St. Petersburg University

Master in Management Program

ECONOMIC FEASIBILITY OF
LIQUID NATURAL GAS TRANSPORTATION
VIA THE NORTHERN SEA ROUTE:
CASE OF YAMAL LNG PROJECT

Master's Thesis by the 2nd year student

Concentration — General Track

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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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АННОТАЦИЯ

Автор	Дворникова Валерия Игоревна
Название ВКР	Экономическая осуществимость транспортировки сжиженного природного газа через Северный Морской Путь: проект Ямал СПГ
Направление подготовки	Менеджмент
Год	2017
Научный руководитель	Профессор, Виталий Иванович Черенков
Описание цели, задач и основных результатов	Исследование представляет модель для оценки затрат на транспортировку сжиженного природного газа (СПГ) в рейсах по Северному Морскому Пути (СМП). Были проанализированы пять маршрутов из порта Сабетта (Россия) или Рас-Лаффан (Катар) в Цзянсу (Китай) или Сагунто (Испания) проходящие через СМП или Суэцкий канал. В качестве судов для перевозки СПГ были рассмотрены газовоз ледового класса Arc7 и стандартный катарский газовоз Q fleet. В результате проведенного анализа было выявлено, что при транспортировке арктического СПГ на рынок Азии СМП обеспечивает конкурентное преимущество по издержкам по сравнению с маршрутом через Суэцктй канал и что арктический СПГ относительно конкурентноспособен с катарским СПГ с точки зрения затрат на транспортировку.
Ключевые слова	Северный Морской Путь, Траспортировка сжиженного природного газа, Арктическое судоходство

ABSTRACT

Master Student's Name	Valeriya Dvornikova
Master Thesis Title	Economic feasibility of Liquid Natural Gas transportation via the Northern Sea Route: case of Yamal LNG Project
Main field of study	Management
Year	2017
Academic Advisor's Name	Professor, Vitally I. Cherenkov
Description of the goal, tasks and main results	The study provides a model for the evaluation of the liquid natural gas (LNG) transportation costs on voyages via the Northern Sea Route (NSR). The five different routes from either Sabetta (Russia) or Ras Laffan (Qatar) to either Jiangsu (China) or Sagunto (Spain) via either the NSR or the Suez Channel Route (SCR) are analyzed. This study is applied to an ice class Arc7 and a standard Q fleet LNG carriers. It concludes that the NSR provides a competitive advantage in terms of costs in comparison with the SCR for the transportation of Arctic LNG to Asian market and that Arctic LNG is comparatively competitive with the Qatari LNG in terms of transportation costs.
Keywords	Northern Sea Route, Liquid natural gas transportation, Arctic shipping

Contents

INTRODUCTION

Globalization has its impact on the international trade by increasing the density and dynamism of merchandise flow not just between continents but also between regions of the same continent. Companies are becoming more and more interested in providing cheaper products on diverse territories and satisfying customers' demand throughout the world. Kaplanoglu (2008) mentioned that the evolution of the world's commerce has relied heavily on the development of efficient transport networks, which reduce shipping costs to a negligible fraction of the product's factory price. Guillaume (2008) gives the data on the world merchandise flow as more than seven billion tons of merchandise were transported worldwide from which 80% or 5.6 billion tons were transported by the commercial shipping lines. From shipping companies perspective economies of scale should be implemented in terms of employing large vessels yet there are the additional port fees which are described as ''the diseconomies of scale'' by Jara-Diaz (2003).

The international trade is developing more and more nowadays and, as a result, companies are seeking for the cheapest ways for transporting their goods from the production sites to the end consumers. Shipping has become one the most convenient modes of transport, especially for the connections between Asia and Europe. There has been one main route for that destination by now, the Royal Route or the route via the Suez Canal. However, it has become overloaded in recent years. Moreover, not all types of newly constructed container ships can pass through the Suez Canal by their technical constraints such as the depth and width of the ships. In addition, political instability in Egypt has raised the question of shipping safety via the Suez Canal which leads to additional costs. So, here emerges the question for alternative routes. The main alternative route is the Northern Sea Route (NSR).

However, the NSR cannot be considered just as a shipping route without any interested parties. Therefore, one of the projects which is connected to the NSR should be analyzed. It is the Yamal LNG Project. Liquid natural gas (LNG) has been playing more and more important role on the world market of the hydrocarbons in recent years. The main reasons for that are delivery convenience, gas quality and environmental issues. Transportation of LNG is rather flexible in terms of distances as LNG is transported in the specific carriers all around the world. LNG is becoming a commodity of the spot market and that reflects the constantly increasing demand in it. Moreover, the quality of LNG is higher than the quality of pipeline gas as there are additional gas cleaning from harmful impurities and sulfur compounds in the liquefaction process. So, LNG is more valuable in comparison with pipeline gas. In addition, LNG is the most environmentally friendly type of hydrocarbon sources of energy that increases the value of LNG even more and increases the demand for that type of fuel in the nearest perspective.

The current development of the Arctic fossil fuel fields brings the issue of transportation of the extracted oil and gas products. One of the latest LNG projects in the region of the Russian Arctic is the Yamal LNG which is taken as the main case for the study. The main purpose of the study is to evaluate the economic feasibility of liquid natural gas transportation via the Northern Sea Route. Object of the study is some logistics items of the Yamal LNG Project in relation to the economic possibilities of shipping through the Northern Sea Route. Subject of the study is the perspectives of development in the field of liquid natural gas transportation discovered in the light of the Yamal LNG Project which include both economic and technological issues. The research questions are the following:

1) What are the operational costs of the LNG transportation via the NSR?
2) To what extend the LNG transportation via the NSR is economically efficient in comparison with other routes?
3) How does the extraction of oil and gas in the Arctic regions influence the development of cargo traffic via the NSR?
4) What measures should be taken by companies in order to use the entire capabilities of the NSR for lowering the transportation costs?

1. LNG TRANSPORTATION VIA NSR: THEORETICAL FRAMEWORKS

The following literature review represents the main findings on the Northern Sea Route (NSR) in terms of its economic viability according to the specific cost structure and its technical characteristics for the shipping of the liquid natural gas (LNG). That point also includes the overview of the cost structure of the Suez Canal Route (SCR) as an analog for comparison of the measurements of the NSR. Another point to be considered is the current situation on the LNG market and forecasts for the world demand of LNG. What is more, the technological issue should be considered as navigation in the Arctic waters and the climate conditions of NSR are one of the obstacles for the development of the shipping routes. Furthermore, legislation for NSR takes separate point as it includes three main issues at the same time which are marine policy of the Russian Federation, international laws for shipping and geopolitics of the Arctic shelf. Last but not least comes an overview of ecological problems connected with oil and gas extraction in Siberia and on the Arctic shelf.

1.1 The Northern Sea Route overview

The Northern Sea Route is a shipping lane from the Kara Sea to the Pacific Ocean which lies in Arctic waters and within Russia's Exclusive Economic Zone (Fig. 1). NSR lies through Kara, Laptev, East Siberian and Chukchi seas. NSR forms the Northeast Passage with Barents and Bering seas. The Northeast Passage is an Arctic shipping route connecting the Atlantic and Pacific oceans. NSR forms the transportation system which covers the Northern part of Russia and coastal Arctic waters.

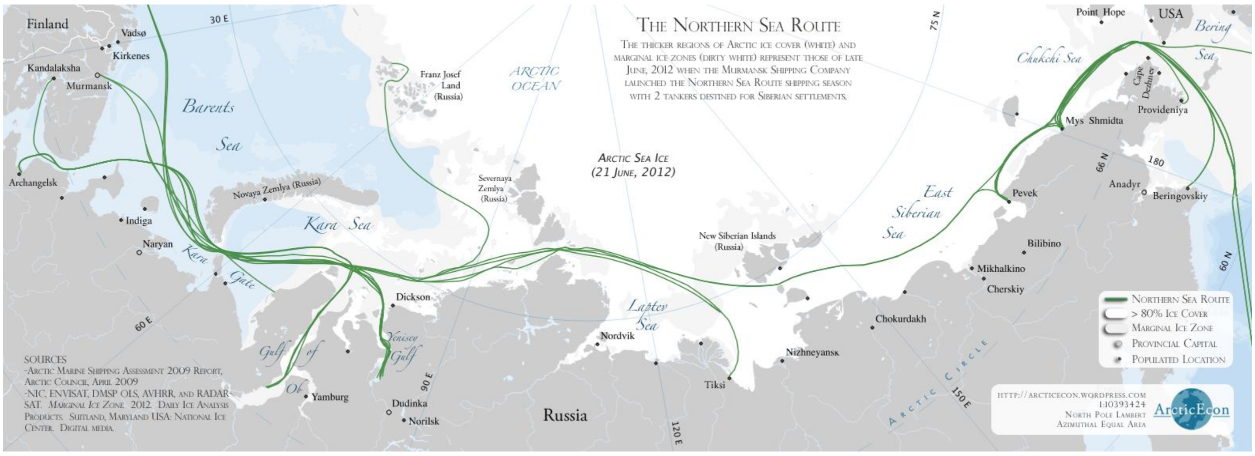

Fig. 1 The Northern Sea Route (Federal state institution The Northern Sea Route Administration, 2016).

The NSR capability is estimated for 50 million tons of cargo per year. The route lies through the entepots of forest, coal, fur and oil products which are the main resources of Siberia and Far East. There are about 50 ports on the route that can accept different types of ships up to nuclear ice-breakers and both national and international carriers. Despite lots of difficulties, NSR is used as a shipping route and the cargo traffic is supposed to increase up to 35 million tons per year (Advisory council of the Russian government 2014). The reason for that is the increasing speed of ice melting which is twice ahead of the global warming speed. Nowadays the ships can navigate via the NSR for seven months from June to December with the help of ice-breakers. The functioning ice-breakers is currently used for providing passages for both convoys of commercial ships and separate ones. The following sections will describe the peculiarities of shipping via NSR.

1.1.1 Cost structure of shipping via the NSR

There is not enough data for calculating the actual economic viability of the NSR for different types of shipping. Generally, researchers tried to compare the NSR with the Suez Canal Route (SCR) and provided the NSR cost structure using SCR parameters with additions on Arctic water shipping.

Lasserre (2014) provided a report that states 26 models on the relevancy of the NSR, which were designed between 1991 and 2013. He highlights the problem of identification of credible parameters for modeling the cost structure of Arctic shipping. Among those 26 models seven models are for bulk shipping via NSR. Three models proves NSR to be profitable and four models state against the NSR profitability. These cost models are a mixture of shipping professional presentations (Paterson 2011; Falck 2012), reports (Mulherin et al. 1996; Kamesaki et al. 1999; Kitagawa 2001) and academic studies (Schøyen and Brathen 2011; Cho 2012). One of the reasons for unprofitableness of NSR for bulk shipping is the fact that ships in use on the NSR had approximately 25% of the carrying capacity of cargo vessels using the traditional warm-water trade routes that eliminates the distance advantage as economy of scale via larger ships cannot be implemented (Mulherin et al. 1996). Another disadvantage of NSR is higher requirements for shipping crew due to the specific weather conditions such as navigation in the fog and through the ice breaks (Paterson 2011). Moreover, Russian administration of NSR is supposed to provide additional obstacles such as taxation and high icebreakers tariffs (Kitagawa 2001). However, among benefits of NSR lies cost and CO_2 emitted savings up to 36% (Cho 2012) and time savings up to 22 days (Falck 2012).

Cariou (2015) underlines four most important components in the cost structure of NSR. These are fuel costs, capital cost premiums for ice-class ships, additional crew costs and risk premiums. The fuel consumption rate varies depending on temperatures and the speed of the vessel. The capital cost premiums for ice-class ships depends on the class and range and varies from +1% to +120% in different observed models. Also, there can be the need for well-trained crew because of difficulties of navigation in Arctic waters. Insurance premiums are stated as 50%–75%–100% in different models. Further, the pricing strategy of the Federal Tariff Service of Russia influences the competitiveness of the NSR. Kronback (2010) states these costs as 16.4–24.4% of the total daily costs.

Faury (2015) highlights the necessity of the equivalent sailing speed for comparative cost analysis of the different shipping routes. He models the sailing speed of NSR as the function of the sailing speed of SCR, taking into consideration speed delays on icebreaker assistance in NSR (Fig. 2). Once the sailing speed equivalent on the NSR is known, the daily revenues and costs for shipping via NSR or SCR can be estimated.

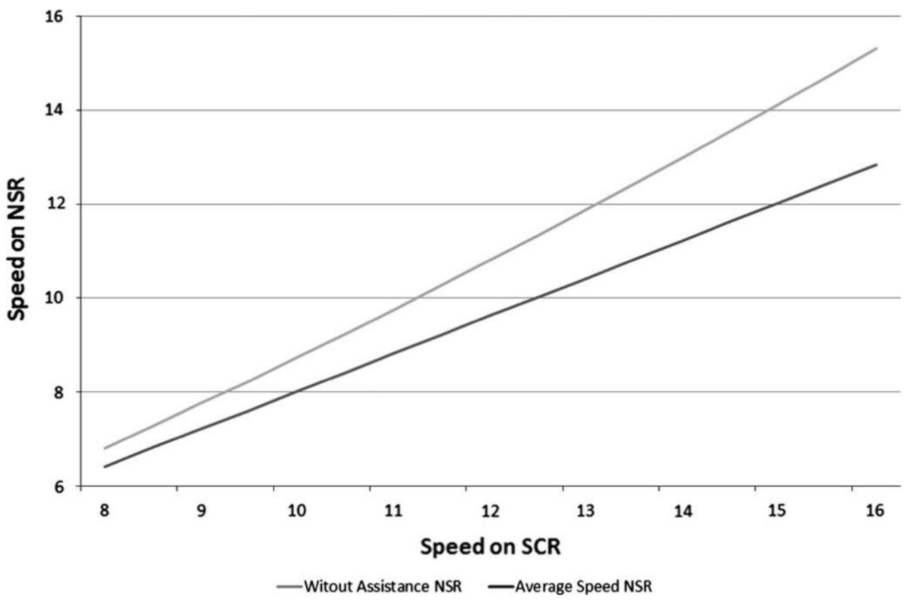

Fig. 2 Sailing speeds on the NSR, as a function of the sailing speeds on the SCR (Faury 2015).

Stephenson (2014) predicts the increase in the number of sailing days from 70 days to 125 in 2050, and to 160 days in 2100 that means the extension of the navigation season on the operational side and a longer period for depreciation of the ice-class vessels on the financial side. Both points give a favor for NSR.

Verny (2009) provided a model which verifies the technical and economic feasibility of regular container transport along NSR on the example of shipping line between Shanghai and Hamburg. Asia has become the key industrial center in the world for the recent decades and it both satisfy the demand of the advanced countries and provides a huge market for consumption.

Therefore, maritime routes linking Asia to Europe and North America have become the main axes of container transport. The most principal route between Asia and Europe which historically exists is the SCR. However, this main line has obtained some problems in recent years. SCR accommodated most of the containerized traffic between Asia and Europe: more than 20,200 ships and 745 million tons of freight in 2007. At present, 46% of vessels transiting SCR are container ships. Despite construction intended to increase the maximum ship size (14,000–16,000 TEU) in 2010, the Suez Canal will soon reach its limits. In fact, granting access to larger and heavier ships will inevitably diminish the number of ships in each convoy. In consequence, the waiting time will increase and the canal will be able to offer its services less frequently. As shipping companies choose to pass through the Suez Canal mainly to save time, these extremely localized technical and financial (more days, more costs) problems could undermine the dynamism of the Asia–Europe economic environment. Moreover, the larger container ships has allowed companies to satisfy the demand, but that fact has also affected the market price of westbound containers. The price of westbound containers means the price of sending a container to Europe includes the cost of returning an empty container to Asia. Because of the imbalance in traffic between Asia and Europe, the cost of transporting a container between two fixed ports is two or sometimes even three times higher for routes from Asia to Europe than for the inverse routes. Therefore, the increasing the size of container ships will not compensate for the limited capacity of the Suez Canal and that brings the necessity for the alternative routes between Asia–Europe market. So, Verny compared three alternatives for the cost of shipping a single twenty-foot equivalent unit (TEU) via SCR, NSR and Trans-Siberian Railway (Fig. 3).

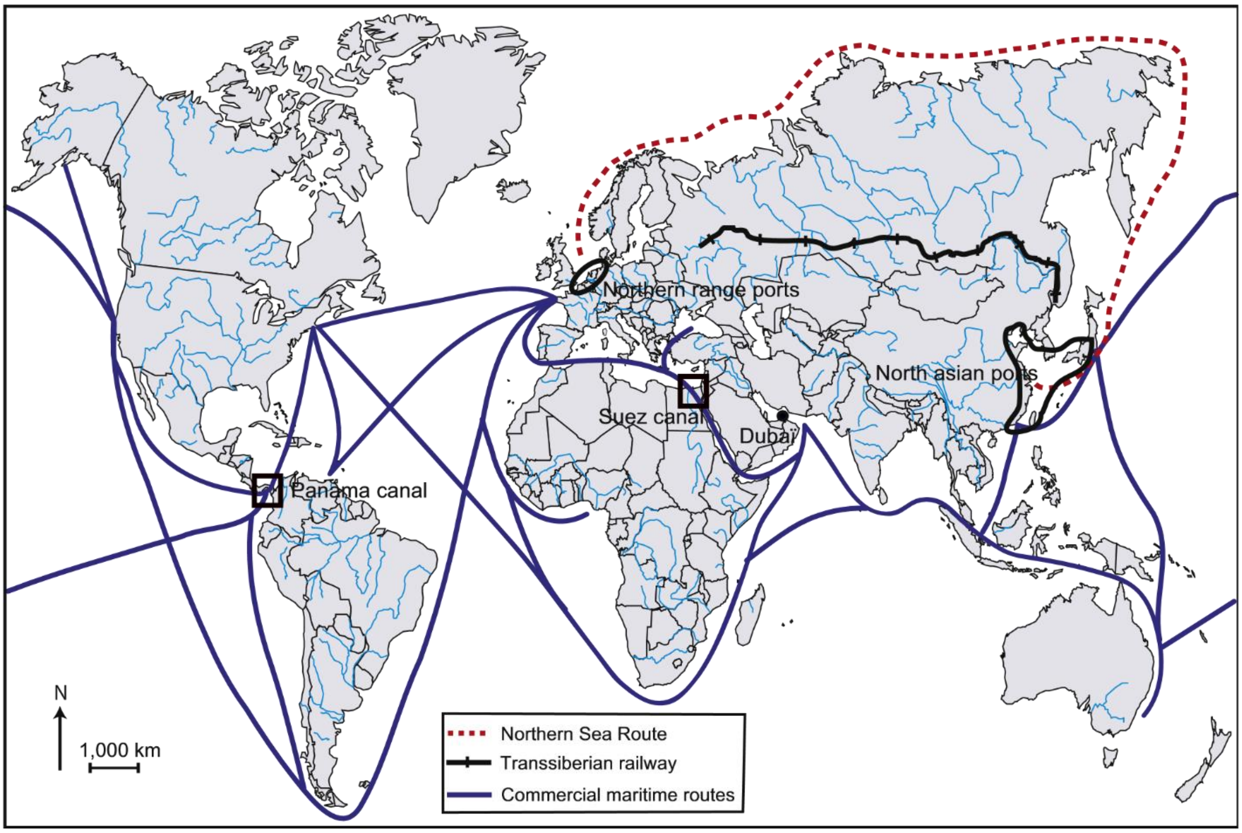

Fig. 3 International commercial routes (Verny, 2009).

One alternative to SCR is Trans-Siberian Railway which straits through Russia. This route can attract carriers by time savings of 10 days. However, only 182,000 TEU were conveyed by this infrastructure in 2007, which corresponds to less than 1% of the total container flow between Europe and Asia. In order to make Trans-Siberian Railway more competitive, Russia needs to further improve its infrastructure by doubling the number of tracks and improving the network's signals and electrical supply, to optimize the network's organization by establishing regular lines with higher frequency and facilitating border crossings, increasing security, improving automated container tracking, creating a dedicated ticket office for freight, and adapting its rails to European standards (the separation is 1.52 m in Russia, compared to 1.435m in most European countries). Reduced transit times, shorter routes and attractive prices are the only advantages of the Trans-Siberian Railway by now with lots of problems on the technical part of the route.

The other alternative to the SCR is the NSR. NSR is considered as an alternative due to the current effects of global warming which allow to ship in the Arctic waters. It was thought that by 2015 the Arctic Ocean would be navigable year-round, in particular along the Russian coast, but the reality differs. Additional reason for consideration of NSR is the improved geopolitical climate since the dissolution of the USSR as the Arctic Ocean has become opened to international traffic. Furthermore, if the NSR begins seeing regular traffic, it could awaken the avarice of coastal nations in this part of the world. If so, the route could rapidly become a key issue in international relations. In general, the advantages of the NSR are closely tied to an international ''geography of places'', which underlines the displacement of production centers and consumer markets. In Europe, the economic ''center of gravity'' is shifting from the West to the Northeast due to the ongoing development of Central and Eastern Europe. At the same time, the growth of China is moving Asia's economic center of gravity from the Southeast to the North. Among the 20 largest container ports in the world in 2007, 13 are Asian and 8 of these are Chinese. Asian ships are gradually abandoning Southeast Asia for Northern China (Das and Sengupta 2009). That new distribution of ports and shipping lines brings the idea of transferring part of the containerized freight from the SCR to the NSR. Indeed, the NSR would reduce the length of voyages from North Asia (mainly the ports of Japan, South Korea, and China) to Northwestern Europe (ports on the Northern Range, starting with Hamburg, Bremen, and Rotterdam) by about 2500 nautical miles. This translates into a gain of about 10 days, which is one-third of the time required for maritime transport by SCR (Fig. 4).

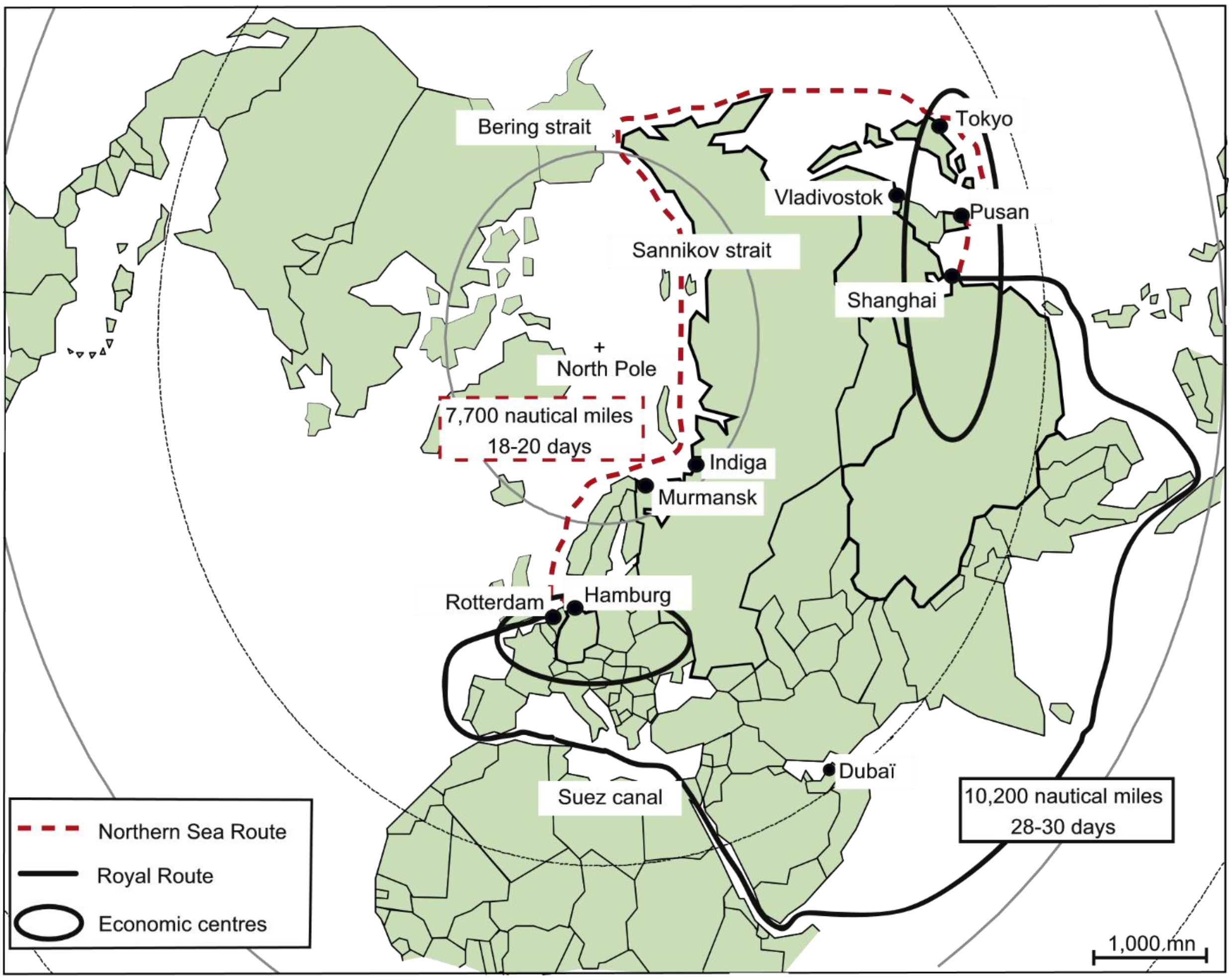

Fig. 4 NSR and SCR (Verny 2009).

On the other side, there are significant obstacles linked to the geographical and climate characteristics of NSR. Firstly, about 2500 nautical miles of Siberian coast between the Bering Strait and the port of Murmansk are nearly uninhabited, so no stopovers are possible. The commercial consequence of that is impossibility of optimization of regular container lines on the NSR through the transshipment within the route itself. For instance, SCR is connected with a network of developed communication lines within the hinterlands of port cities such as river transport and high-quality rails and that allows to use the capacity of SCR more efficiently. The operational consequence is the absence of immediate and close support from inland in case of any technical problems which are in high possibility of occurring due to the extreme climatic conditions, including floating ice sheets, icebergs, fog and violent winds. Therefore, the creation of the regular shipping lines via NSR requires additional stopover points on the coast line, availability of replacement ships and ice-breakers and ports entirely equipped for transshipment of any type of cargo. By now this disadvantage connected with the infrastructure of NSR requires additional insurance premiums and increased costs for both the shipping companies and the end clients. Secondly, the Northern Sea Route Authority imposes a heavy administrative burden on the shipping companies by obtaining multiple tariffs and taxes for navigation via NSR. The total amount of fees ranges from 4.36 to 23.82 USD per ton, depending on the type of hull and the season of passage as the lowest rates are applied to ice-breaker hulls transiting in summer. These fees include payment for the assistance of an ice-breaker ship, meteorological forecasts, and the creation of an adequate itinerary. For comparison, NSR administrative fees are about two times more expensive than those of SCR. So, NSR can be beneficial alternative to SCR in terms of transit time, but still not in terms of costs. That fact will be considered more precisely in the calculations of the cost of shipping one TEU on NSR.

Several components contribute to the cost structure of shipping a single TEU on NSR. Firstly, the speed of vessels should be determined to evaluate the essential fuel consumption on the route. The NSR is currently navigable at an average speed of about 15 knots from June to December and at an average speed of about 11 knots from January to May (Niini 2008). According to the National Ice Center, the speed achievable by ships during the winter period will gradually increase in coming years due to global warming and an average commercial speed will be 17 knots during the period 2015–2025. The speed of 17 knots is attained in waters with floating ice and the speed of 24 knots is attained in waters free of ice cover. Secondly, the measurement of speed gives the forecast for transit time. For instance, the transit time for a complete loop between Hamburg and Shanghai will be 37 days. During this time the ship will make five stops, remaining at each port for 24h, and spend 14 days sailing through occasionally icy Russian waters. In addition, buffer time should be considered. Buffer time for NSR includes climatic hazards, time for maintenance of ships, congestion in the terminals, quays and access lanes of a port and other technical hazards. Thirdly, there is a specific requirements for draught of the ships which cannot exceed the depth of the strait of Sannikov (13 m). Fourthly, the ship size determines the depreciation costs. Moreover, ships should have protection from ice to withstanding the shocks and friction by ice. In order to finance the procurement of Arctic ships, marine companies use bank loans from companies such as Credit Suisse Ship Finance, the German bank HSH Nordbank AG or the Norwegian DnB Nor Group. These investors provide ship-owners with loans covering between 60% and 80% of the market value of a new vessel. Such loans must be repaid before the 20th anniversary of the ship. The loans are indexed to the LIBOR rate (London Inter Bank Offered Rate). Fifthly, the installation of specific navigation systems on board for iceberg detection accounts for additional costs. Sixthly, navigation in glacial waters requires a high level of technical training for the officers and, consequently, costs on crew learning and on higher wages for experienced ones. Seventhly, insurance cover ought to be added as a cost component. Insurance premiums on the shipped cargo depend on many factors and, therefore, they can vary from case to case. The last but not the least come tariffs and administrative fees which varies due to the different zones of NSR and climate conditions during the voyage time (need for icebreakers). The results of evaluation of the costs are presented in Table 1.

Table 1 Multimodal alternatives between Shanghai and Hamburg.

Characteristic	SCR	Trans-Siberian Railway	NSR
Mode	Sea	Rail	Sea
Distance (nautical miles)	10,2	5,375	7,7
Transport time (door-to-door)	28–30	18–20	18–20
Average speed (knots)	24	54	17–24
Carrying capacity in TEUs	9,6	110	2,8
Total costs (USD/TEU)	1,400–1,800	1,800-2,200	2500–2800

Liu (2010) investigated the case study of operating liner service along the NSR between Yokohama and Rotterdam. He proposed the combined usage of NSR and SCR. The model describes ice-classed ships sail along the NSR during the navigable days and sail via SCR for the rest of the year. In order to better compare the performance, identical ship sizes have been chosen for both routes. 4300 TEU ordinary container ships are selected for the routine service and 4300 TEU ice-classed ships for the NSR. It is assumed that there are enough ships to maintain the service for both routes on a regular basis.

The cost components for that conditions include capital cost, voyage cost and operating cost. Capital costs are costs of building an ordinary 4300 TEU containership, in general, they are about 60 million USD. The model assumes 70% of debt, and interest rate payments at the level of about 2.6 million USD and payment to equity around 1.8 million USD, which makes the capital cost 4.4 million USD per year. Capital costs for ice classed ships are 5.28 million USD per year as the building cost are 20% higher due to the principal structure and strength, hull form, propulsion system and other systems need for navigation in Arctic waters. Voyage cost for SCR is the Suez Canal Toll which accounts for 240800 USD per transit per 4300 TEU container ship. Voyage cost for NSR is the ice-breaking fee which is approximately 4 million USD per transit per 4300 TEU container ship no matter how many months the route is navigable. In order to provide more comparable data Liu introduced three scenarios considering the effect of the climate change on the NSR. These scenarios state different navigable periods of three, six and nine months per year. Further, these different navigable periods influence the rate of ice-breaking fees, so the reduction of the current ice-breaking fees was introduced as 50%, 85% and 100% reduction. As a result, the ice-breaking fees are set at the level of 350, 700, and 900 USD per ton (Liu, Kronbak, 2010). Operating costs consist of manning, H&M insurance, P&I insurance, repairs & maintenance, administration and other. As a result, shipping via NSR demands more investments as all cost components are higher when compared to shipping via SCR. However, that model does not consider the distance saving effect of NSR.

Rahman (2014) took a detailed view on the distance saving effect of NSR for marine companies. He uses the studies of Schoyen and Brathen (2010) about benefits achievable through energy efficiency improvements on a shorter NSR which might offset the disadvantages caused by climatic hazards of the NSR. Rahman applied in the shipping industry approach which states that the reduction in the route distance will reduce the total travel time, ultimately reducing the total fuel consumption, bunker fuel cost and vessel operating cost respectively. Moreover, the amount of emissions produced by ships will definitely be reduced and that provides environmental benefits. All in all, the shipping companies' profit margin will increase as their costs decrease due to the time saving effect of NSR. For instance, the difference in navigational distance from North West Europe (London) to Far East (Yokohama) is 4,200 nm, which for 15 knots sustained speed equals a difference in time at sea of about 12 days, all other factors being identical for the two routes. The results of implementation of that approach are presented in Table 2.

Table 2 A comparison of SCR and NSR for the Asia-Europe trade.

Characteristic	SCR	NSR	Comments
Distance (nm)	11585	7356	The navigation distance from Northwest European port (Hamburg) to Far East Asian port (Yokohama) via NSR is an approximately 36% shorter than via SCR.
Fuel Consumption	High	Low	Shipping via the NSR save $550,000 in fuel costs compared to the journey via SCR.
Journey Time	32 days on the speed of 15 knots	18 days on the speed of 15 knots	North West Europe (London) to Far East (Yokohama) Shipping via the NSR save 14 days on the journey compared to via the SCR by using the same speed.
Speed for transit time of 32 days	15 knots	9 knots	Shipping via the NSR using speed only 9 knots on the journey takes the same transit time as shipping via the SCR using 15 knots on speed.
Piracy	Yes	No	The risk of piracy for ships in the Indian Ocean that are using the SCR.
Fees	Low	High	-
Transport Cost (USD/TEU)	1,299	<1,123	-
Cost Saving	Low	High	-

Lee and Song (2014) continued with the analysis of time saving effect of NSR. They implemented a geographical approach for better estimation of time benefits. Europe was divided into three geographic scopes. The region of the Scandinavian/Baltic Sea includes Norway, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Poland and Denmark. The region of the Northern Europe includes Iceland, Germany, Netherland, Belgium, UK and France. The region of the Mediterranean sea includes Portugal, Spain, and Italy. From the Asian part, major ports in China, Korea, Japan, Taiwan, HongKong, Philippines, Cambodia, Thailand, Singapore and Indonesia were considered. Firstly, distance-saving effects via the NSR were considered for that regions. The route from China turned out to save the shipping distance to the region along the Scandinavian/Baltic Sea and to the Northern Europe. From Portugal and the west Mediterranean Sea, shipping distance can be reduced to five ports. Busan, Korea can benefit from the distance-saving effects to Lisbon, Portugal and Japan can also see a positive result for shipping to Valencia, Spain. Other benefiting countries from these distance-saving effects are Taiwan, HongKong, and the Philippines which can get shorter shipping routes up to the region along the Scandinavian/Baltic Sea and Northern Europe. However, Vietnam, Cambodia, Thailand, Singapore, and Indonesia turned out to have no effect on saving distance. The distance saving effect is represented in table 3 in Appendix.

Secondly, time-saving effects via the NSR were analyzed. There are two assumptions. First one is that the non-ice waters in the Arctic Ocean are opened three months, then the vessel can operate at the sailing speed to 3 nautical miles per hour in the ice-water section in order to gain stability for shipping operation and its noise level. The time-saving effect for that case is represented in table 4 in Appendix. Second one is that the Arctic sea is open all year round, then the vessel can operate at the speed of 18 nautical miles per hour for all the routes in the NSR. The time-saving effect for that case is represented in table 5 in Appendix.

So, there are different models for estimation of benefits of NSR in terms of costs and savings. However, the approach which combines all the points has not been designed yet. Moreover, there is no model which can compare container, bulk and tanker shipping in order to evaluate the most beneficial type of shipping. In addition, the usage of NSR in terms of its influence on Trans-Siberian Railway and the Northern regions of Russia is not stated yet. Here lies one of the possible research gaps that should be diminished.

1.1.2 Limitations of the NSR

NSR is supposed to be economically viable but there are some issues which do not allow the NSR to become the actively used shipping route.

Lee and Kim (2015) stated all possible limitations for using NSR for commercial shipping. These limitations are divided into economic barriers, external policy barriers and internal barriers of shipping companies (Fig. 5).

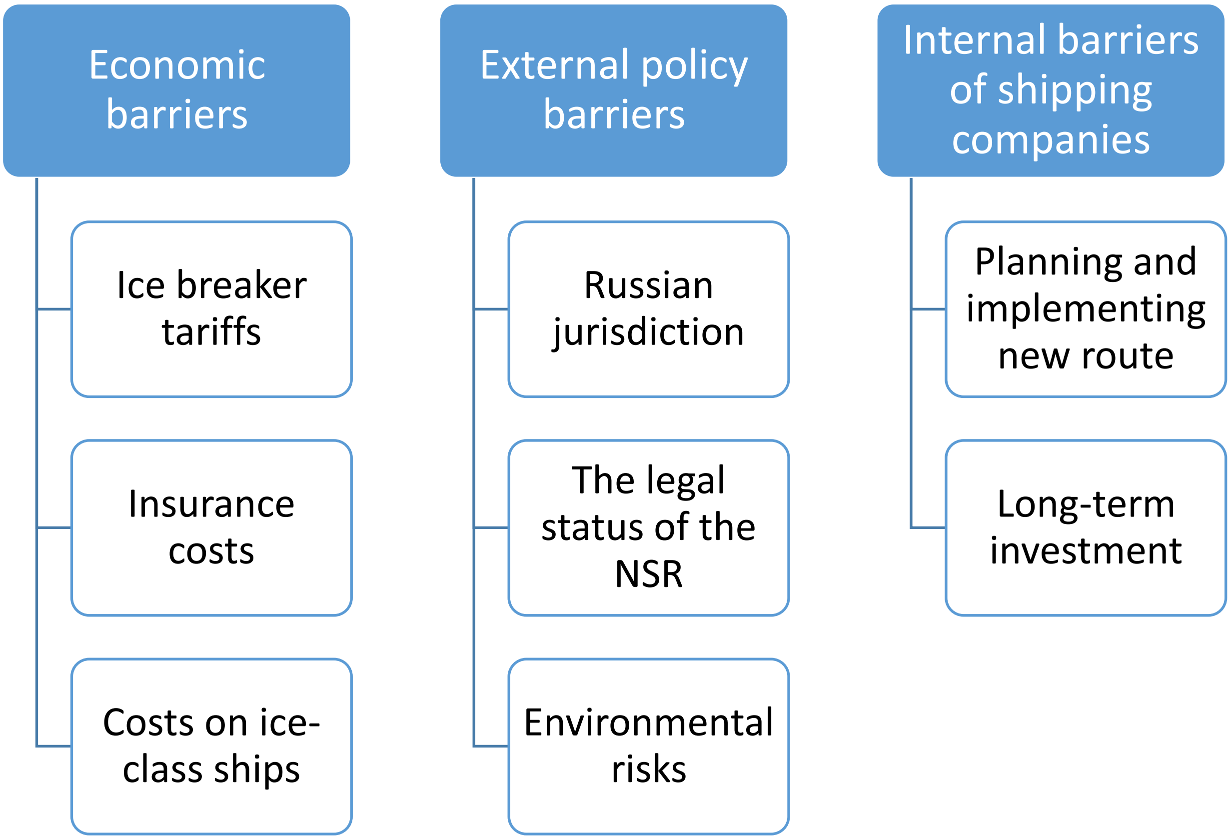

Fig. 5 Barriers of the NSR.

Economic barriers include several factors. Firstly, the ice-free season in the Arctic waters has raised up to about 130 days by now, on average, it is obvious that shipping through the NSR cannot be year-round. Secondly, operating costs, including an ice breaker tariff and insurance costs, should be less in order to attract shipping companies. Additional costs on building ice-class ships for NSR navigation do not improve the situation.

External policy barriers include regulation for navigation and international and Russian laws. The legal status of the NSR may have an impact on its navigation. There has been much debate on whether the NSR should be considered as internal waters, territorial waters, or international straits. Depending on the legal status of the NSR, shipping companies should comply with different legal schemes. At the same time, most of the NSR is under Russian jurisdiction, through Russia's regulations in federal law on the NSR (2012) and the Rules of Navigation (2013). Moreover, multilateral institutions, such as the International Maritime Organization (IMO) and the Arctic Council, might affect the utilization of the NSR by shipping companies. Particularly, multilateral institutes have been keen on the environmental risks associated with NSR navigation encompassing ship strikes of whales, noise disturbance, chronic pollution and oil spills due to the floating ice which can strike tankers and barges carrying oil and fuel.

Company's internal barriers mean the internal decision-making process of shipping companies which also influences NSR navigation. First, the way in which a company's leaders perceive the potential and risks of this new route is crucial. After collecting relevant information and reports on a variety of elements in the NSR, leaders make decisions about whether and to what degree the company will get involved in and utilize this new route. So, if the leadership's perception of NSR risks and uncertainty is high, the company will not initiate the NSR voyage. On the other hand, a positive perception of the NSR's potential leads to a company's participation in exploring the route. Second, another internal factor to consider is which department within the shipping company will take charge of planning and implementing new route development. If there is a high-level manager and organization in charge, further efforts for NSR utilization will be made. Third, a company's financial status will either boost or dampen the new route business; a stable financial condition could facilitate long-term investment in the potential of the NSR (Lee, Kim, 2015).

The crucial problem of the NSR which influences the whole success of the route is its infrastructure. According to the foreign analytics, there are two levels on which actions should take place. Firstly, it is the governmental level. The main difficulties on this level are the procedure of granting the permissions for navigation via the NSR, the tariffs system for ports' and ice-breakers' services and the overall coherency of the Arctic ports administration (Advisory council of the Russian government 2014).

Another point is the company level which includes the attraction of the leading international carriers for organization of schedule of the permanent shipping routes. These cons lead to the raise of risks and, consequently, to the higher insurance costs, especially for the dangerous petrochemical products and LNG (Advisory council of the Russian government 2014). The current prices of oil and natural gas decline the investment attractiveness of the Arctic operations. The situation is worsened by the current sanctions which forbid the western companies to participate in Russian Arctic projects (Zagorskiy 2016).

Lasserre, Beveridge and Fournier (2016) stated the main driver allowing the usage of new routes for shipping companies as the market opportunities which correspond to the current business strategies. He highlighted that despite lots of studies and models which proves the economic viability and profitability of shipping via NSR, the actual transit traffic is quite low and unstable. According to the Fig. 6, only 28% of companies consider NSR as a good perspective for their shipping lanes portfolio and exactly 28% of companies do not consider NSR at all. The quarter supposes that NSR can be used for bulk shipping or natural resources transportation but only if the voyages are destinational.

Fig. 6 Shipping companies perspective on the NSR potential (Lasserre, Beveridge, and Fournier 2016).

According to the Lasserre (2016) survey, companies are not ready to operate on the NSR because of costs, challenges and risks linked to the shipping in the Arctic waters. Up to 66% of the surveyed companies consider capital expenditures on ice-class ship construction as the crucial point for the decision on NSR shipping as these costs can turn up to sunk ones if the NSR is not as viable as predicted. What is more, environmental challenges of NSR brings from one side additional costs in terms of insurance and crew training and from the other side additional risks in terms of drifting ice, growlers and remoteness from search and rescue centers. However, the most popular answer (53%) from shipping companies on the NSR is that the Arctic shipping is not their core business. The NSR is depicted as a really niche market which is still underdeveloped and does not have enough infrastructure in terms of icebreaker escorts and search and rescue facilities. Therefore, companies are not ready to risk entering new route or new business segment.

All in all, there are several issues which significantly slow down the development of the NSR. They include additional costs on shipping in Arctic waters, environmental risks, underdeveloped infrastructure and search and rescue services as well as internal barriers of shipping companies in terms of their business strategies.

1.1.3 Russia's usage of the NSR

NSR was officially opened as an international shipping lane in 1991 by Russian Federation. During the Soviet period the route was used exclusively as a national shipping route. The peak annual traffic on the NSR was reached at the level of 6579 million tons of cargo carried by 331 ships in 1987. The peak annual number of voyages was 1306 (Stephenson, Brigham, and Smith 2013). The fact represents that the NSR was useful transportation system for Russian Arctic region, despite its limited annual accessibility.

Russian interests in Arctic region are connected with the several factors. The Arctic region provides 11% of national income due to the extraction of 90% of Russian nickel and cobalt, 60% cooper and 96% platinoid. Moreover, the hydrocarbon reserves are 5 billion barrels on the current Arctic territory under Russian flag. At present, the Russian state tries to prove to the United Nations that the borders of the continental shelf zone should be broadened beyond the general 200 mile zone due to the fact that the territory is the continuation of the Lomonosov and Mendeleev ridges. The main purposes of the expansion are the rights for free exploring and development of the subsoils and sea bottom (Konishev and Sergunin 2010).

The Arctic zone of Russian Federation includes Murmansk region, Nenets, Yamalo-Nenets and Chuukese okrugs and coastal territories of Krasnoyarsk region and Sakha republic. The first four regions have 90% of all Russian Arctic population and production complexes. The economic situation in these regions have direct influence on the NSR ports. The population outflow from the regions is slowing down but still exists. For the last 15 years 25% of the population of Arctic regions have changed their residence. The index of industrial production in these regions is higher than the average on the country level due to the oil and gas extraction and production facilities. The long-term export contracts and internal energy demand also provide balanced income for the regions. However, the Arctic regions send to the state budget much more than they get back in reverse transfers. The regions infrastructure, including ports of NSR, needs speedy modernization. In addition, the extraction level on Russian territories is on 20% lower than the same level on foreign fields and the overall amount of discovered fields and their reserves is coming to the stable grade. The technological approach to extraction and transportation of oil and oil products ought to be updated in order to get the efficiency level of foreign competitors (Pavlov and Celin 2012).

Russian Federation has additional advantages from the development of NSR. It is the creation of the common transport network across the country which provides the affordable logistic services for both the companies and the population with the standard quality level. The Far East Federal District have poor railway and road connections and needs transportation system with other regions which can be provided by NSR (Zhuravel and Smirnov 2015). Another point covers the interaction with the international transport networks and the increase in the transshipments via the country borders. That was mentioned as one of the strategic aims of Arctic development by President Dmitry Anatolyevich Medvedev in the Fundamentals of the Russian Federation's state policy in the Arctic for the period till 2020 and beyond. The safety provision and environmental issues come as an additional advantage of building the contemporary transport infrastructure (Advisory council of the Russian government 2014).

Russia is the first world exporters of natural gas, especially by pipelines. However, many of the oil and gas fields in the Arctic region demands additional routes. One of the points is the LNG shipping which has been quite low and limited until 2013 when the LNG export shipping rights were granted to more than one company (Gazprom). Novatek and Rosneft have got the opportunity to enter the world LNG market with their projects. The LNG plants represented in Fig. 7 should increase the Russian share of the world LNG production from 4% to at least 10% by 2020, according to the Russian Energy Minister.

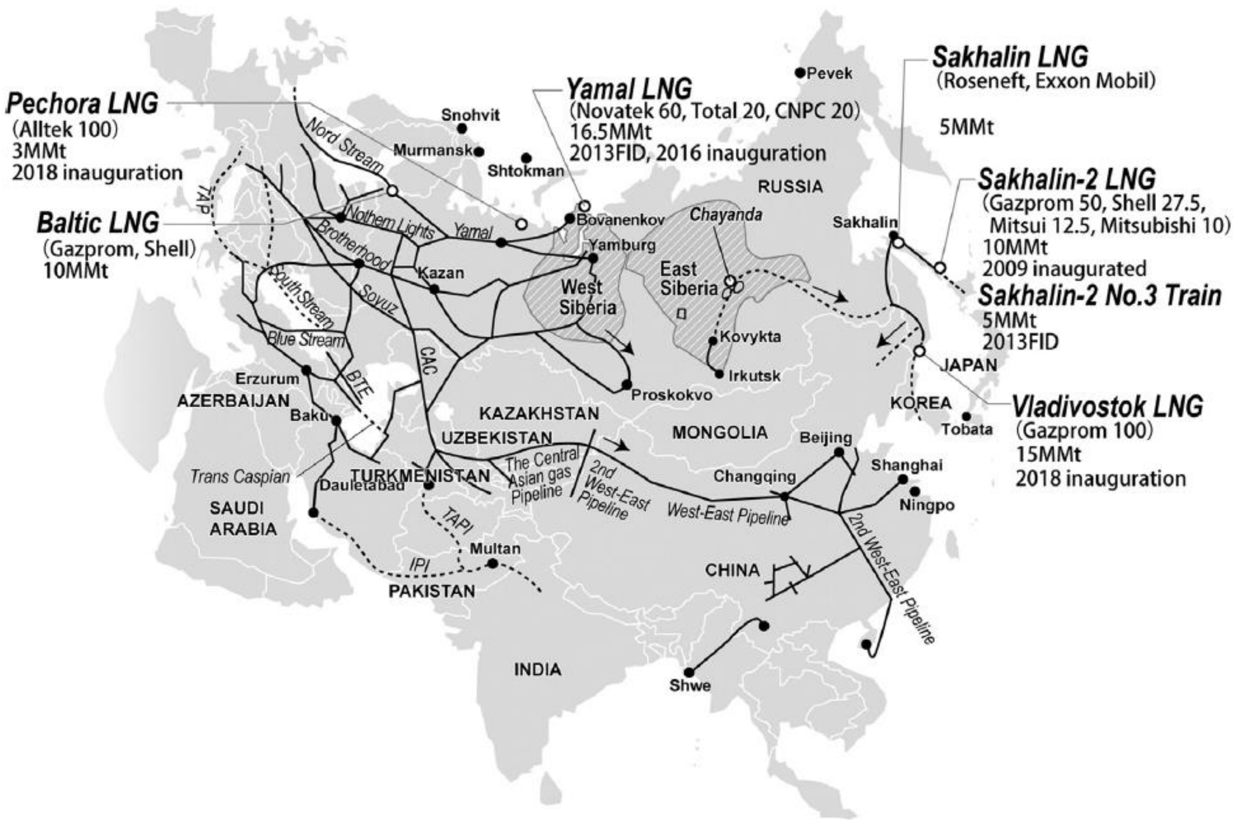

Fig. 7 Russian LNG plants officially confirmed in 2013 (The Ministry of Energy of the Russian Federation 2015).

Russian projects on the Arctic energy demand skills and technological knowledge on operations in extreme northern conditions that can be provided by foreign energy companies. In the last five years several joint ventures were established for fulfilling the lack of expertise on the Russian side. Rosneft and Statoil established several agreements on the cooperation in the Barents Sea offshore Norway and in Sever-Komsomolsk field in the Yamalo-Nenets Autonomous District of Western Siberia. For the first case, Rosneft will organize a Norwegian subsidiary with 33.33% stake and, for the second one, the single operating company will be set up with 66.67% of Rosneft share and 33.33% of Statoil share. Also Rosneft made a joint venture with Eni for the exploration of the Barents Sea offshore Russia with the same distributions of shares 66.67% and 33.33% for the Russian and Italian side respectively. Last but not least comes the upstream partnership between Rosneft and ExxonMobil for the exploration of the Kara Sea (The Oil & Gas Journal 2012). So, Russian companies have already started the long-term cooperation with international energy companies to exploit the Arctic reserves.

To sum up, main advantages and disadvantages of the NSR are presented in the table 3 below.

Table 3 Pros and cons of the NSR.

Pros	Cons
Shorter route	Navigation in the Arctic waters
Time savings	Ice-class ships
No piracy	Ice-breaker and other tariffs
Less fuel consumption	NSR infrastructure needs modernization
Lower CO_2 emissions	No shipping hubs
Route belongs to the one economic zone	Route is not available all year round

1.2 Liquid natural gas

The oil and gas companies' activities in Arctic and Siberian region are growing and that leads to more intensive usage of NSR for transportation of oil products and liquid natural gas (LNG) to Asia. NSR is supposed to become one of the main energy transport routes in near future, according to the advisory council of the Russian government (2014). Further development of NSR is possible with the expansion of ice-breaker's fleet. The functioning ice-breakers are mostly in the current fleet of Russian government and there is no confidence in more governmental investments in the coming years. Therefore, that brings the idea of ice-breakers built on corporate investments. The first in the list of investors are resource extracting companies with operations in the regions bordering the NSR.

The experts of the U.S. Geological Survey reckon that Arctic has the fifth part of the world unexplored reserves of oil and natural gas. The potential reserves of oil are 90 billion barrels, natural gas reserves are 47,3 trillion cubic meters or 44 billion barrels of LNG. All in all, Arctic has 13% of yet uncovered oil reserves and up to 30% of yet uncovered gas reserves. That equals to 375 billion barrels of oil. Additionally, there are several types of ore, including the rare ones (The Geological Society of London 2011).

LNG is natural gas that has been converted to liquid form for ease of storage or transport. It is odorless, colorless, toxic and non-corrosive. The liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty downstream. The natural gas is then condensed into a liquid at close to atmospheric pressure by cooling it to approximately −162 °C (−260 °F). LNG achieves a higher reduction in volume than compressed natural gas so that the volumetric energy density of LNG is 2.4 times greater than that of compressed natural gas. This makes LNG cost efficient to transport over long distances where pipelines do not exist. Specially designed cryogenic sea vessels (LNG carriers) or cryogenic road tankers are used for its transport. LNG is principally used for transporting natural gas to markets, where it is regasified and distributed as pipeline natural gas (Royal Dutch Shell 2017).

According to the BP statistical reviews, a compound annual growth rate of LNG trade is 7,2% in the period between 1990 and 2010 (Fig. 8). The latest data on 2015 year shows the world natural gas production growth rate at the level of 2.2% with the strongest regional growth rate at 6,2% in the Middle East (Fig. 9). The ongoing trend in the Asia-Pacific region which influences the demand side of LNG market is that OECD-Asia counties were the main importers of LNG from 1990 to 2010 but nowadays Non-OECD Asia countries are increasing their import rates of LNG (Fig. 10).

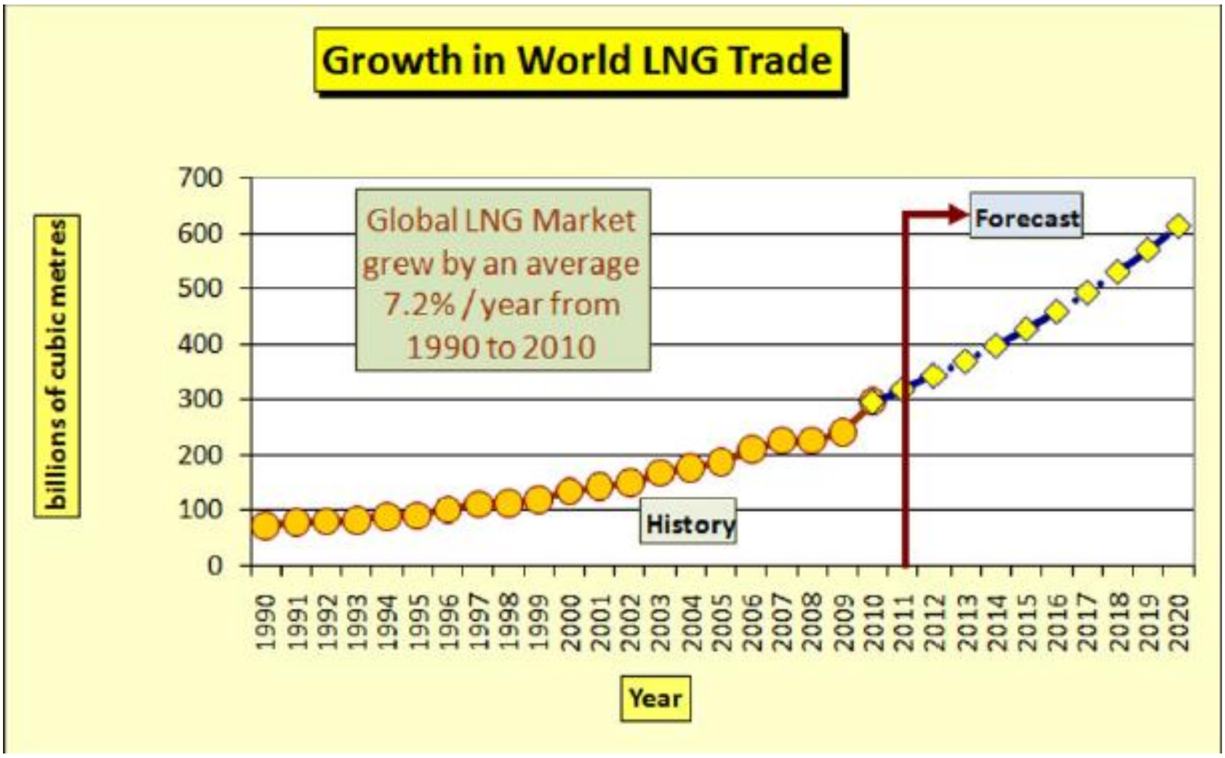

Fig. 8 Growth in World LNG Trade (Wood 2012).

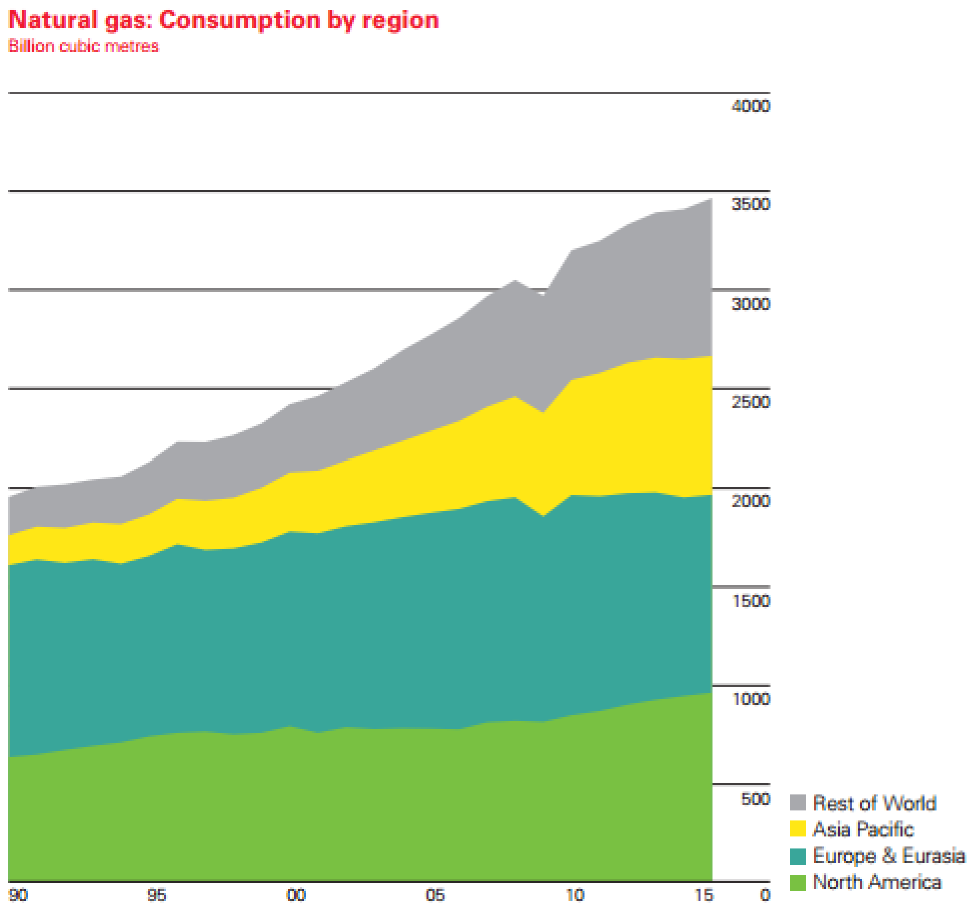

Fig. 9 Consumption of natural gas by regions (BP Statistical Review of World Energy 2016).

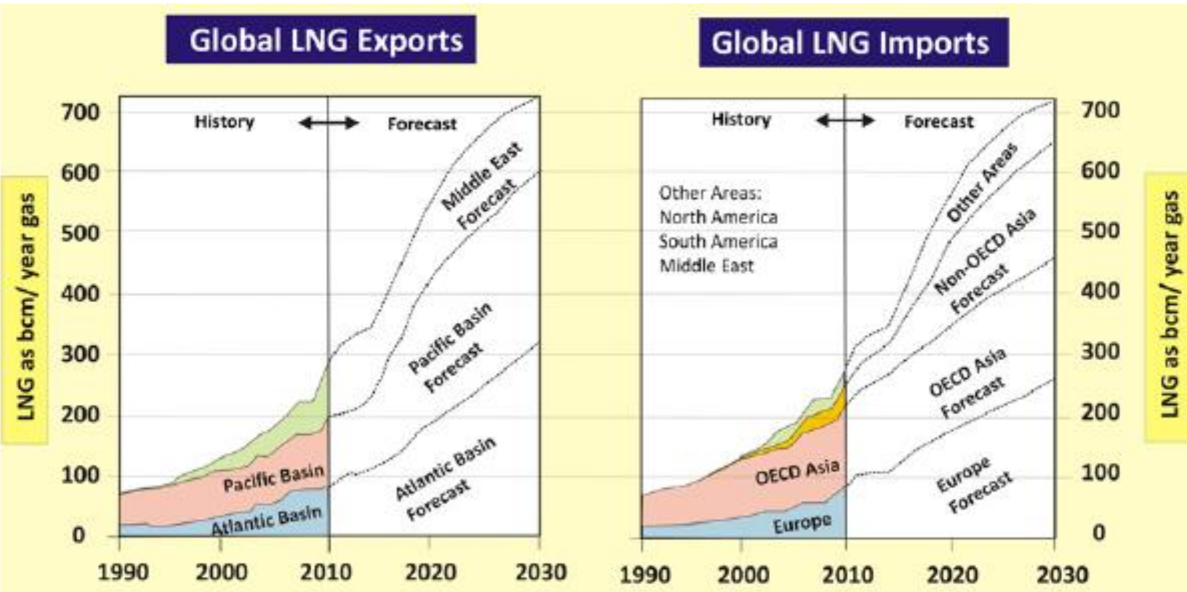

Fig. 10 History and forecasts of LNG exports and imports by region (Wood 2012).

The development of LNG markets has led to the construction of appropriate infrastructure for the obtaining the economies of scale and for the organization of appropriate value chain with improved margins. One of the crucial points in the LNG value chain is the availability of vast transport nets for the flexibility of switching cargo destinations. That allows the exploitation of LNG demand market opportunities and such energy companies as BP, Shell, Statoil, QP and Total were the first to adapt the strategy and get the first mover advantage on the LNG market. The next group of companies which includes ExxonMobil, Gazprom, Chevron and ENI has a significant gap in their value chains in terms of transportation networks and they need to come up with the leaders. Moreover, about 30 countries are constructing or planning to construct new regasification facilities to have enough capacities to convert imported LNG, so the further diversification of the industry is ongoing (Wood 2012).

One of the advantages of LNG comes from its prices. LNG is traded not only by long-term contracts but also on the spot markets for the short-term contracts. There is no sense in long-term take-or-pay contracts which are used for pipeline gas because LNG can be easily transported on the unit and individual basis as most spot-traded commodities. That leads to the growth of LNG usage and the diversification of LNG cargo routes around the world.

The LNG value chain consists of four stages which are exploration and production, liquefaction, shipping, regasification and storage (The Bureau of Economic Geology 2012). The shipping stage has the most meaning for the survey as NSR is supposed to become new route for constant LNG shipping. The figure 11 below demonstrates the lack of routes for gas transportation in Arctic region. The indisputable leader in the export of LNG is Qatar, which export exceeded 100 billion cubic meters in 2015. In addition, it is most LNG routes come to China, South Korea and Japan. Therefore, the Asian demand for LNG exists and can be satisfied via Arctic reserves. However, Dadwal (2014) doubts that the Arctic oil and gas will make a significant impact on the world energy market before 2025. The main reasons for such concerns are the lack of the sufficient infrastructure in the Arctic regions and high capital expenses for both the research and exploitation of the oil and gas fields.

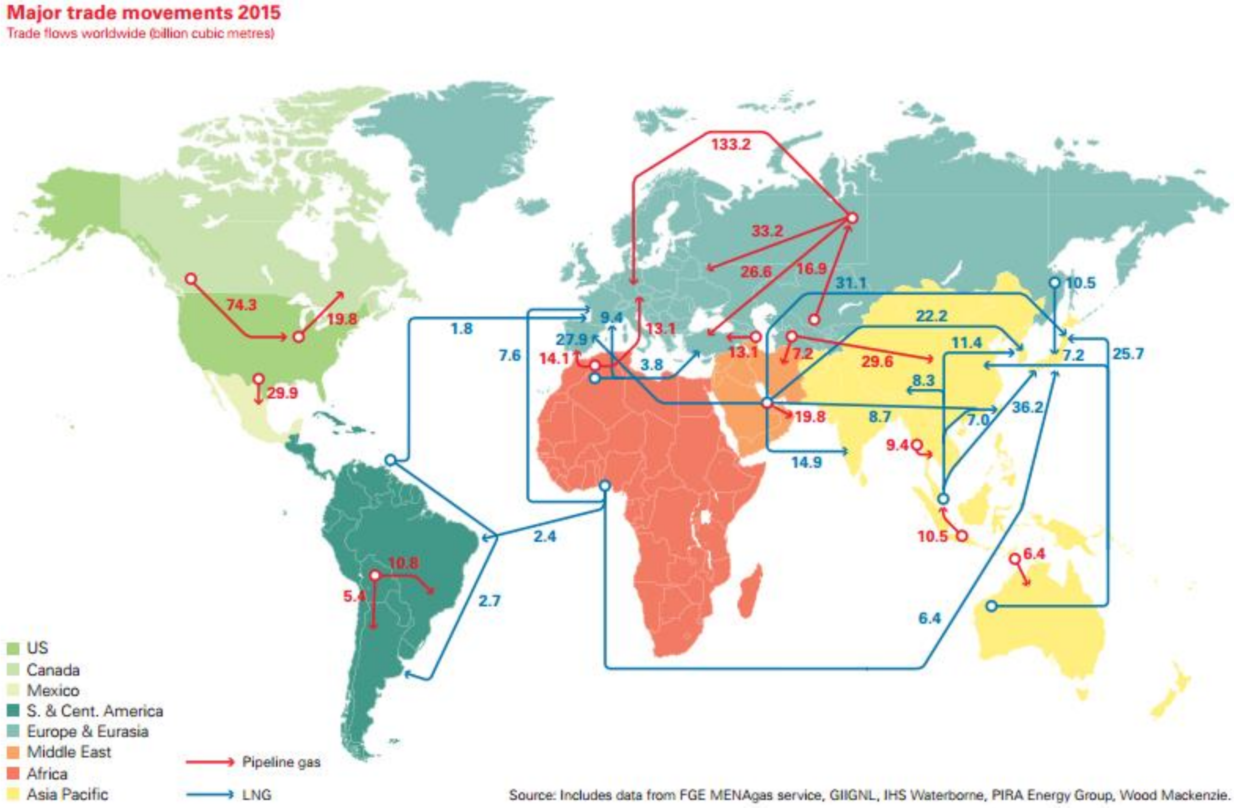

Fig. 11 Major trade movements of natural gas in 2015 (BP Statistical Review of World Energy 2016).

1.2.1 Japan's interest in LNG via the NSR

Japan has recently become one of the countries which interests in the Arctic oil and gas and tracks the marine shipping routes in the North. After the Fukushima accident in 2011 most of the nuclear power plants were stopped and from that time only several ones have been launched again. That brings the idea of the usage of alternative sources of energy such as solar, wind and hydro powers but the construction of such stations and plants requires time, so the traditional energy sources as oil and gas are coming for the change period. This fact explains the growing interest of Japan in Arctic energy sources and the presence of the first LNG carriers on the NSR towards Tokyo (Konishev and Sergunin 2012).

LNG was considered as the most reliable and flexible fuel in order to overcome the power shortage after the stoppage of nuclear power stations. As a result, Japan's import of LNG increased by 25% in three years between 2010 and 2013 (Motomura 2014). Russia has proved to be a reliable supplier in oil and gas in terms of the supply proximity, safety and flexibility. In addition, Russia as a partner increases the bargaining power of Japan in its relations with the Middle East suppliers which still satisfy up to 30% of Japan import energy needs (Fig. 12).

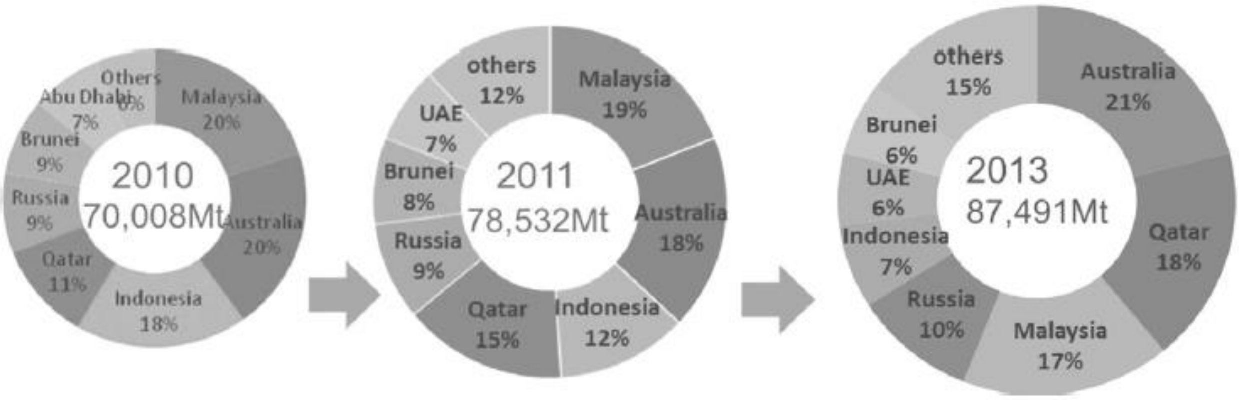

Fig. 12 LNG exporters to Japan by years (Motomura 2014).

Japan was also the first country which imported LNG via the Northern Sea Route in 2012 (Fig. 13). That was the first attempt to estimate the reality of the Arctic LNG shipping which was successful and proved the technical and economic viability of the Arctic LNG shipping from Norway to Japan. The route proved to be efficient as there were 50% distance saving, 40% time saving, 40% fuel saving and 40% of CO_2 saving (Dynagas LNG Partners LP 2014). Therefore, Japan is interested in such method of LNG supply and is eager to decrease its dependency on Middle East and Pacific LNG imports by Arctic shipping from Norway and Russia. One more point is high prices of Japan LNG which especially rocketed after 2009 (Fig. 14). So, if there is an opportunity to import cheaper LNG, Japan and other Asian countries which use the same price system will use it.

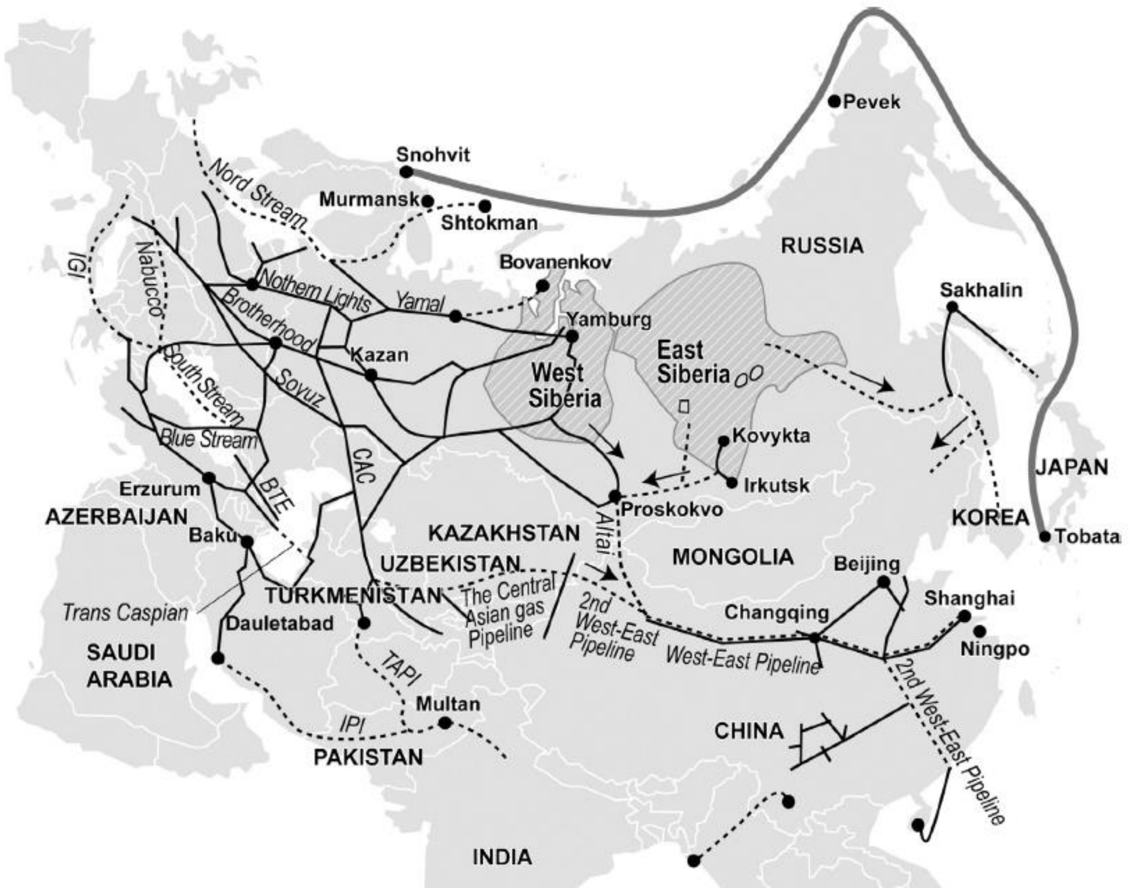

Fig. 13 The first LNG voyage via the Northern Sea Route (Motomura 2014).

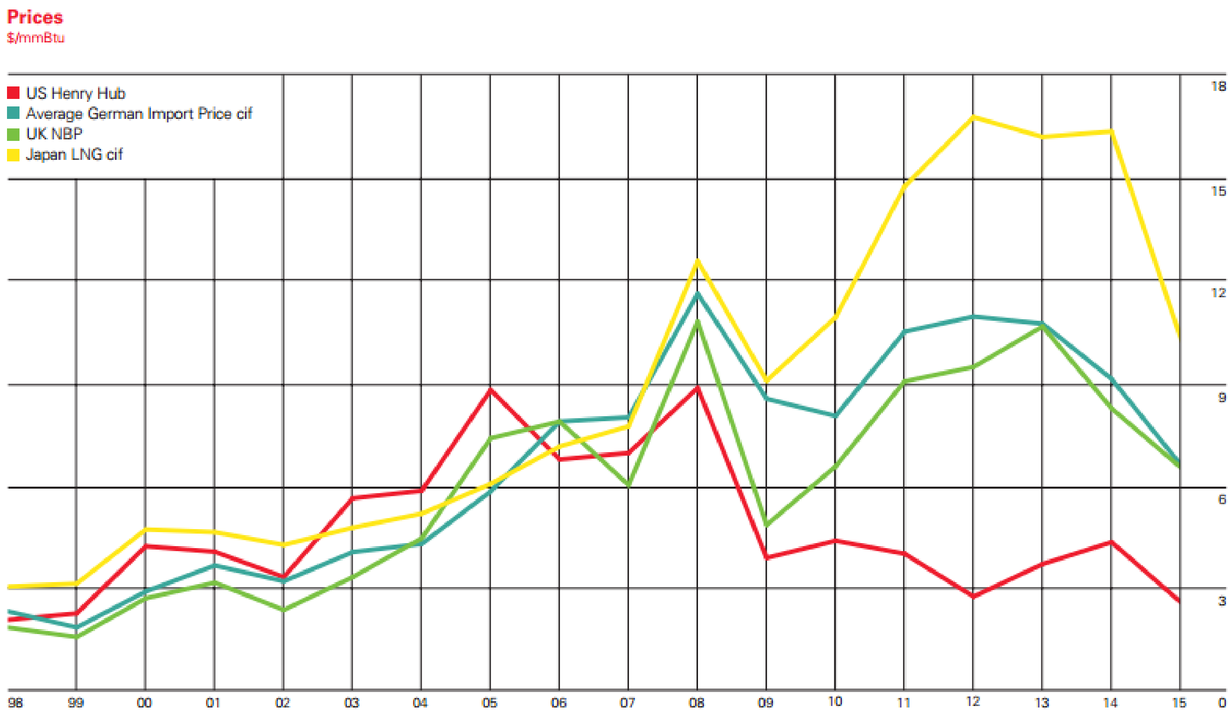

Fig. 14 Natural gas prices from 1998 to 2015 (BP Statistical Review of World Energy 2016).

1.2.2 China's interest in LNG via the NSR

China is connected with the international marine transportation to the extent that 46% of Chinese GDP comes from export and import operations via marine routes (Central Intelligence Agency 2016). Therefore, any changes in global transportation networks have their effect on the GDP, including the NSR development.

China has addressed the concept of Sea Silk Way in 2013 which unites the sea routes across Asia, Indonesia, Oceania and Australia. That Sea Silk route can be combined with the NSR to provide the one route connecting Arctic and Asia-Pacific regions. NSR is considered as a huge infrastructure project which ought to have several investors on either the governmental level or the level of energy companies or even both. New Development Bank BRICS is one of the possible investors for NSR as its main objective is promotion of the infrastructure and sustainable development projects with a significant development impact in member countries. NSR has the significant development impact mostly for Russia and China. India is the third country to be interested in the project. The transportation costs and delivery time will decline significantly that increases the attractiveness of the perspective of Northern-Asian routes (Advisory council of the Russian government 2014). The Arctic policy has not still been officially stated by the Chinese government but there are statements from single politicians that Arctic belongs to all humankind and none of the countries have the sovereignty on it (Danilov 2014). What is more, one of the most powerful scientific ice-breakers are built in China and the expeditions have been permanently going in Arctic waters for 5 years (Pavlov and Celin 2012). In addition, China considers the development of the north-east hub port which can benefit from both the NSR and traditional shipping routes (Ho 2011).

The hydrocarbon fields in Arctic attract the Chinese government as they are one of the solutions for the upcoming demand for energy sources in China. However, China is not the Arctic country and has no direct access to any of the Arctic seas. So, it is not the member of the Arctic Council, only an observer without voting rights, and exactly the Arctic Council is the most significant international organization which regards the Arctic issues (The Arctic Council 2015).

Despite that fact, China is interested in collaboration with Arctic countries. China National Petroleum Corporation (CNPC) was invited by Rosneft for mutual development and exploitation of the Arctic fields of the Russian company. Canada is also the agile partner for China as Chinese investments in Canadian hydrocarbon projects are quite high in recent years. Norway is ready to share its experience and skills in the deep water drilling with Chinese corporations on exchange of financial assistance for its Scandinavian projects (Danilov 2014).

According to CNPC, China is going to quadruple import of natural gas by the year 2030 and lots of negotiations are currently in progress with Qatar, Australia, Indonesia, Canada and Russia. The import will skip from 53 billion cubic meters in 2015 to 270 billion cubic meters annually by 2030 (Slav 2016). The oil consumption is going to double by 2030 and achieve the level of 15 billion barrels per day. Therefore, China needs additional energy sources as its own reserves of coal will be definitely employed to the full in near future. The NSR can provide the successful progress in extraction of hydrocarbon resources in Arctic. According to the Maritime doctrine of Russian Federation, one of the goals of the NSR is the provision of export of hydrocarbon resources, especially to Asia-Pacific region, that corresponds with the growing demand from the side of China. The agreement between Russia and China on the 30-year gas export from 2018 displays the Chinese demand in natural gas and Russian opportunities in supply, especially after 2018 when at least three LNG facilities should be inaugurated (Dadwal 2014).

However, there are some side effects from the Chinese interest in the Arctic. Firstly, Chinese petrochemical companies will try to get the access to the development of the reserves in the Russian Arctic zone for their subsequent transportation to their own country for the processing without passing the Russian processing facilities. Secondly, there can be requests for the preferential use of the NSR or even for the NSR internationalization. Thirdly, the political issues can be directed to the limitation of the Arctic countries rights, including Russia, on the shelf zone (Konishev and Sergunin 2012). Thus, the prosper partnership with China has its perils.

1.3 Models for transportation costs estimation in the Arctic waters

The NSR is a perspective route which has its own peculiarities and there are lots of proposals on the points which should be done for the development of the NSR on both corporate and governmental level. According to Plisetsky (2013), the main recommendations for the NSR development lies in construction of the single management group which is going to control and coordinate the whole number of events from the sides of both the governmental representatives and the commercial organizations. That can be done if the powers of existing Administration of NSR are broaden. For instance, the current administration of the Panama Canal is responsible for the provision of exploitation, administration, management, modernization and providing the associated services within the territory of the Canal. Furthermore, there is a need for the concept of NSR development strategy and the appropriate state programme which underlines the aims, steps, deadlines of the project. Last but not least one comes the need for connection with the current policies on the development of NSR and Arctic regions (Arctic regional information and analytical center of the Russian Institute for Strategic Studies 2015).

Celin (2012) lists the necessary steps for the NSR in connection with the whole Russian Arctic region. These steps include determination of strategic state priorities in the expansion of hydrocarbon fields and making special conditions for the increase of their investment attractiveness; diversification of energy clients around the world through the implementation of marine transportation routes; foundation of special international economic zones in Northern ports; improvements in the insurance policies for cargo and carriers and in the tariff systems (Fig. 15).

Fig. 15 Recommendations for the NSR development

These steps should be taken in order to enhance the usage of the NSR. As it was stated earlier the NSR provides lots of advantages in terms of costs, distance and time. However, there are different models which describe transportation costs via the NSR in several ways. The most relevant assumptions which can be implemented for the LNG transportation costs model are presented in table 4.

Table 4 Assumptions for transportation costs estimation.

Characteristic	Assumption	Author
Sailing speed	Based on ice conditions and ice class of vessels.	Somanathan et al. (2009).
	A deterministic value which varies from 5 to 22 knots.	Lasserre (2014).
Fuel costs	From 25% to 61% of total operating costs.	Raza (2013), Srinath (2010).
	The daily fuel consumption rate for the NSR is the same as for the SCR.	Guy (2006).
	The fuel consumption rate per distance unit is proportional to the square of sailing speed.	Schøyen and Bråthen (2011), Furuichi and Otsuka (2013), Lasserre (2014).
	The fuel consumption rate is higher for ice-class vessels due to increasing weight of vessels or extra required power to transit through ice.	-
Capital costs	Chartering cost	Guy (2006), Schøyen and Bråthen (2011), Raza (2013).
	Depreciation cost	Furuichi and Otsuka (2013), Lasserre (2014).
	Premiums on building cost	Omre (2012).
NSR transit fees	Navigation through thick ice without icebreaker escort.	Chernova and Volkov (2010).
	A hypothetical future scenario where ice conditions have greatly changed and icebreaker support is not essential.	Lasserre (2014).
Insurance	An insurance premium for Arctic shipping ranges from 25% to 100%.	Somanathan et al. (2009), Schøyen and Bråthen (2011), Raza (2013), Furuichi and Otsuka (2013), Lasserre (2014).

Yearly fixed costs of the vessel are calculated accorfing to the formula in figure 16. However, if the assumptions stated above are to be considered, then the model for the operating costs of the vessel is changed to the one stated in formula 1 (operating costs per voyage):

(1) $C = Opt * D_t + F_l * D_l + F_b * D_b + TF_l + TF_b$;

where C stands for operating costs for the round voyage, Opt are general operating costs, D_t are all days of the voyage, F_l and F_b are fuel costs for laden and ballast ship, respectively, D_l and D_b are days of voyage in laden and ballast conditions, TF_l and TF_b are transit fees for laden and ballast conditions.

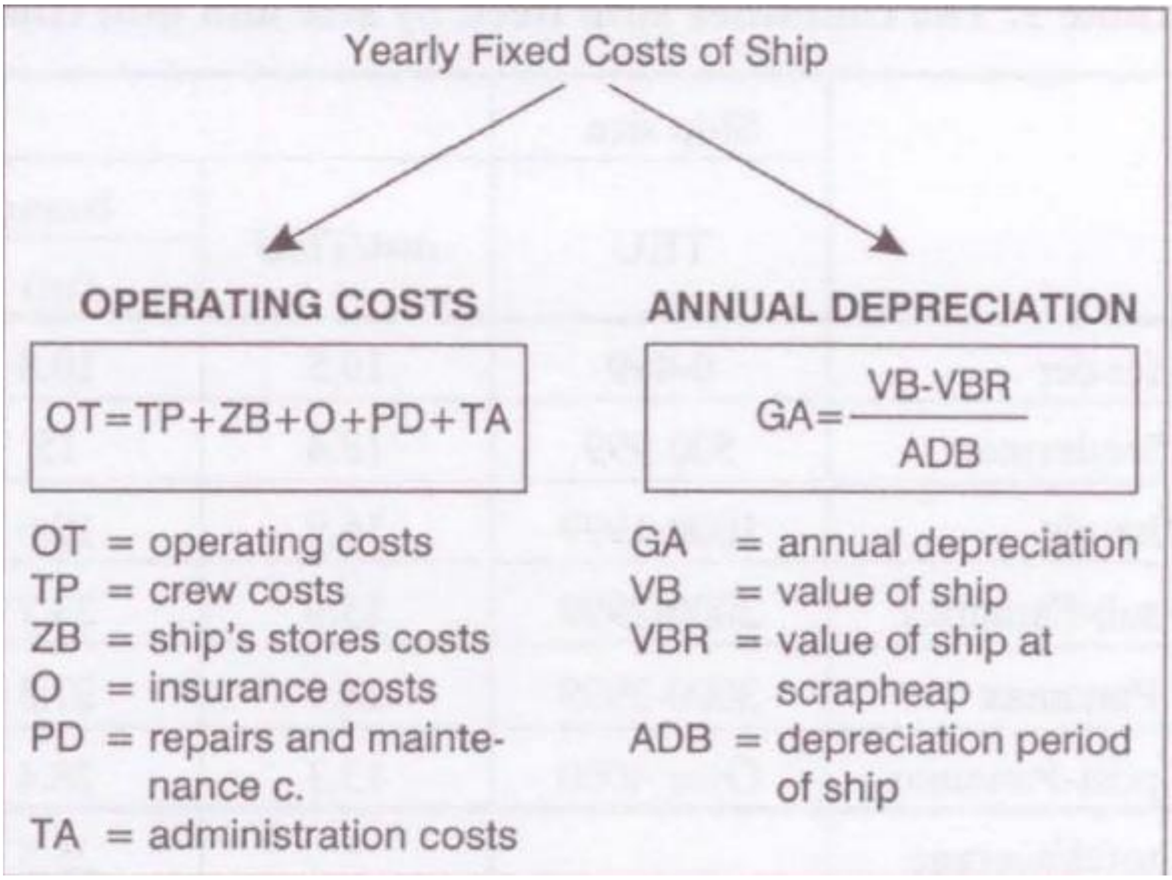

Fig. 16 Yearly fixed costs of the vessel (Pocuca 2005).

Conclusion

The review on the topic of the NSR has proved that the issue is topical and has lot of directions for further research. Considering the main prospects and perils of the NSR (Table 5), the study will evaluate the economic viability of the NSR for destination shipping of LNG, extracted in the Arctic.

Table 5 Prospects and perils of the NSR.

Prospects	Perils
Cost efficiency (distance, time, fuel savings)	Costs of shipping in the Arctic waters (crew training, ice-class ships, ice-breaker fees)
Environmental efficiency (reduction of CO_2 emissions)	Fragile environment of the Arctic (fuel spills, breach of the surface)
Transportation network for the Arctic regions of Russian Federation	Modernization of ports' infrastructure
NSR is Russian Exclusive Economic Zone	NSR Administration (tariff systems, permissions on the vessels' passage, bureaucracy)
Exploitation of the Arctic oil and gas fields (LNG and petrochemical shipping)	Investments for the Arctic oil and gas as well as need for skills transfer and possibility of oil spills
Marine shipping lane connecting Russia and Scandinavia with the Asia	No transshipment hubs along the route
One belt route concept	Vessels ship via the NSR for seven months maximum

The research gap lies on the junction of several issues which are the efficiency of the NSR for the shipping companies, the development of the Arctic regions both onshore and offshore ones and the connections of the Arctic states with the European and Asia-Pacific regions (Fig. 17). That leads to the research questions:

- How does the extraction of oil and gas in the Arctic regions influence the development of cargo traffic via the NSR?
- Is it economically efficient to operate LNG carriers on the NSR?
- What are the most beneficial circumstances for the shipping of liquid cargo, especially petrochemical one?

- What measures should be taken by companies in order to use the entire capabilities of the NSR?

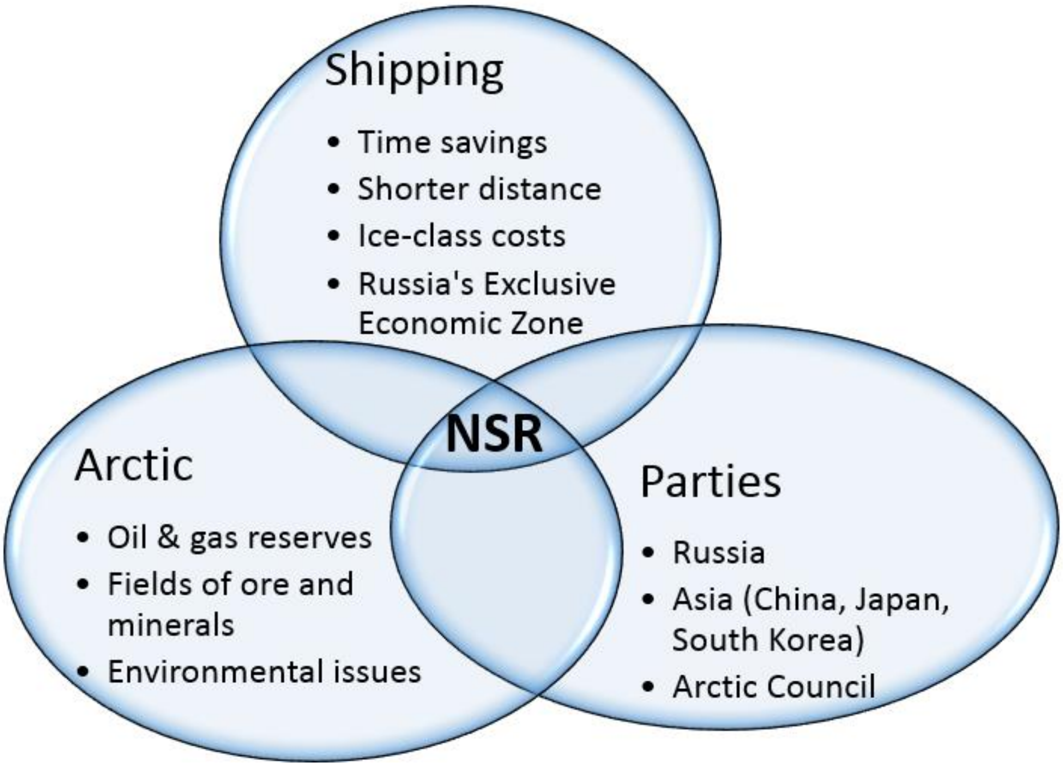

Fig. 17 The research gap of the study.

These questions will be answered is the study. The research design and research methods are going to be determined and described in the next chapter. That will allow to represent the collected data and to perform the analysis. The results of the analysis and the discussion of the research gap will be presented in the last chapter.

2. METHODOLOGY

This chapter includes a brief description and discussion of general research philosophical standpoint and the chosen research approach. As the research gap and the research questions are stated, the research design and appropriate research methods should be chosen. This chapter provides the information on these points. The data collection process is depicted and the validity of the research is proved. Also key limitations are mentioned.

2.1 Research philosophy

There are three main research philosophies which are positivism, social constructionism and relativism, according to Easterby-Smith (2002). Positivism is based on factual knowledge and its main concept states that the measurements should be done objectively in such a way that the observer is entirely external person without possibility of intervention into the observed reality. Positivism is mainly used for external experiments and that is the reason why it is not appropriate to be used for this study. There is no way to model the freight transport via NSR for the study in reality.

Another philosophy is social constructionism which highlights the necessity of subjective perspective throughout the study. Social constructionism assumes that the reality exists in humans' minds where it is constructed by their apprehensions, not by objective and external factors. Therefore, researcher should distinguish different opinions of all interested parties and their communication networks. That can be done precisely if the researcher is engaged in the studied society and not an external observer (Easterby-Smith, et al. 2002). Social constructionism is also not appropriate for the study as the researcher is an external person who is not a part of the any company or organization connected directly to the NSR.

That leads to the third philosophy of relativism. Relativism comes from the positivism and introduces the necessity of participation in the cognition process as the breakthrough influences the result of the study. One of the main methods of relativism is triangulation. Triangulation means data verification via at least two different methods in order to increase the reliability and validity of the results. The usage of several methods allows mitigating biases and giving more detailed view on the study (O'Donoghue and Punch 2003). So, it will be mostly appropriate to use relativism philosophy for the study to be able to implement different techniques for the analysis and triangulation is a necessary tool for combining data, collected from the interviews, case studies, theoretical frameworks and databases as there is a need to compare different perspectives and alternatives in one study.

2.2 Research design

Research design should be defined for the study. Research design can be either descriptive or conclusive. Conclusive research is used for the hypotheses testing and depiction of a specific relationships or phenomenon. The key characteristics of conclusive research include the large representative samples and quantitative analysis on the collected data. Descriptive research is connected with the description of the object and its characteristics. In addition, there is a possibility to use in exploratory research in order to provide details of a certain phenomenon. When the subject of the study cannot be measured in quantitative terms or where the measurement process cannot realistically represent particular qualities, exploratory research can be used (Malhotra, Birks, and Wills 2012).

Furthermore, the decision between quantitative and qualitative approach should be made. The quantitative research is entirely objective due to the use of numbers for the analysis. That allows to study huge samples and provide a more common findings yet at the same time the quantitative research analyzes only several variables and mitigates the holistic view of the problem (Denscombe 2010).

Qualitative research is based on non-numeric information which describes the studied phenomenon. That is mostly suitable for the studies of smaller samples. What is more, the researcher should get the profound knowledge of the sphere as the data should be interpreted in the right way. Qualitative research tries to provide the holistic view of the problem as it explores the relationships among various variables influencing the problem. The most popular research methods used for the qualitative research are case studies, interviews, documents and observation, according to Denscombe (2010).

The study is supposed to research the factors influencing the freight transport and logistics of the Northern Sea Route. So, several factors, relationships among them and their overall and separate influence of the NSR should be stated via the research. The quantitative research is not suitable as it cannot provide the holistic view and there is no assurance for the data, needed for the appropriate analysis, to be available for collection. Therefore, qualitative type of research should be suitable for the description of NSR.

2.3 Research methods

The next step is to define the research methods. The choice of research methods influences the entire process of the study as methods determine the quality of the data and further analysis and overall results of the study. Research methods are different techniques used for studying the problem. As it was mentioned earlier this study can be described via relativism philosophy and it will be exploratory and mostly qualitative. In order to define the best research methods the main aim of the study should be reminded. It is the evaluation of the economic viability of the NSR. That can be done via accumulation of data on NSR from official statistical reports, from the interviews with the interested and involved parties and from the case studies of the similar sea routes.

In addition, it ought to be noted that data is divided into two types which are primary and secondary data. The analysis in this research will be based on both types of data. Primary data is defined as the data collected for the specific purpose of the study by the researcher. That data is specific as it is collected for addressing the specific research question and, therefore, it is significantly relevant and accurate. The primary data will be collected via interviews and case studies. The secondary data is the type of data which was previously collected for purposes other than the studied problem. The secondary data is much easier and cheaper to access but at the same time it can be less relevant or even biased and its utility is more limited in the final analysis in comparison with the primary data. However, secondary data is quite useful for getting knowledge on the topic and for the initial understanding of the problem (Malhotra, Birks, and Wills 2012). The secondary data will be collected via multiple online resources, academic articles and databases. The overall research design is presented in the figure 18 below.

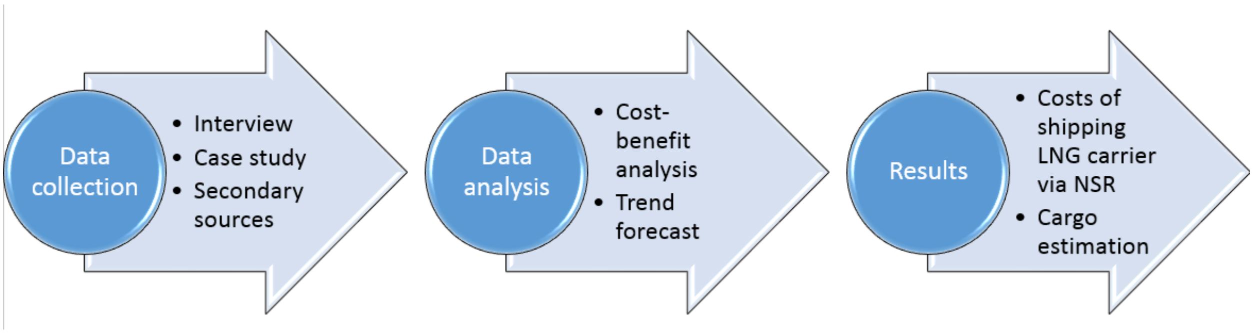

Fig. 18 Research design.

2.3.1 Secondary sources

The secondary sources of information were used for the description of both the theoretical frameworks and the empirical part of the study. Considering the first point, articles from online versions and databases of different scientific journals were analyzed in order to compose the up-to-date perception of NSR from the point of view of professional researchers and nautical community. That has led to the denomination of the research gap and has determined the further course of the study. Due to the results of the literature review, it was highlighted that the NSR development in recent years is only possible via expansion of natural gas extraction and its transportation in liquid form from Arctic waters and Siberia region to Asian countries such as China, South Korea, Thailand and others.

Coming to the second point, Internet sources such as company and organizations official websites, press releases and online newspapers provided additional information for the empirical part of the study, especially in terms of accumulated statistical data for freight turnover, estimated reserves of oil and gas in the regions adjacent to the NSR and ice cover forecasts. Only official and proved websites were used for obtainment the data to provide its reliability. The main advantage of the secondary sources of information is accessibility. Definitely, the information can be biased but if the method of triangulation is used then secondary sources proves to be the adequate source of data for the study.

2.3.2 Interview

The interview method is used for acquiring the primary data for the research. This research method provides the first-hand and most updated information on the topic. It is also possible to get the inside information through the interview process which can be rather helpful for the study.

Generally, there are two types of interviews: quantitative and qualitative. The quantitative interview is connected with large amount of interviewees and with getting the ordered information for statistical purposes. These interviews are strictly structured for the simplification of the collected data. The qualitative interview is aimed at several interviewees which share their knowledge on the topic in an unstructured or semi-structured form. The unstructured interview is done in a form of a conversation which allows an interviewee to speak openly on the stated range of topics. The main disadvantage of that type of interview is the possibility for the interviewee to distract from the main topic and provide a lot of data on some similar issue. Semi-structured interview also allows interviewee to answer in a freeway on a specific set of open questions. That technique allows to get more information on the topic if the interviewee is a more profound expert than the interviewer. The interviewer will get the answers to the exact set of questions and that provides the initial structure for the collected data (Easterby-Smith, et al. 2002).

The best type of interview for getting the detailed data from each interviewee separately is the in-depth interview. It is mainly used for uncovering the attitudes to and aspects of the specific topic in order to get the deeper understanding of the research problem (Malhotra, Birks, and Wills 2012). The interviews for this study will be done face-to-face or via phone and mail with experts in a semi-structured manner.

The important point is the number of interviewees which should be sufficient for the analysis. The recommended number of interviewees ranges from 5 to 22 people. The sufficiency of the sample size is proved when the interviewees provide similar answers without interacting with each other. New topics do not emerge in the interviews and that shows the adequate problem overview (Saunders et al. 2012). Additionally, the interview process itself is important and the interviewer ought to remember about obtaining trust, being aware of social interactions, using the appropriate language, getting access, choosing the location for the interviews, and recording interviews (Easterby-Smith et al. 2002). These points were also considered throughout the process of interviewing.

The interviews were conducted with the representatives of shipping companies, ports and oil and gas companies. Overall, eight experts were interviewed face-to-face in a semi-structured manner. The interviewees provided the information on the base of anonymity, so only their companies and departments are mentioned in the study. The interviews spent with the usage of the Russian language, but the scripts of the interviews provided in the appendix are in English. The list of interviewees includes oil and gas company representatives such as the specialists from the department of logistics and transportation of the Gazprom from the Bovanenkovskoye field; shipping company representatives such as the specialist of the department of shipping operations of Maersk Line, the specialist of the fleet operations department of Murmansk Shipping Company; representatives of state and port administrative organizations such as the specialist of the department of the technical management of the fleet management of Rosmorport, the freight agent of Sea Port of Saint-Petersburg and the engineering specialist of Poltava project which is managed by Gazprom.

The interviewees were chosen according to the principals by Denscombe (2010). These principals include the nature of the research question and the goal of the study, knowledge of the interviewer, relevant experience and position of the interviewees and the interviewees' availability. However, the key point has corroborated to be the interviewees' availability and eagerness to participate in the study. It happened to be extremely difficult to not only get access to the specialists with the needed knowledge, but also to get the permission to use the collected information in the study. Therefore, the interviewees remain anonymous and only data with the given permission is used for the analysis. The general flow of the interview is represented in the figure 19 below.

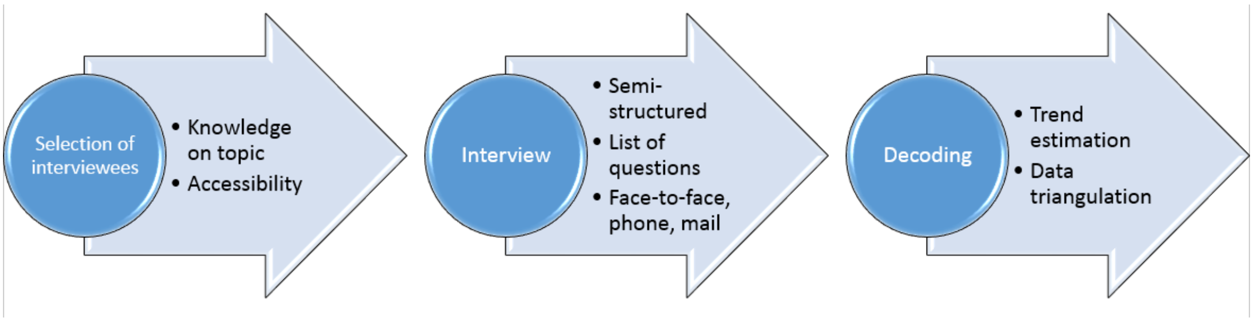

Fig. 19 Interview process.

The topics covered in the interviews are presented in figure 20. The interviews has provided the needed data for the analysis so that the future prospects of the NSR can be estimated and the cargo flow in terms of LNG can be forecasted for the nearest decade.

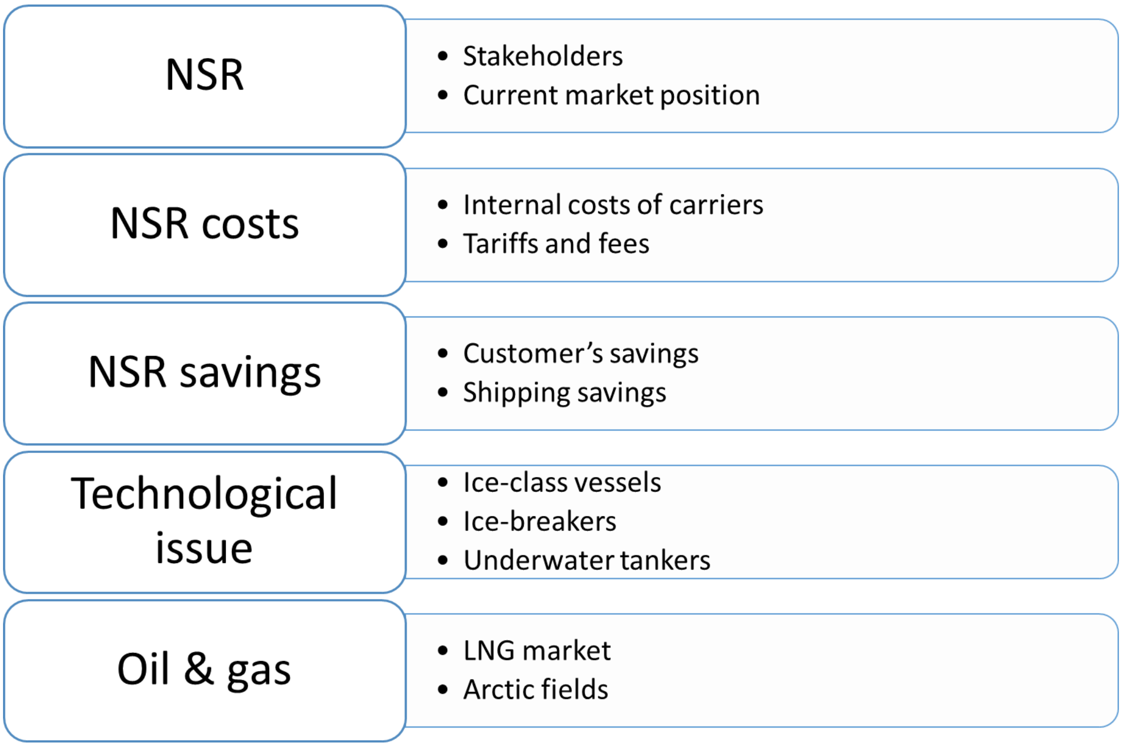

Fig. 20 Interview topics.

2.3.3 Case study

The case study method provides a holistic view on a real situation or event which has already happened. Yin (2009) states that the case study method is suitable in such cases when the researcher cannot control the studied phenomenon or the influencing factors cannot be manipulated. The case study method allows to enquire the phenomenon in its context and provides the detailed look on the integral parts of the research subject (Yin 2009). In addition, the case study method gives the opportunity to make comparisons with the similar real life problems. That provides additional perspective and information on the research topic (Denscombe 2010).

However, there are lots of concerns about the usage of the case study method for the research. First of all, the analysis of case studies is often made without any systematic procedures. As a result, the aftermaths can be biased and quite subjective which distorts the overall study results. Secondly, case studies provide the data for the specific problem and the findings are too explicit for generalization. Thirdly, the case study method demands more time for seeking the needed data through rummage of case studies and the final analysis is also more difficult as the gathered data was initially used for other purposes (Yin 2009).

The case study design should be defined before the data collection process. The foremost designs of the case studies are the single case study and the multiple case study. The single case study is characterized by sensitivity to individual peculiarities of the studied subject. However, the main limitation of the single case study is connected to its main advantage as the study can become subjective and does not provide enough data for the objective evidence or generalization. On the contrary, the multiple case study provides enough information from different points of view for confirmation of hypotheses. Yet the multiple case study is more difficult due to the several factors. Firstly, it is more time consuming as several cases should be chosen as the base for further analysis. Secondly, the data from these cases ought to be systemized and interpreted in the one way for providing data validity (Yin 2009). The multiple case study method is more efficient for studying NSR as it not only provides more details for the research but also allows to make comparisons with other sea routes. The case studies used for the analysis are presented in the third chapter.

2.4 Validity and reliability

The results of the conducted research should be valid and reliable. Firstly, the terms of validity and reliability ought to be stated. According to the Malhotra, Birks and Wills (2012) validity is the extent to which the research results represents the initially stated aim of the research. Moreover, the validity evaluates whether the results meet the requirements of the research methods. The reliability is the extent to which the results are truthful and trusted. These two characteristics determine the results of the study as they are the scientific proof.

As it was mentioned previously, the triangulation method is used in the study and one of its purposes is to achieve higher validity of the research. The data collected from interviews is additionally verified by the data from the secondary sources and case studies also provide additional verification. However, the triangulation is not enough for the proof of validity, so the four validity tests should be taken, according to Yin (2009). These are construct validity, internal and external validity and reliability tests. Firstly, the validity construct is necessary as the initial topic is very broad and the constriction of the research goals is essential. The research is focused on the LNG transportation via the NSR and the costs are calculated in the third chapter as the proof of the economic viability of the NSR for such operations. Secondly, the internal validity estimates whether the conducted analysis corresponds to the research questions. The analysis is aimed to find out the extent to which the Arctic LNG transportation is profitable and to provide recommendations on the future development activities. Thirdly, the external validity is about the generalization of the research results. The research findings can be used for the estimation of transportation of other types of cargo along the NSR and for the analysis of other Arctic marine routes. Fourthly, the reliability highlights that the analysis is repeatable with the same results. The study will provide the same results if only the same data and the same methods are used for the analysis. Therefore, the study is valid and reliable yet it has its specific limitations which are stated in the next section.

2.5 Limitations

The study has several limitations. Firstly, the limitation is connected with the scope of the study. The NSR is a really vast topic which cannot be entirely covered in one research. Therefore, the research questions have narrowed the study and the analysis has only considered the specific circumstances of shipping via the NSR. The main conditions which limit the study are one type of cargo (LNG), fixed ice cover surface, mixed measurements of costs and other spends.

Secondly, the interviews which are used as a data collection method have their disadvantages. The interviews were conducted with experts whom it was possible to contact with. In order to provide more complex view on the problem it would be better to conduct more interviews, especially with the representatives of energy companies and with the officials of the NSR Administration. In addition, the interviewees are supposed to be the experts for the study yet none of them is in the position of a top manager and cannot provide the full view. Also the nondisclosure agreements play an important role throughout the interviews as some data on costs, volume prospects, planned supplies and contracts are trade secrets.

Thirdly, the case study approach implies its own limitations as it does not allow to generalize the results of the study to the full extent. The case studies provides rather in-depth data on the studied questions which cannot be implied for other terms and conditions. The NSR is the Arctic marine route which lies within the borders of one country, Russian Federation. These facts highlight the NSR from all other marine routes in terms of either navigational or international issues or both at the same time. Therefore, the findings of the research has some limitations which corresponds to the external validity mentioned earlier.

In conclusion, the limitations of the research do exist yet they do not disturb its validity or reliability. All of the limitations cannot be mitigated by the researcher as they are connected to the external uncontrollable factors.

Conclusion

This chapter has depicted the methodological design of the study. The research follows the relativism philosophy and it is of the qualitative type. The data collection methods to be used are interview and case study. Interviews and case studies provide the primary data from experts and existing projects, respectively. The interviews were conducted with the representatives of shipping and energy companies as well as with the representatives of port services and administration. In addition, the data from the secondary sources is obtained for getting more reliable information via the triangulation approach. The collected data confirms its validity and reliability within the mentioned limitations. The successive chapter covers the data analysis and main findings of the study as well as the discussion and recommendation issues.

3. CASE OF YAMAL LNG PROJECT

The third chapter provides short description of the Yamal LNG Project and analysis of the shipping routes connected with this project. LNG shipping routes from Yamal are compared with the market leader in terms of transportation costs according to the LNG carriers' operating costs model. The discussion of the results and their further implementation are also mentioned. The concluding point of the chapter is the limitations of the study in terms of the analysis.

3.1 Overview of the Yamal LNG Project

Yamal LNG is the project is based on the Yamal Peninsula, above the Arctic Circle, and utilizes the resources of the South Tambey Field (Novatek 2016). The field's proven and probable natural gas reserves are estimated at 926 BCM. The liquefied natural gas (LNG) plant will be built in three phases which are scheduled for start-up in 2017, 2018, and 2019, respectively. The project will be producing 16.5 metric tonnes per annum (MTPA) of the liquefied natural gas and up to 1.2 MTPA of gas condensate which will be shipped to Asia-Pacific and European markets. The South Tambey Field Development License, held by Yamal LNG, is valid until December 31st, 2045 (Yamal LNG 2016).

Yamal LNG is a joint-venture of NOVATEK (50.1%), TOTAL (20%), CNPC (20%) and Silk Road Fund (9.9%). So, there are direct foreign investors from French and Chinese side which underlines the international interest in such type of Arctic projects. Moreover, JGC Corporation is taking part in the project in terms of engineering and procurement contracts for construction of LNG facilities (JGC Corporation 2017).

The Yamal Peninsula's unique location allows for flexible and competitive logistics, enabling year-round supplies of LNG to the Asia Pacific and European markets. Sabetta has become one of the ports of NSR by the Decree of the Federal Marine and River Transport Agency of July 25th, 2014 when it was included in the Russian Register of Seaports. Construction of a multifunctional Port of Sabetta in the scope of the Yamal LNG Project has been a public-private undertaking. Federal facilities (built by Federal Agency ROSMORPORT) include ice barriers, the harbor's operational aquatic area, the approach channels, the vessel navigation management and traffic control systems, and some buildings housing marine service companies. Yamal LNG facilities include jetties for liquefied natural gas and gas condensate offloading, material off-loading facilities, harbor fleet berths, warehousing facilities, administrative buildings and utilities. The port is being built in two phases – the early phase and the main phase. The early phase includes construction of the cargo terminal to support deliveries of construction materials and process modules. The port is currently operating year-round, facilitating the arrival and unloading of construction cargo, materials and equipment. Jetties for the offloading of LNG and gas condensate are to be built during the main phase of the port's construction, thus enabling the Port of Sabetta to be ready for the first LNG carriers in 2017 (Fig. 21) (Yamal LNG 2016).

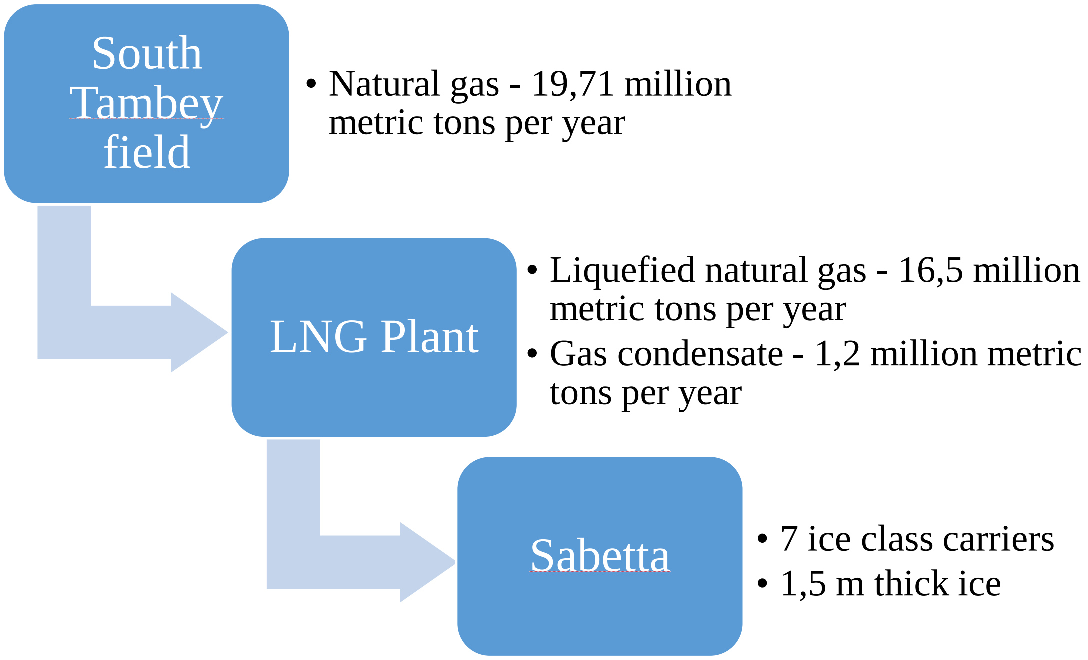

Fig. 21 Yamal LNG Project structure.

Virtually all estimated LNG output volume has already been committed under long-term sales and purchase agreements, and will be supplied primarily to Asian markets. In summertime, LNG will be delivered to the Northeast Asia through the Northern Sea Route, while in wintertime - via westward routes, with transshipment through one of the European regasification terminals. CNPC will purchase at least 3 million tons of LNG per year and 2.5 million tons per year will be supplied to Spanish Gas Natural Fenosa (Motomura 2014).

In order to provide the year-round transportation via NSR seven ice class carriers have been custom-designed and are being built for the Yamal LNG Project to support year-round navigation without any icebreaker assistance along westbound navigation routes, and during summer navigation season - eastbound via the Northern Sea Route. Being one-of-a-kind, these Arctic carriers have been created through the joint efforts of the Russian and international classification societies, leading scientific research organizations, shipyards and ship-owners, gleaning from their experience in navigating the waters of the Northern Sea Route. These LNG carriers are ARC7 tanker with the holding capacity around 170,000 cubic meters of LNG and ability to ship in in 1.5 - 2 meters thick ice (Yamal LNG 2016). The first of the Yamal carriers “Christophe de Margerie”, built on the shipyard of Daewoo Shipbuilding Marine Engineering in South Korea, successfully performed its trial voyage to Zeebrugge, Belgium in February of 2017 (Тэкноблог 2017).

3.2 LNG shipping routes

The term feasibility states the degree of being doable. So, the LNG transportation should be possible from both technical and economic sides. Technical side of the question has already been achieved by engineering and construction of the ice-class LNG carriers which can operate through two meters thick ice, using their own cargo as fuel. The part under consideration for this research is the economic side of LNG transportation. That is done on the example of the Yamal LNG Project. LNG transportation means shipping of LNG from port of load to port of discharge. Three shipping routes are based on the known supply agreements with CNPC and Spanish Gas Natural Fenosa:

- from Sabetta, Russia to Jiangyin, China via the NSR;
- from Sabetta, Russia to Jiangyin, China via the SCR;
- from Sabetta, Russia to Sagunto, Spain.

LNG will be transported via these routes all year round on the ice-class LNG carriers. The shipments will be implemented to Spain all year round, to China via NSR at least five months per year in summer navigation season from June to November, to China via SCR throughout the period of NSR inaccessibility due to extremely severe ice conditions.

The supply agreements for the Yamal LNG have already been signed, so it can be assumed that the LNG extraction and conversion is done according to the stable demand and there are several long-term buyers who has agreed to buy the specific amount of LNG yearly. As there is no data on the exact contract prices of LNG and the LNG cost price, it is rather difficult to evaluate the economic profitability of the LNG transportation. Therefore, the costs of the Yamal LNG transportation ought to be calculated and compared with the market leader in this sector in order to estimate the real economic viability of the NSR as an alternative shipping lane. The market leader in the transportation of LNG is Qatar. So, the transportation costs for the three routes from Yamal will be compared with the transportation costs for two routes from Qatar which are:

- from Ras Laffan, Qatar to Jiangyin, China;
- from Ras Laffan, Qatar to Sagunto, Spain via the SCR.

The routes are presented in figure 22.

Fig. 22 LNG shipping routes.

The LNG is transported in the special LNG carriers via these routes which characteristics are presented in table 6. The Yamal LNG is transported in the ice class Arc7 LNG carriers and the Qatar LNG is transported in the standard Q fleet LNG carriers.

Table 6 Characteristics of the vessels (Qatargas Operating Company Limited, SCF Group).

Characteristics	Q fleet	Arc7
LNG Tank Capacity	135 000 m3	170 000 m3
Length	297,5 m	299 m
Breadth	45,75 m	50 m
Draft	10,95 m	12 m
Speed	19,5 knots	20 knots

3.3 LNG carrier' operating costs

There are several types of estimation of economic efficiency of the voyage. The considered example uses calculations of the operating costs of the voyage with the full load to destination port and in ballast in return via the one route. Operating costs per voyage are calculated as follows in formula 2

(2) $C = Opt * D_t + F_l * D_l + F_b * D_b + TF_l + TF_b$;

where C stands for operating costs for the round voyage, Opt are general operating costs, D_t are all days of the voyage, F_l and F_b are fuel costs for laden and ballast ship, respectively, D_l and D_b are days of voyage in laden and ballast conditions, TF_l and TF_b are transit fees for laden and ballast conditions.

Operating costs for LNG carriers include such subsections as manning, insurance, repair, maintenance, stores and administration. Manning is crew salaries, recruitment and training processes, travel costs, union fees, costs on the medical tests and social dues, bank charges, crew accident insurance payments, sick pay, port expenses, agency fee and costs of navigator if his services are needed on the specific areas of the route such as the Strait of Malacca or Vilkitsky Strait. If the entire ship's crew is without experience of shipping in the Arctic waters, the presence of the professional navigator is the additional cost of manning for shipping via the NSR. Insurance costs can be divided into two types. The first one is the insurance protection for any damage done to the ship itself or to the equipment and machinery which are used for operational purposes and are part of the ship. The second type of insurance is connected with the third-party liabilities which are responsible for the commercial operation of the ship. Repair and maintenance costs mean maintenance of engine and equipment, painting, repair of the break downs and mechanical failures, spare parts for the equipment of the ship, safety equipment and costs on the periodic maintenance or planned docking which is generally done once in five years for the new vessels and once in three years for the long operating ships and which is needed to obtain certification. Store costs are provisions, fresh water supplies, lubricants, paints and other supplies which is needed on the route. Administration or management costs include port and agents' fees, licenses for the electronic maps, communication cost, fees for the passage of the special routes and channels such as the Panama Canal or the Suez Canal, flag state fees, armed security for the navigation in especially dangerous areas such as the Gulf of Aden or the Gulf of Guinea, commercial inspections of the vessel.

The daily operating costs for both types of the ships are presented in table 7. There are differences between each cost item and that is due to many factors. First of all, costs for manning are higher for ice-class ships in comparison with the non-ice-class ones because there is a need in the specifically trained crew and in the more expensive navigation in the Arctic waters. Insurance costs come secondly. From one point the fees should be higher for the more expensive and valuable ice-class ships, but LNG carriers from Q-Fleet have already been operating for many years, some of them even for more than several decades, and that fact increases the insurance rate. Moreover, if the exact case of Yamal LNG Project is to be considered, then it can be stated that the part of the insurance costs connected with the third-party liabilities are minimized as the whole process is done within the scope of Yamal LNG Project. Repair and maintenance costs are generally higher for older ships as there is a need for additional certifications and more often repair services with the years passed. As it was mentioned earlier LNG carriers from Q-Fleet are operating from 2004 and Yamal LNG Project carriers Arc 7 are going to start operating in 2017 (Riviera Maritime Media Ltd 2017). The next one are store costs which differs according to the crew and ship size. The data for store costs for LNG carrier Arc 7 are presented as an approximate estimation and have still not get the confirmation from the real voyage. The last but not the least comes administration costs. The transit fees are often included in this category of costs but not for the considered case and that fact provides the lower administration costs for LNG carrier Arc 7. The more detailed explanation of the transit fees is in the section below. Considering the stated costs, daily operations of LNG carrier Arc 7 are cheaper for nearly 10% than the same of the LNG carrier from Q-Fleet.

Table 7 Daily operating costs for the vessels.

Operating costs	LNG carrier Arc 7	LNG carrier Q-Fleet
Manning	4 760	3 935
Insurance	1 535	1 885
Repair and maintenance	1 715	2 630
Store	1 660	2 170
Administration	1 030	1 295
Total operating costs per day in USD	10 700	11 915

3.3.1 Transit fees

Fees for the passage of the special routes and channels can be considered as an administration costs but for the considered case they will be calculated separately. That is done to provide more accurate approach to the estimation of the operating costs. The Suez Canal passage fees and the NSR fees differ from each other in their initial purpose. The Suez Canal tolls are directly connected with the exact shipping of the vessel through the territory of the Canal which include tug, mooring and pilotage fees, whereas the NSR fees are connected with the ice-breaker assistance for the vessel, it is an additional services which is actually a necessity for most of the vessels when they are shipping in the Arctic seas.

The Suez Canal toll is calculated according to the ship type, its net tonnage, draft and beam. These tolls are presented with the 25% payment reduction for LNG carriers which were introduced in 2015 (Suez Canal Authority 2017). So, for the laden Arc 7 LNG carrier the Suez Canal toll is 163 966 USD, for the same vessel in ballast the toll is 140 573 USD. The toll for the Q-Fleet LNG carrier is a little bit higher due to the vessel's parameters, it is 181 321 USD for the laden ship and 155 325 USD for the ballast one (Table 8).

Table 8 The Suez Canal toll for the vessels (Suez Canal Authority 2017).

The Suez Canal toll, USD	LNG carrier Arc 7	LNG carrier Q-Fleet
Laden	163 966	181 321
Ballast	140 573	155 325

The NSR fees are determined by the navigation period, amount of Arctic zones to be passed through, ice class and tonnage of the vessel. The navigation period is divided into two seasons. The first one is from July to October and the second one is from November to June. These periods differ due to the ice coverage and, therefore, due to the ships' ability to travel via the NSR. The navigation recommendations are presented in tables 9 and 10. These recommendations depend on the ice reinforcement class of the vessel, the ice navigation mode (IN stands for the independent navigation and IS stands for the navigation with icebreaker support), the specific zone of the NSR (South-West part of the Kara Sea, North-East part of the Kara Sea, South-West part of the Laptev Sea, North-East part of the Laptev Sea, South-West part of the East Siberian Sea, North-East part of the East Siberian Sea and the Chukchi Sea) and the ice conditions, according to the Rosgidromet official information, such as S for the severe ice conditions, M for the moderate ice conditions, L for the light ice conditions.

Table 9 Navigation via the NSR for vessels class Arc4 – Arc9 from July to October (+ means navigation is allowed, – means navigation is not allowed) (Northern Sea Route Information Office 2017).

Ships ice reinforcement class	Ice navigation mode	The Kara Sea		The Laptev Sea		The East Siberian Sea		The Chukchi Sea
		South-West part	North-East part	South-West part	North-East part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
Arc4	IN	- + +	- + +	- - +	- - +	- - +	- - +	- + +
	IS	+ + +	+ + +	- + +	- + +	- + +	- + +	- + +
Arc5	IN	+ + +	+ + +	- + +	- + +	- + +	- + +	- + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc6	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc7	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc8	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc9	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

Table 10 Navigation via the NSR for vessels class Arc4 – Arc9 from November to June (+ means navigation is allowed, – means navigation is not allowed) (Northern Sea Route Information Office 2017).

Ships ice reinforcement class	Ice navigation mode	The Kara Sea		The Laptev Sea		The East Siberian Sea		The Chukchi Sea
		South-West part	North-East part	South-West part	North-East part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
Arc4	IN	- - +	- - +	- - +	- - +	- - +	- - +	- - +
	IS	- - +	- - +	- - +	- - +	- - +	- - +	- - +
Arc5	IN	- - +	- - +	- - +	- - +	- - +	- - +	- - +
	IS	- - +	- - +	- - +	- - +	- - +	- - +	- - +
Arc6	IN	- - +	- - +	- - +	- - +	- - +	- - +	- - +
	IS	- + +	- + +	- - +	- - +	- - +	- - +	- + +
Arc7	IN	+ + +	- + +	- - +	- - +	- - +	- - +	- + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc8	IN	+ + +	+ + +	- + +	- + +	- + +	- + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc9	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

The calculation of the NSR fees for the considered case comes from the vessel and route specifications which state that the vessel has ice strengthening class Arc 7 and needs pilotage within all 7 zones of the NSR. According to the table 11, the tariff is 437,91 RUR per a unit of gross tonnage for summer – autumn navigation season. The gross tonnage of the considered LNG carrier is 60 000 tones. Therefore, the overall NSR fees for the laden vessel are 26 274 600 RUR or 445 332 USD.

Table 11 NSR tariffs for ships of gross tonnage from 40 001 to 100 000 (Federal State Institution the Northern Sea Route Administration 2017).

Ice class of vessel	Tariff per a unit of gross tonnage in RUR						
	Conduct in 1 Zone	Conduct in 2 Zones	Conduct in 3 Zones	Conduct in 4 Zones	Conduct in 5 Zones	Conduct in 6 Zones	Conduct in 7 Zones
	Tariffs for summer – autumn navigation period						
None	446,84	536,21	625,58	714,95	804,32	893,68	893,68
Ice 1	312,79	375,35	437,91	500,46	563,02	625,58	625,58
Ice 2	290,45	348,54	406,63	464,72	522,81	580,90	580,90
Ice 3	268,11	321,73	375,35	428,97	482,59	536,21	536,21
Arc 4	223,42	268,11	312,79	357,47	402,16	446,84	446,84
Arc 5	221,19	265,42	309,66	353,90	398,14	442,37	442,37
Arc 6 - Arc 9	218,95	262,74	306,53	350,32	394,12	437,91	437,91
	Tariffs for winter-spring navigation period						
Arc 4	558,55	670,26	781,97	893,68	1005,40	1117,11	1117,11
Arc 5	552,97	663,56	774,15	884,75	995,34	1105,94	1105,94
Arc 6 - Arc 9	547,38	656,86	766,33	875,81	985,29	1094,76	1094,76
Icebreaker 6 - Icebreaker 8	541,80	650,16	758,52	866,87	975,23	1083,59	1083,59

However, the NSR tariffs stated in the table above are not always the final ones. There are special discounts which depends on the type of ship, type of cargo and the overall amount of voyages throughout the route per year. The amount of discount for the ice-class vessels can be up to 80%, for the hydrocarbon cargo such as oil and gas it is up to 50%. Yamal LNG Project has one of the best ice-class ships which are built to transport LNG on a year-round basis, therefore, according to the statistical data of the NSR Information Office, the estimated discount should be about 70%. The final NSR fees for both routes are presented in table 12.

Table 12 NSR fees with discount.

Route	Sabetta - Jiangsu	Sabetta - Sagunto
Zones of the NSR	7 zones	1 zone
NSR fees in $	133 600	16 147
NSR fees per round voyage in $	267 199	32 295

3.3.2 Fuel costs

Fuel costs are stated separately as they provide at least half of all the costs for round voyage. There are several types of calculations of fuel consumption and for the considered case study the model with the Specific Fuel Oil Consumption (SFOC) is used. Specific Fuel Oil Consumption is related to calculation of fuel efficiency in an engine which burns fuel to produce a thrust as an output. The fuel consumption in that model depends on the design and state of hull and engine power. The calculations of the fuel consumption of the LNG carrier is presented in formula (3)

(3) Fuel consumption = SFOC * engine power * sailing hours

SFOC values are known for different types of vessels and they are 180 gram/kW/hour for the LNG carrier Q-Fleet and 200 gram/kW/hour for the LNG carrier Arc 7 (MAN Diesel & Turbo 2017). Engine power for both types of the vessels is 15 MW. Sailing hours for each route are presented in table 13.

Table 13 Sailing hours for the routes.

Characteristic	**Route type**				
Port of departure	Sabetta, Russia	Sabetta, Russia	Ras Laffan, Qatar	Sabetta, Russia	Ras Laffan, Qatar
Port of arrival	Jiangsu, China	Jiangsu, China	Jiangsu, China	Sagunto, Spain	Sagunto, Spain
Sailing hours	405	645	296	210	244

According to the formula (3), the fuel consumption for the laden voyage is stated in tons. The fuel consumption for the ballast voyage is lower by 30%. The fuel costs are calculated as fuel consumption * price of fuel. The LNG carriers can use different types of fuel such as Intermediate Fuel Oil (IFO), Marine Diesel Oil (MDO) and Marine Gas Oil (MGO), depending on their type of engines, but in recent years they are using MGO more and more and even trying to use LNG which is their cargo as a fuel. Therefore, the price for MGO will be taken as an average for the last 3 months from data of Rotterdam port (Ship & Bunker, Bunker ports news worldwide). The price is

487 US dollars per metric ton of MGO. As a result, the calculations for the fuel costs can be done and they are presented in table 14.

Table 14 Fuel consumption for the routes.

Characteristic /Costs	**Route type**				
Port of departure	Sabetta, Russia	Sabetta, Russia	Ras Laffan, Qatar	Sabetta, Russia	Ras Laffan, Qatar
Port of arrival	Jiangsu, China	Jiangsu, China	Jiangsu, China	Sagunto, Spain	Sagunto, Spain
Fuel consumption in laden in tons	1 215	1 936	799	630	659
Fuel consumption in ballast in tons	851	1 355	560	441	461
Fuel cost in laden in $	591 838	942 856	389 278	306 956	320 836
Fuel cost in ballast in $	414 286	659 999	272 494	214 869	224 585
Fuel cost per round in $	1 006 124	1 602 856	661 772	521 825	545 421

3.3.3 Total operating costs per round voyage

All components of the model of the operating costs of vessel per voyage have been described and, therefore, the total operating costs per round voyage for the each route can be stated (table 15).

Table 15 Total operating costs per round voyage.

Characteristic/Costs	Route type				
Port of departure	Sabetta, Russia	Sabetta, Russia	Ras Laffan, Qatar	Sabetta, Russia	Ras Laffan, Qatar
Port of arrival	Jiangsu, China	Jiangsu, China	Jiangsu, China	Sagunto, Spain	Sagunto, Spain
Via NSR or SCR	NSR	SCR		NSR	SCR
Distance between ports (nm)	5 482	12 907	5 773	4 202	4 758
Days of voyage	22	32	17	12	15
Operating costs in $	468 206	682 437	413 104	251 539	361 422
Manning	4 760	4 760	3 935	4 760	3 935
Insurance	1 535	1 535	1 885	1 535	1 885
Repair and maintenance	1 715	1 715	2 630	1 715	2 630
Store	1 660	1 660	2 170	1 660	2 170
Administration	1 030	1 030	1 295	1 030	1 295
Total oper costs per day	10 700	10 700	11 915	10 700	11 915
Fuel costs in $	1 006 124	1 602 856	661 772	521 825	545 421
Laden fuel costs	591 838	942 856	389 278	306 956	320 836
Ballast fuel costs	414 286	659 999	272 494	214 869	224 585
Fees costs in $	267 199	336 834	-	32 295	336 646
NSR fees	133 600	16 147	-	16 147	-
NSR fees per round voyage	267 199	32 295	-	32 295	-
SCR fees laden	-	163 966	-	-	181 321
SCR fees ballast	-	140 573	-	-	155 325
Total USD	**1 741 530**	**2 622 127**	**1 074 877**	**805 660**	**1 243 488**

According to the results of the calculations, if LNG is transported from Yamal to the Asian market, for instance, China, then transportation via the NSR allows to save up to 34% of the transportation costs. However, even the usage of the NSR will not allow to compete with the market leader (Qatar) as the costs are higher on 38% in comparison. That is mainly due to the NSR transit fees and fuel consumption rate in the Arctic waters. If LNG is transported from Yamal to the European market, the considered case is Spain, then the LNG shipping is economically effective as the transportation costs go 35% below the market leader. In this case, that is mainly due to the SCR tolls. Therefore, in both cases of transportation LNG to European and Asian market the operating costs differs crucially to transit fees and fuel consumption rate. That are two main obstacles on the cost efficiency of LNG transportation from Yamal LNG facility.

3.3.4 Limitations

The study has several limitations for the conducted analysis and the final results. These limitations are connected with the lack of availability of information.

First of all, there are not so many ice-class LNG carriers and the data on their capital costs differs among different companies both manufacturing and shipping ones. That has led to the fact that the model used for the analysis of the LNG carrier's shipping costs includes only operating costs of the vessel. If the data on capital costs is available and relevant, it should be added to the model in order to provide more holistic approach for the analysis of the transportation costs.

Secondly, if the operating costs of LNG carriers are to be considered more precisely, then there are also differences in the approaches of calculations. The study has been conducted on the basis of all available information on LNG carriers' costs which had been provided according to the clauses of the non-disclosure agreements. However, the more accurate data can be used for the analysis if companies are agreed to provide it for the study.

All in all, the limitations of the results are linked either with the lack of the relevant statistics on the vessels' operating costs or with the corporate rules of non-disclosure of information, especially those information which is connected with the operations.

3.4 Discussion and further implementation of the study

3.4.1 Oil and gas fields in the Arctic region

The considered case of the Yamal LNG Project can be adopted to some other oil and gas fields which are currently under development phase in the Arctic region. According to the figure 23, there are several international oil and gas projects within the NSR that means the usage of the NSR for the transportation of oil and gas products has still not been used to the entire capacity.

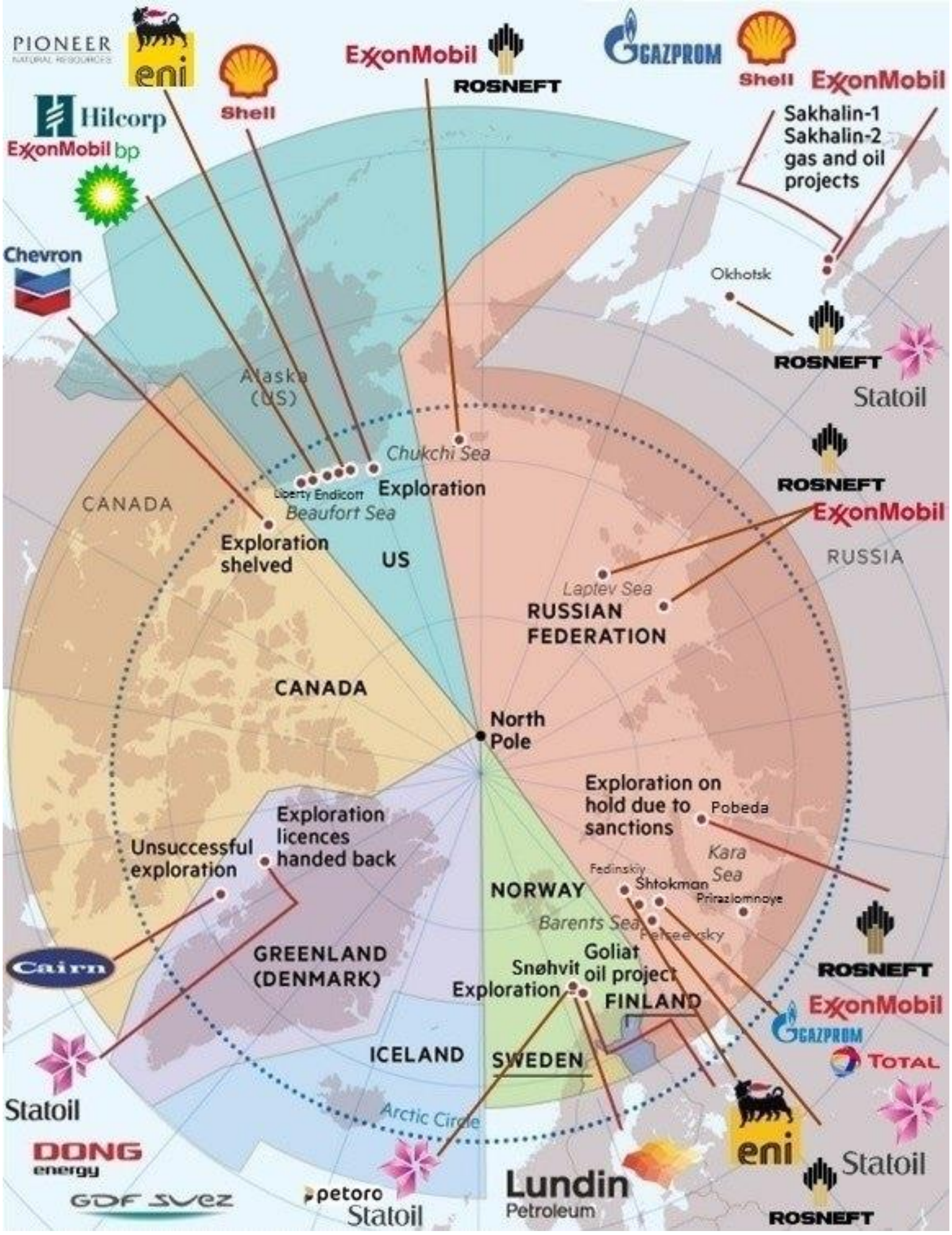

Fig. 23 Oil and gas development in Arctic divided among Arctic countries («Арктика-Инфо» 2016).

One of such examples is the Shtokmanovskoye (Shtokman) gas and condensate field which is presented in figure 24. The closest ports which the LNG is planned to sail from are Teriberka and Murmansk. The development of the Shtokman field is divided into three phases. Shtokman will produce 23,7 billion cubic meters of gas per year after the implementation of the Phase 1 facilities and 47,4 billion cubic meters of gas per year after the Phase 2 facilities are commissioned. The field will reach its design capacity of 71,1 billion cubic meters of gas per year after the launch of the Phase 3 (Gazprom 2017). Therefore, the NSR is supposed to be demanded for LNG transportation from this field to the Asian market which is struggling for the gas more and more in recent years. Another gas field which can influence the LNG traffic via NSR is Bovanenkovskoye field (fig. 24). Bovanenkovskoye field is the largest field in the Yamal Peninsula. Its explored and preliminary estimated gas reserves amount to 4,9 trillion cubic meters. Gas production is planned at 115 billion cubic meters annually. Overall, there will be three upstream facilities in operation. Two of them have been already brought into action in 2012 and 2014 (Gazprom 2017).

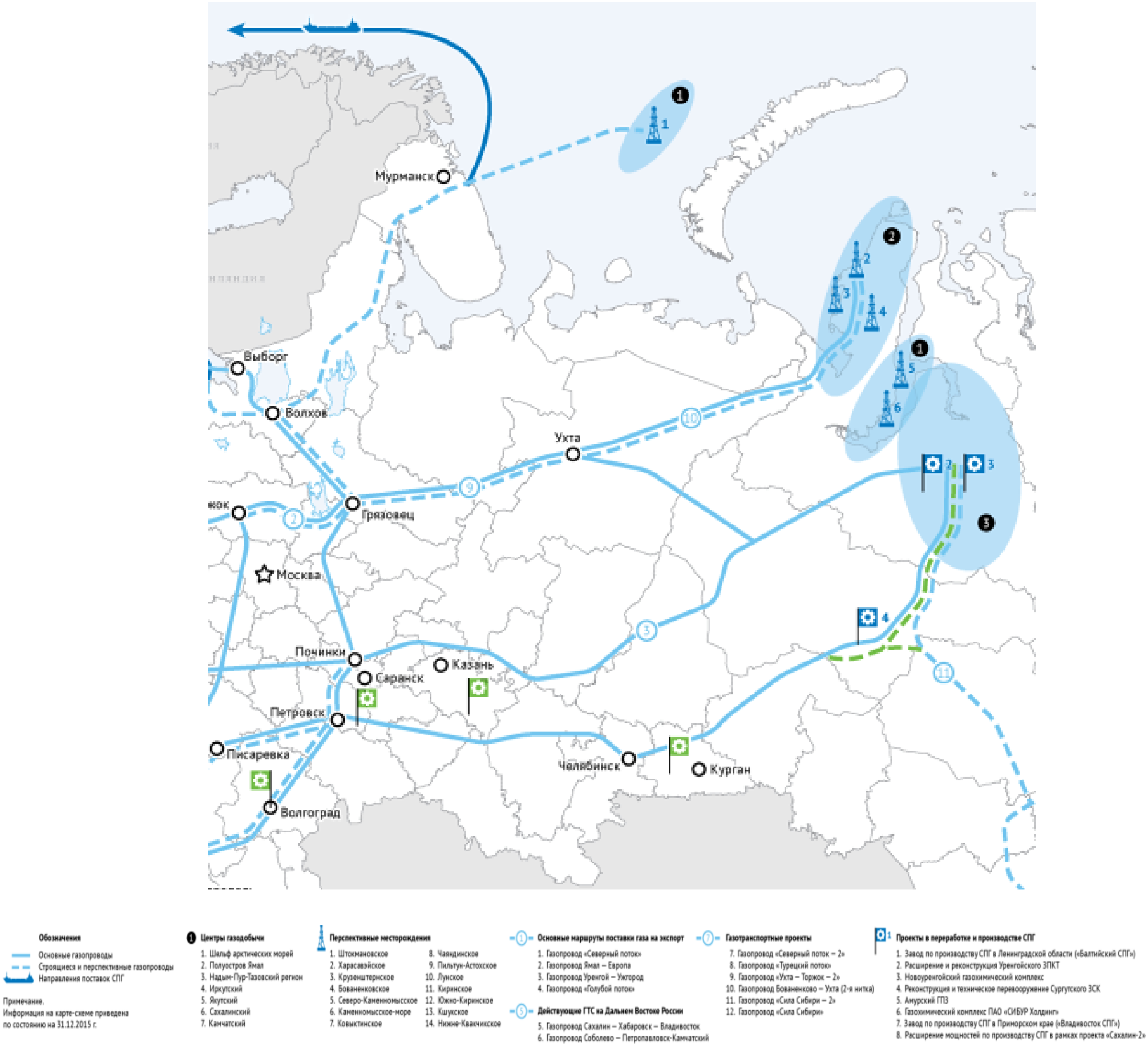

Fig. 24 Gazprom current and future projects (Gazprom 2017).

All in all, the NSR traffic in terms of LNG and petrochemicals transportation has not developed yet as most of the fields which are going to use it are still under exploration and construction phases. However, when these facilities are launched, the NSR will become the demanded shipping lane and the approach introduced in the study can be used for the comparison of the transportation efficiency among different routes.

3.4.2 Underwater LNG carriers

The innovative peculiarity of the Yamal LNG Project is the development of ice-class LNG carriers exactly for the operating via the NSR. The analysis of the fuel consumption rate has considered the most updated information on the ice-class LNG carriers. However, the engineering progress is coming further than the improvement of engines. One of the latest ideas for the transportation via the NSR is the introduction of the underwater LNG carrier (fig. 25).

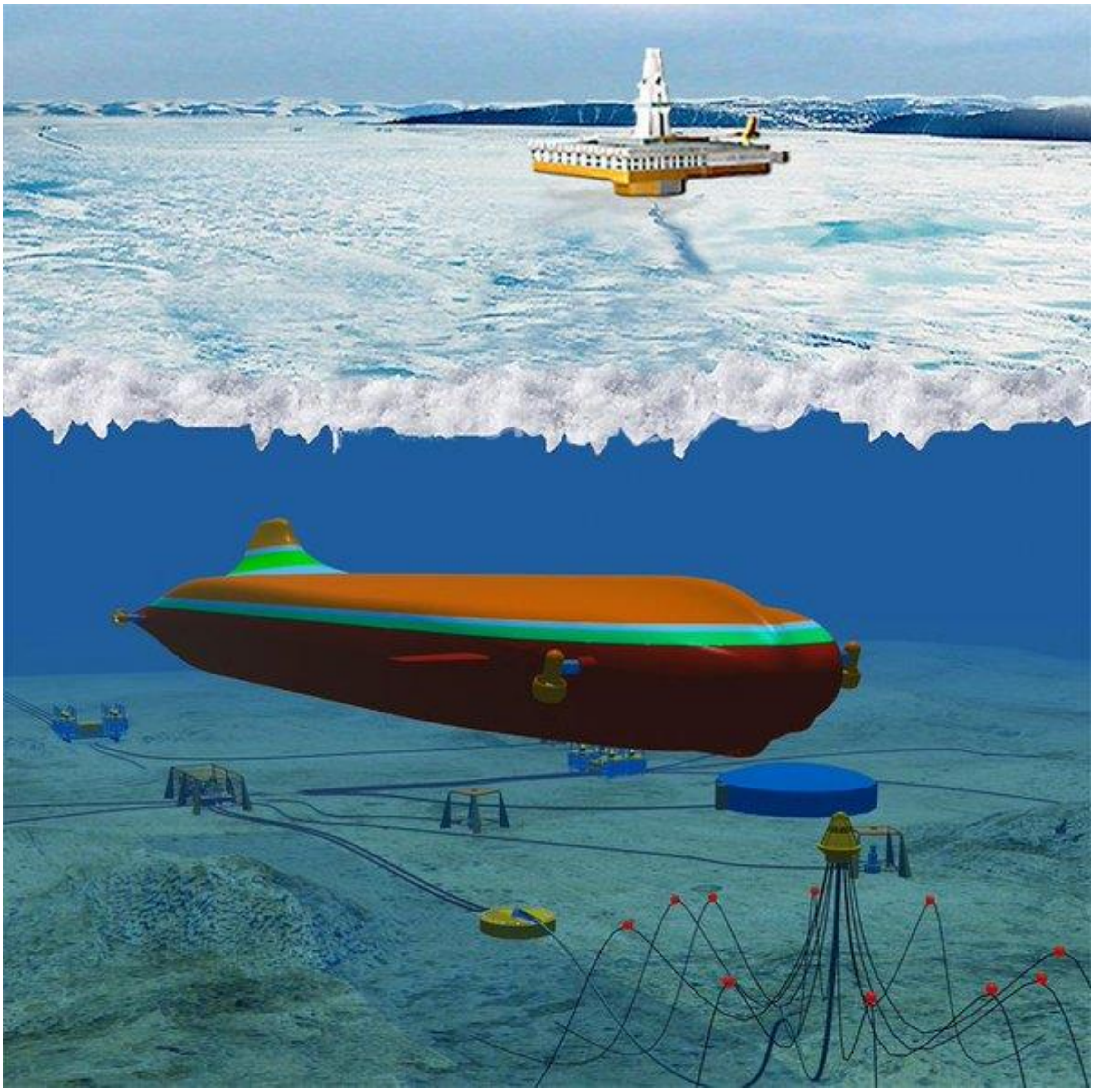

Fig. 25 Underwater LNG carrier (Researchgate 2017).

The underwater LNG carrier has already been patented and relates to the underwater shipbuilding. The exploration of oil and gas fields in the Arctic region will bring the issue of gas and oil products transportation throughout the year via the NSR which is covered by impassable ice for at least five months per year. The implementation of underwater carriers solves this issue. However, the underwater vessels are built and used mainly for scientific and military reasons, not for the commercial ones. That fact worsens the perception of the underwater carriers as a possible and justified type of marine transport for shipping companies.

Considering the technical issues of the underwater LNG carrier, it can be stated that the capacity can be up to 150 000 cubic meters which is comparable to the usual LNG carrier. LNG is transported in closed spherical shells of small diameter which are put in a lightweight underwater LNG carrier. The shell design considers both the external water pressure and the internal pressure of the gas. Therefore, LNG can be transported all year round, despite weather conditions of the Arctic regions. Moreover, the round voyage of the underwater vessel is at least twice shorter than the same voyage of the usual vessel (RussianPatents). In conclusion, the constant development and improvement of the LNG carriers will lead to the gradual implementation of the underwater commercial vessels and that brings the question of the cost efficiency of such vessels and the cost of transportation on these carriers in comparison with the ordinary ones.

Conclusion

The chapter was devoted to the analysis of the LNG transportation on the case of the Yamal LNG Project. The general description of the project itself as well as the transportation routes and the LNG carriers was provided. The routes represented the two main sites of LNG production (the considered case and the market leader) and the two main buyers of LNG (European and Asian markets). Operating costs for five routes were analyzed according to the model and provided the results which proved the economic feasibility of the usage of the NSR for LNG transportation. The chapter is concluded by the discussion on the possible further directions of the study.

CONCLUSION

The study has provided an overview of the liquid natural gas transportation via the Northern Sea Route on the example of the Yamal LNG Project. The purpose of the study was to evaluate the economic feasibility of liquid natural gas transportation via the Northern Sea Route. That has been done through the analysis of the academic views on the issue, the modelling of the appropriate approach for calculation of the transportation costs and the comparison of the Yamal LNG Project results with the market leader.

The first chapter has described, from one side, peculiarities of the NSR in terms of its usage by shipping companies and its issues as the shipping lane within the Russian Exclusive Economic Zone and, from the other side, the liquid natural gas market and its upcoming trends which have direct influence on the traffic of vessels via the NSR. The main existing models for calculation of cargo transportation via the NSR have concluded this chapter.

The second chapter was devoted to the explanation of the research design and methodology. The data for the analysis was collected from the interviews with experts and opened secondary sources of information. That has led to the usage of the single case study method as the appropriate one due to the limited availability of the information. The case of the Yamal LNG project was used as the latest and most updated example of the developed Arctic field entirely connected to the NSR in terms of transportation of its final products.

The third chapter provided the detailed analysis of different routes of LNG transportation. These routes are based on the officially signed contracts of the Yamal LNG Project and represents the two main buyers of Russian LNG which are Europe and Asia. The routes were constructed from Sabetta, Russia to both Jiangsu, China and Sagunto, Spain. These routes were compared with the alternative routes to the same point of destination from the market leader in LNG transportation, Qatar. The LNG carrier operating costs per round voyage for each route has been calculated. The results has proved the superiority of the NSR in comparison to the SCR in terms of time and fuel consumed per round voyage. Also the results of the analysis showed that Russian LNG can be comparatively competitive to the Qatari LNG in some cases. The results of the study in their correspondence to the research questions are shown in figure 26.

Research question	Result
What are the operational costs of the LNG transportation via the NSR?	• 1 741 530 USD per round voyage of ice-class LNG carrier
To what extend the LNG transportation via the NSR is economically efficient in comparison with other routes?	• LNG via NSR to China allows to save up to 34% of the transportation costs • LNG to Spain is 35% below the market leader in terms of costs
How does the extraction of oil and gas in the Arctic regions influence the development of cargo traffic via the NSR?	• Increase of the traffic by 25%
What measures should be taken by companies in order to use the entire capabilities of the NSR for lowering the transportation costs?	• More vessels on the route >> Less ice-breaker assistance >> Lower costs

Fig. 26 The research questions and results.

In conclusion, it can be stated that the NSR will develop as a shipping lane as the demand for it is increasing with the development of gas fields in the Arctic region. However, there are a lot of circumstances which distort and prevent the active usage of the NSR by carriers. These issues ought to be taken precisely and be solved as soon as possible as the demand for the Arctic liquid natural gas is constantly growing and the only way to decrease its transportation costs is to use the entire capabilities of the Northern Sea Route.

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