Current status and future operational models for transit shipping along the Northern Sea Route

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CURRENT STATUS AND FUTURE OPERATIONAL MODELS FOR TRANSIT SHIPPING ALONG THE NORTHERN SEA ROUTE

ABSTRACT

The Northern Sea Route (NSR) has received increased international attention during the recent years as an alternative transit corridor for shipping between Europe and East Asia. In 2015, the project "Feasibility and Reliability of Shipping on the Northern Sea Route and Modeling of an Arctic Marine Transportation & Logistics System" was established to perform a comprehensive analysis of the current status and future prospects of NSR transit shipping. The project brought together several partners and numerous participants representing industry, governmental bodies, and research groups from Europe, Asia, and Russia, thus providing a unique and comprehensive overview of the subject. This paper is based on the insights gathered during the project. Firstly, it provides a comprehensive overview of the NSR's current regulations and support services. Secondly, it combines the information on the current status of the route with feedback received from the stakeholders during project discussions for the purpose of establishing several possible future operational models for transit shipping along the NSR. It is concluded that the most probable of the analyzed operational models is a combination of ice-strengthened vessels and independent ice-going cargo vessels. This model requires a decrease in severity of ice conditions to allow for year-round commercial navigation, an increase in bunker prices, further development of maritime infrastructure and icebreaking support, and the development of new maritime insurance models. Additionally, establishing transshipment hubs at each end of the NSR with ice-going cargo vessels sailing between them is also considered to be a viable future option.

Keywords: Northern Sea Route (NSR); Trans-Arctic shipping; Inter-continental shipping; Russian icebreakers; NSR maritime infrastructure, ARCTIC 2030.

1. INTRODUCTION

The Northern Sea Route (NSR)[1] presents a potential shortcut for transit shipping[2] between Europe and East Asia, which can be used in order to save fuel and/or time (see Østreng et al., 2013 for details about shipping along the NSR). In recent decades, the reduction of ice extent and thickness in the Arctic resulted in increased international interest in using the NSR for intercontinental shipping (DNV, 2010). Specifically, in 2010, Tschudi Shipping and its partners realized the first international transit voyage along the NSR resulting in costs savings (Tschudi, 2010). This event triggered a surge of interest for the NSR amongst non-Russian shipowners resulting in a rise in the annual number of commercial transit voyages along the NSR, culminating in 71 transits in 2013 (transit statistics available at www.arctic-lio.com). In the following years, however, the number of transit voyages decreased again due to various reasons, such as reduced bunker prices, geopolitical circumstances, cargo unavailability, ice conditions, etc.

Transit shipping along the NSR has been extensively studied throughout the years. In recent years, several studies have discussed the current status and future prospects of the NSR transit shipping from different perspectives. Marchenko (2014) presented an overview of historical development of the NSR together with the current status of various shipping-related aspects. Bekkers et al. (2016), Kiiski et al. (2016), Pruyn (2016) and Zhang et al. (2016a) discussed future prospects of NSR transit shipping from a techno-economic perspective. Jianmin et al. (2015) analyzed the

[1] "The area of the Northern Sea Route means a water area adjoining the northern coast of the Russian Federation, including internal sea waters, territorial sea, contiguous zone and exclusive economic zone of the Russian Federation, and limited in the East by the line delimitating the sea areas with the United States of America and by the parallel of the Dezhnev Cape in the Bering Strait; in the West, by the meridian of the Cape Zhelanie to the Novaya Zemlya archipelago, by the east coastal line of the Novaya Zemlya archipelago and the western limits of the Matochkin Shar, Kara Gates, Yugorski Shar Straits." (definition adopted from The Federal Law of July 28, 2012, N 132-FZ "On Amendments to Certain Legislative Acts of the Russian Federation Concerning State Regulation of Merchant Shipping on the Water Area of the Northern Sea Route")

[2] The term "transit shipping" applies for using the NSR for sailing between continents. Due to the lack of intermediate hubs along the NSR resulting from the lack of hinterland in the Russian Arctic, only cargo going directly from Europe to East Asia (or vice-versa) is considered eligible for transit shipping via the NSR. The NSR can also be used for destination shipping (e.g. supporting energy projects in the Russian Arctic), but that is not the focus of this paper.

potential of container shipping through the NSR, while Cariou and Faury (2015) discussed bulk shipping. Zhang et al. (2016b) discussed the NSR transit shipping from the shipowners' perspective, while Lee and Kim (2015) performed a similar analysis focusing on three South Korean shipping companies. Kim (2015) discussed South Korea's Master Plan for the development of Arctic shipping, while Zhao et al. (2016) discussed China-EU container shipping network in the context of the NSR. Beveridge et al. (2016) discussed general interest of Asian shipping companies in navigating the Arctic.

These studies provide valuable insights from their own perspectives. However, an integrated study comprising of insights from stakeholders from different fields and from all three regions involved – Europe, Asia, and Russia – is currently missing. This is especially true regarding accurate and up-to-date information from the Russian side, which is scarce in the literature.

The project "Feasibility and Reliability of Shipping on the Northern Sea Route and Modeling of an Arctic Marine Transportation & Logistics System" was established in 2015 to address this issue and provide a more complete picture of the current state and future perspectives of transit shipping along the NSR. The project was initiated by Centre for High North Logistics (CHNL, www.chnl.no) of the Nord University in Bodø, Norway and the Institute of Arctic Logistics (IAL) of the Youngsan University in Busan, South Korea. The project was funded by the Ministry of Foreign Affairs of Norway (ARCTIC 2030 Programme) on one side and by the Ministry of Oceans and Fisheries of South Korea on the other. The project lasted from April 2015 until December 2016 as a joint research venture of CHNL and IAL with the following project partners: Federal State Unitary Enterprise (FSUE) Rosatomflot, Murmansk, Russia; Department of Marine Technology at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway; DNV GL, Høvik (Oslo), Norway; and Norwegian Shipowners' Association, Oslo, Norway. The project was organized in a series of six one-day workshops held in Norway and South Korea, with the goal to perform a comprehensive analysis of the current commercial transport and logistics operations, operational efficiency, cargo base, costs, infrastructure needs, and security and safety of transit shipping along the NSR. At each workshop, project partners presented their research on different topics, followed by the discussions. In addition to project partners listed above, workshops brought together various participants from industry and academia, including representatives of Norwegian academic institutions; international oil & gas companies; Norwegian and Finnish ship owners with experience in NSR sailing; South Korean shipyards; Norwegian Protection & Indemnity (P&I) company; and political authorities of South Korea. Additionally, interviews with several important stakeholders (mainly on the Russian, Norwegian and South Korean side) who were unable to participate at the workshops were conducted by the project partners, insights from which were included in their presentations. Consequently, this combination of partners and participants from different fields and regions of the world – Europe, Asia, and Russia – provided a new and more complete perspective on the subject of NSR transit shipping.

This paper is based on the insights gathered during the project and uses them as a basis for establishing future operational models for transit shipping along the NSR. Section 2 presents an overview of the NSR's current regulations and support services based on the publicly available information and on the knowledge collected during the project. The challenges identified by the project partners and participants are discussed in Section 3. In Section 4, different future operational models for transit shipping along the NSR are studied. Section 5 concludes the paper.

2. NSR'S CURRENT REGULATIONS AND SUPPORT SERVICES

During the project discussions, it became apparent that there is still a lack of information amongst non-Russian shipowners regarding various aspects of the NSR transit shipping. This section tries to reduce this knowledge-gap by providing a comprehensive overview of the existing data and adding to it with the information gathered during the project.

2.1 Rules and regulations governing the NSR shipping

2.1.1 Russian rules and regulations

Since the opening of the NSR for international traffic in 1991, the Russian Federation has been continuously developing rules and regulations governing shipping along the NSR (for details on historical development of the regulations see Solski, 2013).

The year 2013 marked the beginning of a new era for the NSR, mainly through the implementation of the “New Rules of Navigation on the NSR” (Rules of navigation in the water area of the Northern Sea Route, 2013). Also, “The Northern Sea Route Administration Office” (NSRA, www.nsra.ru) was reorganized and established in its current form the same year. The aim of the 2013 rules was to simplify administrative procedures and processing of applications for the NSR sailing permit, issued by the NSRA. Table 1 presents an overview of the most important changes to come out of the new regulations and bureaucratic reorganization implemented in 2013.

Table 1, Comparison of NSR regulations before and after 2013

Before 2013	After 2013
Every vessel intending to navigate through the NSR – either for destination shipping or transit – shall obtain a sailing permit.	
Ship’s master or person replacing him shall be experienced in operating a vessel in ice.	
Obligatory requirements to have Civil Liability Certificate for oil pollution.	
Shipowners intending to use the NSR should submit a request for a sailing permit to the Administration of the NSR at least 4 months in advance.	The application for the sailing permit with all necessary documents attached is to be sent to the NSRA via e-mail no earlier than 120 calendar days and no later than 15 working days before the intended date of the entering of the ship into the NSR water area.
Mandatory ship inspection.	Ship inspection not needed, only documents sent by e-mail.
Vessel must have at least Arc4 or 1-A ice class (for transit).	Flexible system. Admittance criteria dependent on season, ice class, NSR area, and actual ice conditions.
Mandatory icebreaker (IB) assistance.	IB assistance can be either mandatory or optional depending on prevailing ice conditions.
Calculation of IB assistance costs reached through negotiations.	Calculation of IB assistance costs according to tariff tables, which present maximal allowable tariffs. Still, the operator has freedom to reduce the price if deemed justified.

2.1.2 Admittance criteria for the NSR sailing Permit

For a shipowner to use the NSR for transit shipping, it is necessary to obtain the NSR sailing permit, which is issued by the NSRA and is free of charge. The shipowner applies for the sailing permit by submitting the voyage details through the application portal on the NSRA's website. The application for the sailing permit is then considered by the NSRA and a decision is made within 10 working days. The admittance criteria regarding ice conditions, NSR's navigational zones, vessel's ice class, mode of sailing (with or without IB support), and sailing season can be found in the Rules of Navigation in the Water Area of the Northern Sea Route (2013).

The most common reasons for refusal of issuance of the NSR sailing permit are:

- Some or all of the submitted documents are expired.
- The documents will expire before the period of the planned navigation on the NSR.
- Planned area of navigation is beyond the permitted area as specified by the classification certificate.
- Attachments to the application for the sailing permit are not provided. The application is not filled out or filled incorrectly (dates or routes of navigation are indicated improperly).

2.1.3 International rules and regulations

The main international regulating bodies relevant for the NSR are the International Maritime Organization (IMO), together with international conventions UNCLOS, SOLAS, MARPOL, and STCW (see e.g. Buixadé Farré et al., 2014 for more details on international rules and legislation). In January 2017, IMO's Polar Code (IMO, 2017) came into force introducing new safety requirements for ships sailing in polar waters. Shortly thereafter, the Ministry of Transport of the Russian Federation made the Polar Code's certificates (Polar Ship Certificate, Polar Water Operational Manual, and Qualification of Deck Officers) a mandatory requirement for issuance of the NSR sailing permit (www.arctic-lio.com/node/266). This is expected to have a positive effect on safety and long-term sustainability of NSR shipping, reducing risks and aligning Russian rules and regulations with international standards.

2.1.4 Maritime insurance for vessels sailing along the NSR

According to AMSA (2009), Arctic shipping will not be sustainable without the availability of marine insurance at reasonable commercial rates. Regular Hull & Machinery (H&M) insurances do not offer coverage in latitudes above 70° North ("excluded trading areas") or in areas such as the Barents, White, Chukchi, and Okhotsk Seas. There, special arrangements are required with the insurer, including additional Hull premiums. Currently there are no additional premiums or restrictions on the P&I coverage for sailing in the Arctic, despite increased marine liability risks in these areas. According to Russian legislation, P&I insurance is required for foreign ships sailing along the NSR. The insurance market is currently not charging additional premiums for cargoes on Arctic trade routes under a worldwide policy. For special cargoes, perceived additional Arctic exposure is likely to be taken into account in the original rating. Still, due to limited number of transit voyages, the risks of sailing the NSR are difficult to calculate for the insurance companies.

2.2 Sailing in ice and icebreaker support

2.2.1 Classification of ice conditions

Ice conditions along the NSR are evaluated by the Arctic and Antarctic Research Institute (AARI, www.aari.ru). The ice charts are available on the NSRA's website and updated on a regular basis. Ice conditions are classified as: "heavy" (20% more severe ice conditions than multi-year averages for certain part of the route and season); "medium" (multi-year average ice conditions for certain part of the route and season); and "low" (20% less severe ice conditions than multi-year averages for certain part of the route and season), see Mironov (2013) for details on classification of ice conditions. The ship's master can obtain both the current ice conditions as well as forecasts for the planned route and determine whether IB assistance will be required according to the recommendations laid out in the sailing permit (in the case of IB assistance being optional).

2.2.2 Icebreaker assistance and Rosatomflot’s tariff system

IB assistance is performed by the icebreakers authorized to navigate under the state flag of the Russian Federation and the list of organizations providing such services is available on the NSRA website. Rosatomflot is the only organization operating nuclear-powered icebreakers and is usually employed as a convoy escort along the NSR since the nuclear icebreakers have the highest level of autonomy and icebreaking capacity (see www.rosatomflot.ru for the Rosatomflot’s nuclear IB fleet).

In 2014, the current tariff system for the Rosatomflot’s IB services was established. A tariff calculator is available on the NSRA’s website and calculates the highest possible tariff a shipowner can be charged (note: Rosatomflot reserves the right to reduce the IB tariffs if needed). The tariff is based on the following parameters:

- Number of navigational zones along the NSR for which IB assistance is required.
- Season of navigation.
- Vessel’s ice class.
- Vessel’s gross tonnage.

It should be noted that the calculated tariffs are valid only for assistance provided by Rosatomflot and not for other providers. The tariffs are valid both for destination and transit shipping along the NSR and apply only to escort services. Other IB services (e.g. salvage operations, icebreaking to provide port access, assistance to vessels stuck in ice, etc.) are not regulated by the tariff system.

2.2.3 Ice pilots/navigators

In the case that a ship’s master has insufficient experience navigating in ice along the NSR, an ice pilot needs to be present on the bridge. Such a requirement is stated in the sailing permit. The purpose of ice pilot’s assistance is to ensure the safe navigation through the NSR, prevent accidents, and protect the marine environment in the water area of the NSR. The rates for ice pilot assistance along the NSR have not yet been officially determined. In practice, approximately 1000 USD per day, per person has been charged. A list of organizations providing ice pilotage services is available on the NSRA's website.

2.2.4 Russia's icebreaker fleet

Out of approximately 80 icebreakers in operation worldwide, more than 40 are sailing under the state flag of the Russian Federation. Most of these are diesel-powered icebreakers and only five are nuclear icebreakers.

Presently, both nuclear and diesel icebreakers are mainly engaged in supporting energy projects in the Russian Arctic (e.g. Yamal LNG). The support of transit shipping along the NSR currently accounts for only a small portion of IBs' services. However, if the number of transit voyages increases in the future, the IB operators will have to find a mode of operation that satisfies the needs of both local energy projects and trans-Arctic shipping.

The operators are currently renewing and improving their icebreaking capabilities. By 2021, Rosatomflot plans to add three new nuclear-powered icebreakers to their fleet (www.rosatom.ru/en/rosatom-group/the-nuclear-icebreaker-fleet/); each with 60 MW of installed power and capable of breaking ice up to 2.9 m thick. Plans to build even more powerful nuclear icebreakers of the Lider class with 110 or 120 MW installed power, a width of 50 m, and capable of breaking ice up to 4.5 m thick have recently been delayed due to budgetary reasons. Nevertheless, building IBs with increased width is important for the future development of the NSR transit shipping as they can create even wider channels, allowing larger vessels to enter the NSR thus taking advantage of economy of scale.

The latest diesel-powered IB project is the development of IB Viktor Chernomyrdin for the state-owned company Rosmorport. This is going to be the world's largest and most powerful diesel-powered icebreaker with 25 MW of installed power and able to break ice up to 2 m thick (www.rosmorport.com/news.html?id=4000).

2.3 Maritime infrastructure, safety, and navigational support for shipping along the NSR

Historically, the driving forces behind the development of the NSR were internal Soviet (and later Russian) interests and the needs of the economy. Therefore, the NSR has never really been integrated into the world's shipping market and its scarce infrastructure struggles to meet the requirements of the modern shipping industry. As of today, 18 ports exist in the Russian Arctic (see Figure 1), the most significant of these being Murmansk, Arkhangelsk, Sabetta, and Dudinka (note: only Murmansk, Archangelsk, Vitino, Sabetta, and Pevek are currently open for international transport).

The development of the NSR's infrastructure and supporting services is included in the Transport Strategy of the Russian Federation up to 2030 (see Shcherbanin, 2013 and www.government.ru/en/dep_news/13191/ for details). Furthermore, there is a plan to develop Murmansk into a major transport hub, with planned construction of oil and coal terminals, container terminal, facilities to handle fertilizers, and a new railroad (www.rosmorport.com/mur_developmentofports.html). Planning is underway to develop Dvina Gulf (located on the White Sea 55 km north of the city of Arkhangelsk) into new deep-water seaport, operating year-round and servicing vessels up to 100,000 dwt and transporting up to 30 million tons of cargo annually by 2030 (www.rosmorport.com/arf_developmentofports.html). Container shipping is seen as a key component of the new port.

Figure 1, Russian Arctic ports

Obtaining exact information on the current status of the NSR's infrastructure and support services is currently challenging for non-Russian shipowners. Therefore, CHNL has initiated the development of the first interactive map of the NSR's infrastructure, the initial version of which is shown in Figure 2.

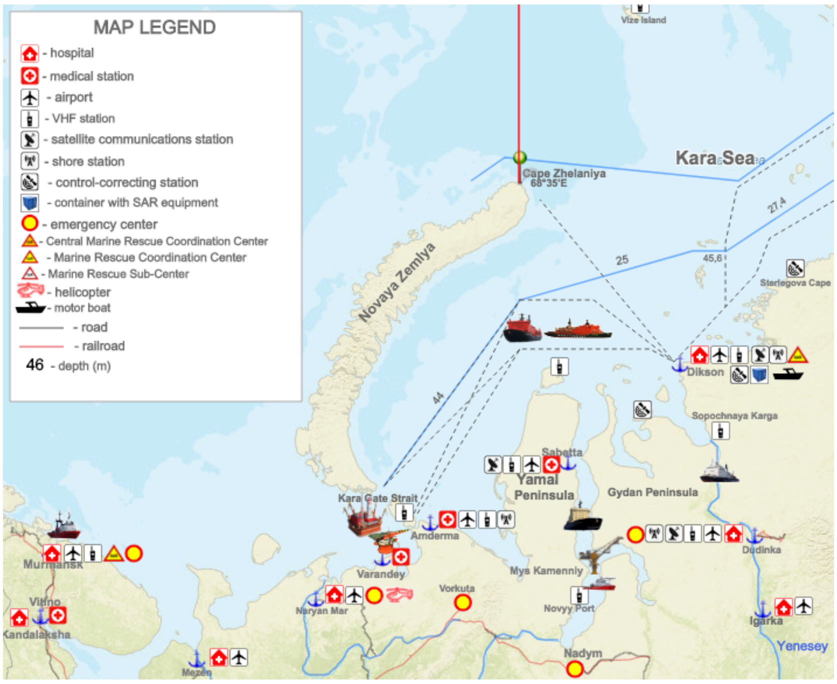

Figure 2, Snapshot of CHNL's NSR infrastructure map

2.3.1 Search and Rescue (SAR)

The large area, combined with limited SAR infrastructure and harsh weather conditions that can cause long response times in critical situations, presents a major challenge for successful SAR operations in the Arctic. Therefore, vessels operating in Arctic waters must have high level of autonomy.

Still, with the exception of the Norwegian part of the Barents Sea, the SAR infrastructure is better along the NSR than elsewhere within the Arctic Ocean. Currently, four general emergency response centers are fully operational in Naryan-Mar, Arkhangelsk, Dudinka, and Murmansk. In addition, there are several centers specifically dedicated to maritime SAR along the NSR (see the NSRA's website for details):

- The Maritime Rescue Coordination Centre (MRCC) in Dikson operates year-round and is equipped with rescue vessels, boats, and long-range aircrafts.
- The Maritime Rescue Sub-Centre (MRSC) in Tiksi operates from July till October, and is equipped with rescue vessels and boats, long-range aircrafts, and light helicopters.
- The MRSC in Pevek also operates from July till October, and is similarly equipped with rescue vessels and boats, long-range aircrafts, and light and medium-sized helicopters.

2.3.2 Navigational aids and communication challenges

After the collapse of the Soviet Union, state funding for navigational aids declined dramatically and NSR's navigational support system operated at the minimum safety level until 2010. During the recent years, the situation has improved significantly: Navigational aids for the NSR area now consist of approximately 730 navigational charts (including 233 in English), 1240 coastal visual signs, and 300 floating markers. There are also ice pilot books for different NSR navigational zones that provide support for navigation in ice along the NSR.

Recently, the main focus of hydrographic research has been the development and opening of high-latitude tracks for larger vessels with drafts of up to 18 m. Maps showing minimal water depth for different routes along the entire NSR have been made available by Russian authorities. This helps independently sailing shipowners (i.e. without IB support) to select safe routes without the risk of entering low draft areas.

As for the hydro-meteorological services, the NSRA continuously provides the following information on its website:

- Seasonal forecasts of sea ice conditions within the NSR's 7 navigational zones for the first and second period of summer/fall navigation.
- Short-term forecasts of sea ice conditions.
- Sea ice charts for the NSR's water area.
- Synoptic charts (diagnostic and forecast), showing air pressure, precipitation, wind, wave height, ocean current, and temperature distribution in waters of the Russian Arctic.

Communication challenges on the NSR are mainly related to the fact that service reliability based on geostationary satellites is reduced when passing 72°N latitude, furthermore, service cannot be considered reliable in areas above 75°N. Therefore, numerous signal-enhancing stations have been established along the NSR, providing increased reliability of satellite services. Still, it is not uncommon for a satellite signal to be lost in high latitudes, indicating the need for further improvements of service reliability. Radio centers and coastal stations provide unhampered and free reception and transmission of alarm messages, unscheduled navigation notifications, and storm warnings to the addressees, regardless of their location.

2.3.3 Oil spill preparedness

Due to the sensitivity of the Arctic ecosystem, oil spill preparedness (OSP) is an important part of the NSR's logistics system. The presence of sea ice affects the behavior of oil spills (see e.g. Afenyo et al. 2015 for more details on oil spills in ice covered waters). Russian state laws require operators to pay for the cost of cleanup operations and environmental damage in the case of an oil spill. The damages to the marine environment caused by an oil spill within the NSR area are calculated using methods approved by the Ministry of Nature Resources and Ecology of Russia and the Federal Agency of Fisheries (Bambulyak et al., 2014).

The Marine Rescue Service (MRS) manages both response and recovery operations in case of an oil spill from a ship within the NSR area. Oil spill response equipment is located in the ports of Dikson, Tiksi, Pevek, and Provideniya. Still, the most effective component of the Russian OSP system are the IBs, as they are expected to be the first ones to reach the location of an oil spill. Out of them, IBs Vaygach and Admiral Makarov are equipped with oil-spill response equipment.

3. CHALLENGES IDENTIFIED BY THE PROJECT PARTNERS AND PARTICIPANTS

One of the key aspects of the project was to receive feedback from project partners and participants on challenges related to the use of the NSR for transit shipping. In order to model future development of the route, it is crucial to understand the main issues that the different stakeholders are facing in their operations. This section summarizes the project partners' and participants' comments and opinions gathered during the discussions, which are sorted under several topics presented below.

3.1 Ice conditions

There was a general consensus amongst the industry stakeholders that year-round operations are necessary for the NSR transit shipping to be profitable. This is mainly due to the perceived unprofitability of investing in a fleet of ice-strengthened vessels[3] that can only operate along the NSR during the summer season under the current ice conditions. During the winter/spring season, these ice-strengthened vessels would have to sail in open-water (e.g. along the Suez Canal Route) – a sailing mode for which they are not optimal (see e.g. Erikstad and Ehlers, 2012). On the other hand, current ice conditions during the winter/spring season require prohibitively expensive investments in ice-going cargo vessels[4] that would be needed for year-round operations. Moreover, ice conditions in the eastern parts of the NSR are currently so harsh during winter that even the technical feasibility of such operations is questionable. To illustrate the point, the ice-going LNG carriers designed for the Yamal LNG project may only sail westwards from Sabetta during winter.

The uncertainty related to future ice conditions in the Arctic also presents a significant obstacle for shipowners. Shipowners have to evaluate their Arctic

[3] Ice-strengthened vessels cannot break ice on their own. They can only sail in very light ice conditions independently, or through a brash ice channel created by an icebreaker.
[4] Ice-going vessels can sail independently in ice without icebreaker support except in heaviest ice conditions.
For details on types of vessels sailing in ice, see Riska (2010).

operations for several possible future ice conditions, adding additional complexity to their long-term planning.

3.2 Bunker prices

The recent drop in bunker prices has weakened the competitiveness of the NSR compared to other sailing routes, e.g. the Suez Canal Route, which was recognized during the project discussions. The NSR can be used as a shortcut that allows for considerable fuel savings, but this advantage becomes less important when bunker prices decrease. The decline of interest in the NSR after 2013 can therefore also be attributed, at least in part, to the reduction in bunker prices during the same period.

3.3 Russian legislation, icebreaker assistance and maritime infrastructure

One of the key insights from the project is that there is still a lack of knowledge outside of Russia regarding Russian legislation governing NSR shipping. For example, several project participants expressed surprise when informed of the fact that Russian regulations allow sailing the NSR during the summer/fall navigational season without IB assistance, if the ice conditions are favorable and/or the vessel has an appropriate ice class – thus basically sailing the NSR for free. Generally, with the 2013 rules in place, the administrative obstacles for the international use of the NSR for transit shipping have been considerably reduced.

Russia is currently planning to make substantial financial investments in the future development of the NSR, both in terms of IB support and infrastructural development. However, shipowners seem reluctant to make significant investments and plan their long-term operations using the NSR before the intended infrastructural projects are realized.

Concern was expressed during discussions over liability in certain hypothetical situations; for example, who is responsible if a vessel that had not previously required and had been traveling without IB support suddenly experiences an accident and needs help. In that case, according to Russian sources, rescue centers along the NSR will organize salvage operations in accordance with existing Russian and international regulations, although it is unclear what the legal and financial repercussions may be.

It can be challenging for a shipowner to calculate the total IB support fees when planning the trip several months in advance. It is difficult to anticipate how many NSR's navigational zones will require IB assistance due to the unpredictability of future ice conditions. There have been comments from the Russian side about a possible willingness to adopt a different IB tariff system, if that would increase the interest in the NSR transit shipping.

Concerns have been stated about the possible unavailability of IB assistance in case of ad hoc requests. According to Rosatomflot's usual practice, this might indeed be a problem, especially for low tonnage ships since it is unprofitable to employ expensive IB assistance in such cases. This is amplified by the fact that most of Rosatomflot's IB resources are currently employed supporting energy projects in the Russian Arctic. Presently, escort for transit shipping is not a priority. Consequently, Rosatomflot plans transit convoys based on their largest customers' needs, which can be unfavorable for smaller shipowners as they might have to adjust their schedules, thus loosing flexibility.

IB tariffs are calculated in Russian rubles so the cost is strongly related to USD/RUR exchange ratio, which is a significant uncertainty when planning for long-term operations.

There was an idea mentioned during discussions about the possibilities of using non-Russian IBs for assistance along the NSR. Currently, only Russian IBs are allowed to provide assistance along the NSR. However, there have been no attempts so far to use non-Russian IB assistance.

One shipowner stated that there was interest in investing in an ice capable fleet for the Arctic operations, but the questionable availability of IB assistance was a project stopper.

All partners and participants agreed that additional investments into NSR infrastructure are required to support the shipping operations. This especially goes for SAR and towing services.

3.4 Maritime insurance

Sailing the NSR without IB support (independently) is allowed under Russian rules during the summer/fall season if the ice conditions are favorable. However, insurance companies might restrict independent sailing for non-Russian shipowners in some cases (even if the ice conditions allow it), since the IBs currently provide the most efficient support in case of vessel damage. During the discussions, it has been stated that there is a need for independent voyages to be insured, since the operational window for this mode of sailing has become significant during the summer/fall season. This initiative has been supported by the knowledge that the Russian authorities will organize salvage operations (including Rosatomflot's assistance if needed) for independently sailing vessels as well.

A representative of a P&I insurance company present during the discussion indicated that they would most likely insure independent sailing if the H&M insurance company would as well.

Insurance companies consider remoteness to be a larger risk than sea ice. The lack of ports of refuge and repair facilities as well as limited availability of rescue facilities are mentioned as major obstacles for the development of NSR transit shipping. While the number of reported incidents remains low, even small accident becomes very expensive due to remoteness. Furthermore, the lack of reliable statistical data, due to the limited number of voyages, presents an additional problem when calculating risk, which is the base for calculating insurance premiums.

4. FUTURE OPERATIONAL MODELS FOR TRANSIT SHIPPING ALONG THE NSR

4.1 Definition of operational models (OMs)

Assuming that the NSR is to become a viable transit route in the future, there are different ways in which it could be developed. From a shipowners' perspective, different operational models (OMs) could be used to utilize the NSR as an inter-continental transit corridor. The term OM defines the mode of utilization of the NSR with respect to ice capabilities of the fleet and/or requirements for IB assistance. In this section, such OMs are defined and analyzed based on the current status of the route and on the feedback received from the project partners and participants. The analyzed OMs are:

- OM0 – Ice-strengthened vessels with/without IB support (seasonal navigation):
  The NSR is utilized in the same manner as today, meaning that ice-strengthened vessels are transiting the NSR with or without the IB assistance during summer/fall season, depending on the ice conditions (currently, the majority of vessels sailing along the NSR for the purpose of destination shipping are sailing without IB support during the most favorable part of the summer/fall season when waters are ice-free; in fact, many of these ships either have no ice class or very low ice-strengthening).
- OM1 – Ice-strengthened vessels with/without IB support (year-round navigation):
  Similar to OM0 with the difference being that the ice conditions allow for year-round navigation. IB assistance is needed during the winter/spring season, while sailing during summer/fall season is without IB support.
- OM2 – Ice-strengthened vessels without IB support (year-round navigation):
  Ice conditions allow ice-strengthened vessels to sail along the NSR independently year-round.
- OM3 – Independent ice-going cargo vessels (year-round navigation):
  Independent ice-going cargo vessels of a high ice class that can break ice independently are used. Similar to the oil tankers servicing the Arctic Gate Terminal in the Ob Bay or the LNG carriers servicing the Yamal LNG project (both with Arc7 ice class).
- OM4 – Non-Russian IBs escorting ice-strengthened vessels (year-round navigation):
  Non-Russian shipowners are using their own (or contracted) IBs to escort ice-strengthened vessels along the NSR.
- OM5 – Transshipment hubs with ice-going cargo vessels sailing between them (year-round navigation):
  Intermediate transshipment hubs at each end of the NSR with ice-going cargo vessels sailing between the hubs in ice and with the feeders in the open water sections of the route.

4.2 Parameters influencing the feasibility of operational models

The feasibility of each of the defined future OMs[5] will depend on several influencing parameters (IPs). These IPs are identified in Section 3 and are considered to be the main factors affecting the future development of the NSR transit shipping. The IPs are viewed from the perspective of how they need to change compared to their current status in order for each of the OMs to become feasible. The IPs are:

- IP1 – Ice conditions:

  The future development of the NSR as a transit route will mostly depend on the ice conditions, as it was also the case in the past. According to the ice class admittance criteria, ice-strengthened vessels (with ice classes Arc4 and Arc5, corresponding to 1A and 1A Super) are currently allowed to sail along the NSR during winter/spring season only under "low" severity of ice conditions, either independent or assisted (see Rules of Navigation in the Water Area of the Northern Sea Route, 2013). In other words, given current average ice conditions, year-round navigation of ice-strengthened vessels is not possible. The same goes for ice-going cargo vessels (e.g. Arc7 LNG carriers servicing the Yamal LNG project), which at the moment cannot commercially operate in the eastern parts of the NSR during winter/spring season under average ice conditions. Therefore, the severity of ice conditions needs to decrease in order for the NSR to become commercially navigable year-round. This is a prerequisite for all OMs apart from the OM0 and, also, a main condition identified by the industry stakeholders.
- IP2 – Bunker prices:

  It is expected that bunker prices will need to increase for all of the OMs to become feasible since the voyage costs savings become more pronounced with increased bunker prices. However, it should be kept in mind that it is possible that the NSR will be used within operational models where time savings are the primary target instead of reduction of voyage costs. In that case – which

[5] Each of the OMs can be applied for either liner or bulk shipping. However, liner shipping via NSR is more complicated to implement, due to strict demands on keeping the schedule.

has not been considered in this analysis – the bunker prices may no longer be as important.

- IP3 – Russian support (legislation, icebreakers, maritime infrastructure):
  Russian support will be necessary for all OMs. This is mainly in order to increase the safety and reliability of shipping along the NSR since the currently available infrastructure and IB support might struggle with increased traffic.
- IP4 – Maritime insurance:
  Maritime insurance companies will need to create new insurance models since most of OMs present modes of sailing that have not been used so far. These new insurance models will need to capture the specifics of each OM. However, insuring the independent voyages, which are already possible nowadays during summer/fall season, needs to be the first step.

The conditions of feasibility of future OMs, with respect to different IPs, are summarized in Table 2. The change in IPs is described qualitatively compared to their current status.

Table 2, Conditions of feasibility of future operational models for NSR transit shipping

OMs vs. IPs	IP1 Ice conditions	IP2 Bunker prices	IP3 Russian support	IP4 Maritime insurance
OM0 Ice-strengthened vessels with/without IB support (seasonal nav.)	Same	Increased	More IBs and infrastructure if traffic increases	Insurance needed for independent voyages
OM1 Ice-strengthened vessels with/without IB support (year-round nav.)	Less severe	Increased	More IBs and infrastructure	Insurance needed for independent voyages
OM2 Ice-strengthened vessels without IB support (year-round nav.)	Much less severe	Increased	More infrastructure	New insurance models needed
OM3 Independent ice-going cargo vessels (year-round nav.)	Less severe	Increased	More infrastructure	New insurance models needed
OM4 Non-Russian IBs escorting ice-strengthened vessels (year-round nav.)	Less severe	Increased	More infrastructure	New insurance models needed
OM5 Transshipment hubs with ice-going cargo vessels sailing between them (year-round nav.)	Less severe	Increased	Significant port and fleet investments	New insurance models needed

4.3 Discussion of OMs

As shown in Table 2, all OMs with year-round navigation require less severe ice conditions, increased bunker prices, improved Russian infrastructure and IB support, as well as new maritime insurance models. If any of these parameters develop in the opposite direction, they will present a significant hindrance for the future development of the NSR transit shipping.

The decrease in the severity of ice conditions is considered to be the key prerequisite for the development of the NSR into a viable transit route in the future. Therefore, the choice of the most suitable future OM will mainly depend on the magnitude of the decrease in the severity of ice conditions. In a most favorable case for shipping, ice conditions will allow independent year-round navigation of ice-strengthened vessels, which is OM2. This scenario will require very light ice conditions along the NSR year-round, which is not likely to happen in the foreseeable future.

However, if the severity of ice conditions gradually decreases, year-round commercial navigation could become possible, thus allowing OM1 and OM3 to be implemented. An advantage of OM1 is that it is less cost-intensive than OM3, thus not requiring investment in an expensive fleet of ice-going cargo vessels. On the other hand, advantage of OM3 lies in the fact that it does not depend on IB support. This is a significant benefit considering that current Russian IB capacity might struggle to meet the demands of NSR transit shipping if the amount of traffic significantly increases.

As for OM4, the fact that shipowners would not depend on the availability of Russian IB support is an advantage, thus increasing the flexibility of operations. Issues are large investments necessary to build new IBs (although IBs currently operating in e.g. Baltic could be used) and operational issues of non-Russian IBs sailing along the NSR (crew experience, etc.). Also, currently only Russian IBs are allowed to provide support in the NSR water area, which presents an additional obstacle.

Regarding OM5, the transshipment hubs with cargo transferring capabilities and ice-going cargo vessels for sailing between them are needed. This option was brought up several times during the project discussions and it seems that there is a strong interest amongst Russian authorities and stakeholders to explore this possibility further. Multi-purpose ships, container ships, and LNG carriers were mentioned as possible ice-going vessels sailing between the transshipment hubs. The advantage of transshipment hubs for the shipowners lies in the fact that they would not need to build their own ice-strengthened or ice-going cargo vessels; rather, they would only need to deliver the cargo in the open water to one of the hubs and collect it at the other end for a fee. Transshipment hubs could be used not only for transit shipping but also to support destination shipping along the NSR and to serve as catalysts for the regional development. However, the profitability of investing (and also the funding source) in such an advanced model needs to be further assessed.

Naturally, any combination of the presented OMs is possible. OM1 and OM 3 are especially compatible, as some shipowners might choose to build ice-going cargo vessels while others might opt to use Russian IB support to escort their ice-strengthened ships. The authors of this paper believe that such a solution is the most likely model for the future development of transit shipping along the NSR, since it provides the most flexibility considering the uncertainty of future ice conditions.

5. CONCLUSIONS AND FUTURE WORK

In this paper, the current status of the NSR regulations and support services is presented based on a review of the currently available information and on the input gathered during the project "Feasibility and Reliability of Shipping on the Northern Sea Route and Modeling of an Arctic Marine Transportation & Logistics System". Additionally, comments and opinions from the project partners and participants related to various aspects of the NSR transit shipping are presented. Finally, several possible future operational models for transit shipping along the NSR are established based on the current status of the route and on the input from project partners and participants.

It is concluded that any further development of NSR transit shipping will require a decrease of severity of ice conditions allowing year-round commercial navigation, an increase in bunker prices, further development of maritime infrastructure and IB support along the NSR, as well as new models for maritime insurance. If the severity of ice conditions gradually decreases, it is concluded that the most probable future operational model for the NSR transit shipping is a combination of ice-strengthened vessels being escorted by the Russian IBs and independent ice-going cargo vessels. Additionally, establishing transshipment hubs at each end of the NSR with ice-going cargo vessels sailing between them is also considered to be a viable option for the future.

Future work could consist of an evaluation of each of the presented operational models using a transit simulator for sailing along the NSR. In that way, different scenarios could be quantified, allowing for a more accurate comparison between them.

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List of abbreviations

AARI	Arctic and Antarctic Research Institute
CHNL	Centre for High North Logistics
OM	Operational Model
FSUE	Federal State Unitary Enterprise
H&M	Hull & Machinery
IAL	Institute of Arctic Logistics
IB	Icebreaker
IMO	International Maritime Organization
IP	Influencing Parameter
LNG	Liquefied Natural Gas
MRCC	Maritime Rescue Centre
MRS	Marine Rescue Service
MRSC	Maritime Rescue Sub-Centre
NSR	Northern Sea Route
NSRA	Northern Sea Route Administration Office
NTNU	Norwegian University of Science and Technology
OSP	Oil Spill Preparedness
P&I	Protection & Indemnity
SAR	Search and Rescue

REFERENCES

Afenyo, M., Khan, F., and Veitch, B., 2015. A state-of-the-art review of fate and transport of oil spills in open and ice-covered water. Ocean Engineering. 119:233-248.

AMSA, 2009. Arctic Maritime Shipping Assessment 2009 Report. Arctic Council. Available from: http://www.pame.is/images/stories/AMSA_2009_Report/AMSA_2009_Report_ 2nd_print.pdf. (accessed 13.10.2017)

Bambulyak, A., von Bock und Polach, R., Ehlers, S., Sydnes, A., 2014. Challenges with oil spill risk assessment in Arctic regions: Shipping along the Northern Sea Route. International Conference on Offshore Mechanics and Arctic Engineering, Volume 4B: Structures, Safety and Reliability. DOI: 10.1115/OMAE2014-24419.

Bekkers, E., Francois, J.H., Rojas-Romagosa, H., 2016. Melting Ice Caps and the Economic Impact of Opening the Northern Sea Route. Econ J. DOI:10.1111/ecoj.12460.

Beveridge, L., Fournier, M., Lasserre, F., Huang, L., Têtu, P.-L., 2016. Interest of Asian shipping companies in navigating the Arctic. Polar Science 10 (2016) 404-414.

Buixadé Farré, A., Stephenson, S.R., Chen, L., Czub, M., Dai, Y., Demchev, D., Efimov, Y., Graczyk, P., Grythe, H., Keil, K., Kivekäs, N., Kumar, N., Liu, N., Matelenok, I., Myksvoll, M., O'Leary, D., Olsen, J., Pavithran A.P.S., Petersen, E., Raspotnik, A., Ryzhov, I., Solski, J., Suo, L., Troein, C., Valeeva, V., van Rijckevorsel, J., Wighting, J., 2014. Commercial Arctic shipping through the Northeast Passage: Routes, resources, governance, technology, and infrastructure. Polar Geography (Taylor & Francis). DOI: 10.1080/1088937X.2014.965769.

Cariou, P., Faury, O., 2015. Relevance of the Northern Sea Route (NSR) for bulk shipping. Transportation Research Part A: Policy and Practice, DOI: 10.1016/j.tra.2015.05.020.

DNV, 2010. Shipping across the Arctic Ocean: A feasible option in 2030-2050 as a result of global warming? Research and Innovation, Position Paper 04-2010.

Erikstad, S.O., Ehlers, S., 2012. Decision support framework for exploiting Northern Sea Route transport opportunities. Ship Technology Research. 59(2).

IMO (International Maritime Organization), 2017. Adoption of an international code of safety for ships operating in polar waters (Polar Code). http://www.imo.org/en/mediacentre/hottopics/polar/pages/default.aspx (accessed 13.10.2017)

Jianmin, S., Yuan, F., Potential for container transport through the Arctic Northern Sea Route. Chinese Journal of Polar Research.

Kiiski, T., Solakivi, T., Töyli, J., Ojala, L. 2016. Long-term dynamics of shipping and icebreaker capacity along the Northern Sea Route. Marit Econ Logist. DOI: 10.1057/s41278-016-0049-1.

Kim, H.J., 2015. Success in heading north?: South Korea's master plan for Arctic policy. Marine Policy 61 (2015) 264–272.

Lee, T., Kim, H.J., 2015. Barriers of voyaging on the Northern Sea Route: A perspective from shipping companies. Marine Policy 62 (2015) 264–270.

Marchenko, N., 2014. Northern Sea Route: Modern state and challenges. Proceedings of the ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Mironov, Y., 2013. Forecasting of the type of ice conditions for planning sea operations at the Northern Sea Route. 2nd International Conference "The Northern Sea Route", St. Petersburg, 14-15 November 2013.

Østreng, W., Eger, K.M., Fløistad, B., Jørgensen-Dahl, A., Lothe, L., Mejlænder-Larsen, M., Wergeland, T., 2013. Shipping in Arctic Waters: A Comparison of the Northeast, Northwest and Trans Polar Passages. Springer. ISBN 978-3642167898. DOI:10.1007/978-3-642-16790-4.

Pruyn, J.F.J., 2016. Will the Northern Sea Route ever be a viable alternative? Maritime Policy and Management. DOI: 10.1080/03088839.2015.1131864.

Riska, K., 2010. Ship–Ice Interaction in Ship Design: Theory and Practice. Encyclopedia of Life Support Systems (EOLSS), Paris.

Rules of navigation in the water area of the Northern Sea Route, 2013. Available at: www.nsra.ru/en/ofitsialnaya_informatsiya/pravila_plavaniya/f120.html (accessed 13.10.2017)

Shcherbanin, Y.A., 2013. Transport and Transport Infrastructure in 2030: Some Predictive Estimates. Studies on Russian Economic Development, Vol. 24. No. 3, pp. 259-264. DOI: 10.1134/S107570071303009X.

Solski, J.J., 2013. New developments in Russian regulation of navigation on the Northern Sea Route. Arctic Review on Law and Politics, vol. 4, 1/2013 pp. 90–119. ISSN 1891-6252.

Tschudi, 2010. Historic sea route opens through the Arctic to China. http://www.tschudiarctic.com/page/206/Northern_Sea_Route (accessed 13.10.2017)

Zhang, Y., Meng, Q., Ng, S.H., 2016a. Shipping efficiency comparison between Northern Sea Route and the conventional Asia-Europe shipping route via Suez Canal. Journal of Transport Geography, DOI: 10.1016/j.jtrangeo.2016.09.008.

Zhang, Y., Meng, Q., Zhang, L., 2016b. Is the Northern Sea Route attractive to shipping companies? Some insights from recent ship traffic data. Marine Policy, DOI: 10.1016/j.marpol.2016.07.030.

Zhao, H., Hu, H., Lin, Y., 2016. Study on China-EU container shipping network in the context of Northern Sea Route. Journal of Transport Geography 53 (2016) 50–60.