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State of Research in Arctic Maritime Logistics

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Purpose: The Arctic is of interest for many states and commercial organizations as it has a large undiscovered potential but very challenging climate and logistical conditions. Arctic maritime logistics need significant investments in infrastructure and is supposed to cause a minimal impact on the environment during port operations and cargo transit by creating efficient and safe supply chains. At the same time, ensuring the most efficient, reliable and safe functioning of supply chains is required.
Methodology: The methodological basis of the paper is the analysis and structuring of existing publications on Arctic maritime logistics, a systematic review and formulation an applied system of relevant performance indicators related to Arctic supply chains (e.g. ice conditions, vessels and their parameters, the safe operation of floating production facilities and properties of ports).
Findings: The result of this paper is a systematic overview of the current state of research on Arctic maritime logistics challenges and the influencing key performance indicators as well as approaches to assess the performance at all stages of the Arctic supply chain to facility and improve Arctic supply chains in the future.
Originality: The originality of the study is defined by the scope of the review conducted. It is the first comprehensive overview over Arctic supply chains covering all relevant countries from a maritime logistics standpoint. The results of this paper create a solid foundation for further research in the area of developments of Arctic maritime logistics.

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1 Introduction

The exploration of the Arctic has become the object of close attention of governmental bodies, the scientific community, and individual researchers. Characteristics of the Arctic that determine the need for special approaches to its development are the "extreme climatic conditions, focal (cluster) nature of the territories development, […] remoteness from major industrial centers, high resource intensity" (Didenko, Skripnuk and Rudenko, 2015 cited in Yakovlev et al., 2019, p. 1), lack of labor force, outflow of the population, inaccessibility of regional facilities, dependence on the supply of resources from other regions, low sustainability of ecosystems, and the presence of waste and pollution from human activities. Globally, the Arctic is the region with the highest undiscovered hydrocarbon potential. The Arctic exploration of offshore hydrocarbon deposits (the so-called offshore zone) entails not only economic benefits from the production and sale of hydrocarbons, but also has significant social effects associated with job creation and increasing the region's attractiveness for the inhabitants, as well as environmental effects associated with violation of the ecosystem of the region and the need for removal and disposal of waste from the activities of mining enterprises (Katysheva and Tsvetkova, 2017). The evolution of the Arctic shelf deposits within the sustainable development concept requires consideration of various economic, social, natural, environmental, and institutional factors, each of which determines certain limitations and sets decision criteria for the development and operation of individual deposits and the exploration and development of the shelf zone and the entire region as a whole. Thus, the sustainable development of the

Arctic 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 (social and ecological ones) (Tsyganov, 2019; Infrastructure Development Plan for the Northern Sea Route until 2035). The transport and logistics infrastructure of the shelf zone and the region is one of the key factors for the economic, social and environmental efficiency of shelf field development since it determines the possibility of developing and operating the field, as well as the availability, terms of provision and cost of the resources necessary for the development and operation of fields (personnel, material and technical resources) and, as a result, profitability of hydrocarbon production.

2 Methodology

As a research methodology, qualitative methods were used in the form of an analysis of the results of materials published in scientific literature on the Arctic shelf zone development. Interpretative methods to analyze the results are used. The study used a systematic approach to conducting a literature review. It consisted of a wide-ranging review of the available scientific literature, its assessment, and the formation of the research result.

In relation of the development of the Arctic region and the Russian fuel and energy sector, the authors conducted a study to develop an effective model for offshore field development in the Arctic zone of the Russian Federation (Balashova and Gromova, 2017). For the development of offshore fields the model of creating consortia was considered and analyzed, considering the specifies of the Arctic region (Balashova and Gromova, 2017). In this model, from two large companies onwards, companies are temporarily merged to carry out a specific project under agreed conditions. At the same time, the state provisionally selects potential candidates (Balashova and Gromova, 2017).

The authors also conducted a study to develop proposals for the Artic region's selection of work organization technology, considering social aspects (Kozlov et al., 2017). The advantages of long-distance commuting strategy (shift work) for the mining industry and for remote regions such as the Arctic, where skilled labor is not available, are revealed. At the same time, this technology also has drawbacks, and therefore further research is planned to select an effective technology for the Arctic (Kozlov et al., 2017). Also, this group conducted a study to develop a concept of enterprise architecture and a methodology to develop and implement an Integrated

Management System (IMS) for mining companies (Ilin et al., 2017). It is recommended that the implementation of the IMS Project takes place in synchronization with the master plan of the project in corporate construction (Ilin et al., 2017). This allows to improve the development and integration of automated systems, build "a business model for an effective enterprise management system, and reduce future costs for the modernization of production and services". Further studies are supposed to build the most efficient architecture for the mining industry and the Arctic region (Zaychenko, Ilin and Lyovina, 2018; Ilin, Levina and Iliashenko, 2017). In addition, models for creating effective value chains in relation to the Arctic region were considered (Afonichkina, Afonichkin and Didenko, 2019). Also, the decision-making support methodology may be the methodological basis for planning the development of the Arctic region, which allows assessing future risks and compensating for them in advance. This methodology predicts economic and financial indicators and financial risks, evaluates various development options. The relationship between risk and return is also calculated (Bril et al., 2017).

3 Results

To collect and analyze information on the state of research in development of the Arctic shelf zone under the logistic approach, the relevant scientific literature in this area has been studied. Information on basic research studies are presented below.

As part of the study of the problems of the Arctic, including areas of innovation and technological development, world scientific researchers include research universities and scientific organizations of the Arctic countries (Rachold, Hik and Barr, 2015). All countries conduct research on various problems relating to the Arctic, including universities and scientific organizations of Russia, studying, and implementing projects for the constituent entities of the Russian Federation included in the Arctic zone.

The organizations listed below are the main global researchers on Arctic research:

The United States Arctic Research Commission (USARC, 2020) focuses on a wide range of problems under the slogan "The USA is an Arctic power with borders and fundamental interests in the Arctic zone". The United States Artic Research Commission publishes a wide array of studies and reports regarding topics of interest in the Artic like oil exploration but also on social issues of the people living in the Artic (USARC, 2020).

The University of the Arctic (UArctic, 2020) representing an international network of colleges, research institutes, universities, as well as organizations working in the field of higher education and research in the circumpolar North. The research results are published in the Arctic Yearbook, an international peer-reviewed publication that addresses current topics of “regional geopolitics, circumpolar relations, and security” (UArctic, 2014) in a

broad sense. A review of research issues shows that they affect: strategic, political, and technological aspects; problems of increasing human resources potential in the Arctic; higher education and vocational training; workforce development; emergency preparedness and response; tourism; transport infrastructure; military / state security infrastructure; increased local participation in resource development and research; regional management capacity; migration regional innovation and human capital; healthcare and social security (UArctic, 2014).

An approach has been developed that divides the Arctic space into target subspaces (Didenko, Skripnuk and Krasulina, 2016; Didenko, Skripnuk and Rudenko, 2015; Rudenko and Didenko, 2015). The Arctic zone of the Russian Federation is composed of the possible types of target subspaces, which will be named and partly be explained below (Didenko and Skripnuk, 2018; Didenko, Skripnuk and Krasulina, 2016; Didenko, Rudenko and Skipnuk 2015):

- Base cities are medium-sized to large settlements and factories, on which area "industrial organizations, construction sites, railway terminals and other industrial infrastructure facilities, as well as commercial, domestic, medical, cultural, educational and administrative facilities" (Didenko and Skripnuk, 2018, p. 4) can be found.
- Normally mobile shift camps are located close to mineral deposits or in areas where infrastructure facilities are built and maintained. Permanent infrastructure is difficult and economically disadvantageous (Didenko and Skripnuk, 2018).
- Territories for the extraction of mineral resources (Didenko and Skripnuk, 2018).

- Recreational areas are mainly reserves, national parks and tourism (Didenko and Skripnuk, 2018).
- Arctic fisheries include facilities and infrastructure for industrial fishing and require an approach that is extremely cautious due to the Arctic ecosystem's fragility and its vulnerability to climate change (Didenko and Skripnuk, 2018; McBride et al., 2014).
- The infrastructure for protecting a safe existence, includes "various defense establishments and facilities, threat detection and prevention services, means for security of communications and information, customs, ecology, reconnaissance satellites, etc." (Didenko and Skripnuk, 2018, p. 5).

Northern Sea Route (NSR) differs from the target subspaces mentioned above in its size, complexity, and numerous combinations with other subspaces (Didenko and Skripnuk, 2018). The Northern Sea Route is listed to be a single target subspace, mainly because of its geo-economic significance (Didenko and Skripnuk, 2018; Smith and Stephenson, 2013, Rothwell, 2012). In addition to a possible shipping route, the Northern Sea Route also consist of port and service facilities that form its subspace (Didenko and Skripnuk, 2018; Stenson and Hammill, 2014). The key ports of the Northern Sea Route are Murmansk, Dudinka, Bilibino, Pevek, Anyuysk, Chersky, the ports of Chukotka, several fields, and Providence Bay (Didenko and Skripnuk, 2018). The Northern Sea Route's role is growing with global warming and is to become an important trade route between Asia and Europe. At present, ship passes have been implemented on the Murmansk - Dudinka - Busan (South Korea) - Shanghai (China) route, from Norway to Japan and other countries (Miheeva, 2019). Advantages of the Northern Sea

Route are also related to the relocation of production centers and consumer markets in Europe across the north to the northeast in Asia (Verny and Grigentin, 2009). Moreover, the Northern Sea Route development is associated with the solution of problems linked to the geographical features of the territories (uninhabited, undeveloped, insufficient port infrastructure), extreme climate conditions, and increased service risks. The warmer temperatures and thus the receding of ice leads to other further shipping routes, e.g. the Northwest Passage (NWP). The NWP could be used instead of the Panama Canal (Pizzolato et al., 2014). This will shorten the route between Shanghai and Rotterdam by 27% (Buixadé Farré et al., 2014). Ng et al. (2018) also state the potential for new shipping routes in the Artic. Authors like Wang and Overland (2012) assume that the Artic will be without ice during summer season by 2030. Melia, Haines and Hawkins (2016) predict that by 2050 moderately ice-strengthened vessels are likely to be able to operate on trans Artic routes 10-12 months per year. They also indicate that transit times form Asia to Europe will be 10 days faster than alternative routes. Browse et al. (2013) state that the shorter distances will lead to a positive effect by reducing shipping emissions globally but only lead to a negligible increase of black carbon in the Artic. Schøyen and Bråthen (2011) compared the NSR with the Suez Canal for bulk shipping and came to the conclusion that the small adverse effects / external costs in the Arctic (e.g. increased air pollution or possible oil spills in environmentally sensible areas) are offset by a global reduction in CO2 emissions when the NSR is used instead of the Suez Canal.

Lasserre (2014) did a case study examining the profitability of Artic shipping looking at 27 different models proposed between 1991 and 2013. Lasserre

(2014) deemed the use of Artic shipping not profitable but his paper was challenged by Wang et al. (2016) which on the contrary stated that shipping lines using the Arctic routes have indeed a high commercial value compared to the use of the Suez Canal. Cariou et al. (2019) investigate why the NSR is not used as commercial route (except for some trials by shipping companies) even though it is ice free for three months per year and come to the conclusion that the NSR is currently only 1.5 months per year a competitive alternative to the Suez Canal. Yuan, Hsieh and Su (2019) examine the effects of new shipping lines on the resilience of operational container routes by using a fuzzy cognitive map. Afenyo et al. (2017) did an analysis for shipping accidents in the Arctic using Bayesian networks. Rahman et al. (2020) developed a Bayesian marine logistics risk model for operations in the Flemish Pass Basin (Newfoundland and Labrador, Canada).

The target subspaces for this article are considered as objects participating in supply chains. The integration into the chain of Arctic subspaces, considering environmental, social requirements, and risks, gives a synergistic effect in the developing Arctic regions. Particularly, general transport as well as logistics infrastructure ensures a reduction in transportation costs and revenue growth.

Baydukova et al. (2019) in their work consider issues of a promising resource base for the protection of the Russian Arctic region, based on capabilities of modern supply chain management (SCM) systems in logistics. Katysheva and Tsvetkova (2017) considers the organization of a logistic scheme for oil transportation in Arctic fields, which allows increasing production and the efficiency exploitation of oil fields. Dudin et al. (2016) con-

sider methodological approaches to organize the logistics of facilities located in the Arctic territories using an approach that integrates “green” logistics technologies and methods of economic and mathematical modeling. The article by Kozlov et al. (2019) explores the issues of optimizing the management system of "transport and logistics services of companies operating in the Arctic zone" (Kozlov et al., 2019). The article of Veretennikov, Mikulenok and Bogachev (2018) explores the problem of creating and developing an Artic logistical system based on the implementation of key performance indicators related to provide secure key processes. In the following studies by Tsyganov (2019), Radushinsky et al. (2017), Akimova (2018), Petrov et al. (2019), the conditions for an organized development of infrastructure in transport, energy, information, and telecommunications in the Arctic region based on transport and logistics corridors of the Northern Sea Route are considered.

The study of researchers from the Kola Science Center of the Russian Academy of Sciences (Tsukerman, Fadeev and Kozlov, 2019) analyzes the actions to formulate a strategy for the development of oil and gas areas on the Arctic shelf, covering the problems of justifying science, regulatory framework, consistency, adaptation, development of innovation, effectiveness, quality of products, informatization and efficient use of labor, and environmental protection. A research group from Finland conducted an analysis of promising technologies for using the natural resources of the Arctic region (Myllylä, Kaivo-oja and Juga, 2016). Zhura et al. (2019) state in their paper that the NSR "has turned into the most important transport and logistics network, having its major impact on the economic development of the northern territories and logistics network, having its major impact on

the economic development of the northern territories and overall transportation support of the industrial, social and defense structure of the Artic Region as a whole and the northern coastal areas of Russia specifically".

Work in the Artic contains the following potential risks - natural, technical, infrastructural, environmental. Carayannis, Cherepovitsyn and Ilinova (2017) also considered additional features, risks, and difficulties in developing shelf fields in the Arctic region. Researchers from Canada, for example, are considering pollution risks from oil spills, governance, and sovereignty between Arctic states (Gulas et al., 2017). Statoil (Utvik and Jahre-Nilsen, 2016) considers the safety and sustainability of the Arctic region as part of an assessment of objectives and production possibilities. This is pursued by "planning of exploration and development operations where safety and sustainability related risks are addressed early to ensure appropriate mitigating actions" (Utvik and Jahre-Nilsen 2016, p. 1). This improves the quality and reliability of risk management and allows to identify needs in the field of development of science and technology. The company creates risk assessment instruments for environmental management and decision assistance, as well as methods for effective monitoring of the environment (Utvik and Jahre-Nilsen 2016). Examples of mitigating technology-related risks are ice management and the developing of a numerical model for icing and snowfall (Utvik and Jahre-Nilsen 2016). Under the aspect of operational safety, risk reduction is mainly associated with actions to protect the working environment in the Arctic and logistics planning. Among other things, in scientific articles, attention is paid to raising the internal rate of return (IRR) of such projects.

The risk groups indicated underline the high level of difficulty in the Artic shelf development and thus demonstrating the need of developing an effective decision support system (DSS) in this area, which will take into account all the required factors (Balashova and Gromova, 2017). Simultaneously, the concept of sustainable development of the territory is required. Issues of the DSS development were considered in the research of Ilin et al. (2017) and Bril et al. (2017). Issues of using DSS in manufacturing companies are considered in articles by Kasie, Bright and Walker (2017) and Felsberger, Oberegger and Reiner (2016). There are studies on the possible application of DSS by drilling crews by using the available resources for the prevention of accidents at on- and offshore industrial facilities (especially oil and gas) (Asad et al., 2018). At the same time, the issues of using DSS in mining companies, their functionality, capabilities, and the effects achieved are not widely considered in scientific literature, while being very relevant. In this context, it is planned to implement a study aimed at developing effective DSS in mining enterprises, including considering the peculiarities of the region of the Arctic. In this case, attention is paid to the solution of the problem by developing the infrastructure of transport and logistics of the region.

The study by Keil (2017) comprehensively examines the outlook for the Arctic shelf oil and gas industry, including global markets, international relations, issues of resource choice and the use of international energy companies. All these issues are important for understanding the importance of the Arctic in global energy supply. The same issues were considered in the study of McCauley et al. (2016), which analyzes the evolution of necessary energy infrastructure and principles of energy policy in the Arctic region in

the context of global relations. The study by Henderson and Loe (2016) considers the environmental risks in the Arctic region from hydrocarbon exploration and production, as well as issues of the necessary infrastructure and economic development indicators, including from the perspective of other energy sources. This article gives an overview of oil and gas development on the Arctic shelf and outlines the development potential of the region. The oil, gas and business opportunities of the Arctic region are considered in the article (Motomura, 2018). In particular, the analysis of this issue considers the complex and expensive operating conditions of fields, as well as the parameters of the worldwide hydrocarbon market.

The development of Arctic maritime logistics should be considered comprehensively, considering the development of the Northern Sea Route, accelerating the socio-economic developing of the Arctic zone, and implementing investment projects for mining. To accomplish these tasks, it is important to create port and coastal infrastructure, to expand the Northern Sea Route's icebreaker to reduce the risks of navigation along the Northern Sea Route, and combine the sea routes with freight traffic within the framework of the general transport infrastructure (Northern latitudinal passage) (Didenko and Cherenkov, 2018; Infrastructure Development Plan for the Northern Sea Route until 2035). It also requires a common set of measures for navigational and hydrographic support and navigation safety, and the creation of a unified global system of maritime communications along the northern sea route. An important task is to ensure year-round navigation (Gurlev, Yemelyanova and Klimashkina, 2019).

4 Interpretation of the results

The literature research showed that this topic is very relevant and there are a lot of different opinions in the scientific community. The literature research also showed that most research was done in Russia and Canada about Arctic supply chains and to a lesser degree in other countries. This paper also showed that the interest in this topic increased over the last years with changes in temperature in the Artic and thus new opportunities. Another key finding is that not only the approaches to the topic vary widely but also the findings.

Based on the information obtained as a result of the analysis of existing thematic scientific literature, it is relevant to establish the foundations of sustainable development for the Arctic shelf development system and the DSS model, which allows to process and analyze heterogeneous data on the decision-making situation, as well as create potential scenarios for the development of the situation. Such DSS should consider all the above-mentioned groups of risks associated with the provision of Arctic maritime logistics.

The implementation of such a fundamental task requires the involvement of researchers and practitioners with competencies in the fields of socio-economic systems management, logistics, IT, expertise in the field of hydrocarbon production, transport and business modeling, design of information systems and applications, and the formation of requirements for IT services. To solve the problem of an effective sustainable development of shelf fields and the development of the corresponding regions of the Arctic zone in a multifactorial and multicriterial way, it is necessary to provide an

appropriate theoretical and methodological approach of such a development. A complete analysis of the decision-making situation for each individual project (field), a description of all possible scenarios for the development and operation of individual fields from a sustainable development perspective, as well as scenarios for the development of the shelf zone and the region as a whole are required.

It is important to establish a theoretical and methodological foundation for the development of the Artic shelf. On this, a decision model support system is modelled. This allows processing and analyzing heterogeneous data about the decision-making situation and thus working out possible scenarios.

It is also recommended to introduce a key performance indicator system that covers all parameters of the supply chain (ice conditions, vehicles used and their parameters, safe operation of floating production facilities, port characteristics, etc.). A constant analysis of the system of such indicators will be required to identify ways to improve the efficiency of supply chains and weaknesses.

A promising way to develop Arctic marine logistics is to expand the Northern Sea Route. This should address the above unsolved problems associated with it and the existing risks. Accordingly, several proposals are required to effectively address the identified problems.

5 Conclusion

A significant complication of the development of marine logistics in the Arctic are problems in the Northern Sea Route with operations. In connection with this, further studies are needed that can offer ways to solve these problems. Especially with warmer temperatures in the Artic and thus less / thinner ice new routes will become economically feasible and be a competition for established routes, e.g. the Northern Sea Route could be an option for transports from East Asia to Northern Europe. This will lead to lower costs and also to less CO2 emissions in the shipping sector. Further studies are also planned to develop an optimal system of indicators of the efficiency of the functioning of supply chains.

Thus, the focus of research on marine logistics in the Arctic is on the topics of integrated development of the region, calculation and accounting of risks, optimization of the population, optimal integration of the Arctic subspaces, use of digital technologies in the developing of the Northern Sea Route.

Previous studies have shown significant problems that should be addressed. These problems are mainly associated with the climatic features of the region, the small number and uneven distribution of the population, settlements, ports, as well as with the identified risks. They also require solving the problems of the operation of the Northern Sea Route. The Northern Sea Route is investigated as an option to the Suez Canal (Skripnuk et al., 2020). Currently this is further a theoretical issue since the route is only three months ice free. In the coming years however with melting ice in the Artic these routes can be economically feasible and by the smaller dis-

tances can also lead to lower environmental pollutions worldwide. The issues of calculating the logistics chain, considering the minimum possible costs and effective international cooperation on the Northern sea route, remain open.

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