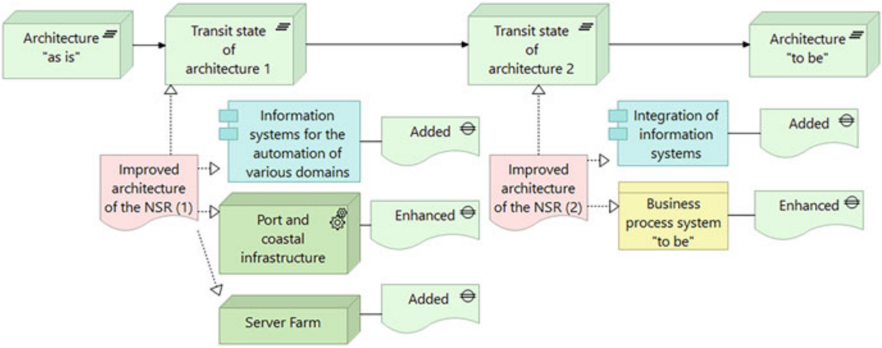

Fig. 6 Stages of transition to the target architecture of the Northern Sea Route

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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