ØRTS HANSEN, GRØNSEDT, LINDSTRØM GRAVERSEN AND HENDRIKSEN

ARCTIC SHIPPING – COMMERCIAL OPPORTUNITIES AND CHALLENGES

CBS MARITIME

CROSS DISCIPLINARY PROBLEM-FOCUSED RESEARCH AND EDUCATION IN THE MARITIME INDUSTRY CONTEXT

AUTHORS
CARSTEN ØRTS HANSEN
PETER GRØNSEDT
CHRISTIAN LINDSTRØM GRAVERSEN
CHRISTIAN HENDRIKSEN

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EXECUTIVE SUMMARY

Over the last few decades the Arctic Ocean has experienced a rapid reduction in both the extent and volume of sea ice. These changes, caused by the global temperature increases, have opened up previously inaccessible shipping lanes and made possible the extraction of major natural reserves of fossil fuels. Following these changes in the Arctic environment, the last decade has seen an influx of maritime activities in the segments of liquid bulk shipping, offshoring and cruise tourism. The Arctic is one of the last frontiers on our planet and consequently the need to shed light on marine activities in and around the Arctic Ocean has arisen. The aim of this study is to address and analyze some of these challenges and opportunities in the spheres of both the private and public sector.

On the industry level previous and ongoing projects are mapped out for each of the four major maritime sectors. This involves liner shipping, bulk shipping, offshoring and cruise tourism. Additionally the possibilities and challenges are analyzed qualitatively, with a particular focus on the future prospects for each of these four sectors, from a combination of past literature and economic theory.

As a part of the chapter on the opportunities for the liner shipping sector in the Arctic a quantitative economic analysis is performed. The aim of the quantitative analysis is to examine the economic feasibility of transporting containerized goods using the Northern Sea Route (NSR) between Northern Europe and East Asia as an alternative to the Suez Canal Route (SCR). More specifically the study will aim to determine when (if ever) the investment in an ice-reinforced container ship operating along the NSR would be preferable to an investment in an open water vessel solely navigating the SCR.

Finally this report presents a descriptive analysis of the political and regulative environment is executed, with an emphasis on how the regulatory environment is created. The aim is to facilitate how these political and regulative institutions impact the future prospects for maritime activities in the Arctic. The analysis will investigate international cooperation and unilateral standards, focusing on how each of these scenarios affects regional stability. This is performed in a theoretical framework incorporating the past, present and future. This provides a holistic overview of how the Arctic regimes are interlinked and thus creates the regulatory space, which companies operate within.

The findings of the report conclude that major opportunities for the maritime sector exist if the ice cover on the Arctic Ocean continues to decline. The sector of dry bulk and offshoring are currently the sectors with the largest potential as the Arctic hosts and abundance of the natural resource. The results from the quantitative study on the feasibility of liner shipping across the NSR indicate that Arctic liner shipping may become economically feasible around 2040, if the ice cover continues to diminish at the present rate. The possibility of a major expansion of the maritime activities within the sectors of bulk, offshoring and liner shipping before midcentury rests upon several crucial assumptions which are all subject to major uncertainties. These uncertainties include the hazardous environmental conditions, port and infrastructure availability and high costs of operation compared to the southern shipping lanes. Additionally the Arctic Ocean lacks an international governmental and regulative framework in combination with high entry costs creates uncertainty for the maritime industry seeking to operate in and around the Arctic Ocean.

The calculations presented in the liner shipping quantitative study, are based on a calculation tool specifically designed to support the conclusions of the case study. This calculation tool, available for download along with the report, allows researchers and industry professionals to insert the specifications of a given vessel, along with environmental and economic parameters in order to obtain information on the feasibility of transporting containerized cargo along the NSR. Specifically, the model allows the user to determine the year when the investment in an ice reinforced containership operating along the NSR during the navigation (and the SCR at other times), will become favorable compared to an ordinary container ship solely operating on the SCR.

1 INTRODUCTION

This report forms part of the ambitious CBS Maritime research initiative entitled "Competitive Challenges and Strategic Development Potential in Global Maritime Industries" which was launched with the generous support of the Danish Maritime Fund. The competitiveness initiative targets specific maritime industries (including shipping, offshore energy, ports, and maritime service and equipment suppliers) as well as addresses topics that cut across maritime industries (regulation and competitiveness). The topics and narrower research questions addressed in the initiative were developed in close dialogue between CBS Maritime and the maritime industries in Denmark.

CBS Maritime is a Business in Society (BiS) Platform at Copenhagen Business School committed to the big question of how to achieve economic and social progress in the maritime industries. CBS Maritime aims to strengthen a maritime focus at CBS and create the foundation for CBS as a stronger partner for the maritime industries, as well as for other universities and business school with a devotion to maritime economics research.
The competitiveness initiative comprises a number of PhD projects and five short term mapping projects, the latter aiming at developing key concepts and building up a basic industry knowledge base for further development of CBS Maritime research and teaching.

This report attempts to map the opportunities and challenges for the maritime industry in an increasingly accessible Arctic Ocean.

1.1 RESEARCH QUESTIONS:

1. What are the major challenges to an increase in maritime activity in the Arctic?
2. What are the major opportunities for the maritime industry segments of liner shipping, bulk, offshoring and cruise ship tourism?
3. Will the Northern Sea Route become competitive compared to the Suez Canal Route on the Europe to East Asia trade?
4. How will current and future regulative regimes impact the maritime industry operating in the Arctic?
5. What are the underlying intentions of the Arctic governmental bodies?
6. Are the Arctic governmental bodies heading towards more cooperation?
7. How will the governmental bodies impact the maritime industry operating in the Arctic?
8. What are the opportunities for Danish maritime companies and sub suppliers in the Arctic?

1.2 READERS GUIDE

The report is divided into nine parts with the first part containing the summary, acknowledgements and research questions. The second part introduces the shipping lanes of the Arctic Ocean and the maritime challenges as well as possibilities created by climate changes in the region. Part three presents the newest research on the impact of climate change in the Arctic Ocean and aims to give an estimate on the pace at which the Arctic sea ice is melting. In part four, the possibilities and challenges for liner shipping in the Arctic are presented. Chapter five continues in the subject of liner shipping by presenting a quantitative study aiming to determine when shipping along the Northern Sea Route may become feasible compared to the Suez Canal Route on the Europe to Asia trade.
Part six analyses the possibilities and challenges for the dry and liquid bulk sector and presents current and future resource extraction activities in the Arctic of relevance to the maritime industry. The seventh part analyses the possibilities and challenges for the cruise shipping sector in the Arctic while the seventh part gives a brief presentation of the opportunities for the Danish maritime industry in an increasing accessible Arctic Ocean. Finally the ninth and last part presents the political environment of the Arctic, mapping the relevant institutions and their regulatory power, to understand future trajectories.

1.3 ABBREVIATIONS

NSR:	Northern Sea Route
SCR:	Suez Canal Route
NWP:	North West Passage
TSR:	Transpolar Sea Route
PCR:	Panama Canal Route
IMO:	International Maritime Organization
CCG:	Canadian Coast Guard
NSRA:	Northern Sea Route Administration
TEU:	Twenty Foot Equivalent
NM:	Nautical Miles
SAR:	Search and Rescue
IPCC:	International Panel on Climate Change
DWT:	Dead Weight Ton
GCM:	General Circulation Model

Source: Scanpix / Iris

2 THE ARCTIC – A NEW REGION FOR MARITIME EXPANSION?

GLOBAL WARMING HAS OPENED UP NEW SHIPPING ROUTES IN THE ARCTIC PRESENTING A NEW FRONTIER FOR MARITIME ACTIVITIES. ESPECIALLY THE NORTHERN SEA ROUTE AND THE NORTH WEST PASSAGE HAVE THE POTENTIAL TO SERVE AS MARITIME SHORTCUTS BETWEEN THE WORLDS ECONOMIC CENTERS. UNDERDEVELOPED AND REMOTE THESE ROUTES PRESENTS MAJOR CHALLENGES FOR TRANSITING VESSELS AND ICE CONDITIONS STILL POSE A THREAT TO EVEN THE STRONGEST ICEBREAKERS.

The Arctic Ocean‘s sea ice is melting at a rapid pace, leaving an ever larger section of the polar seas ice-free each summer. The six years with the lowest observed summer sea ice extent have all occurred within the last decade (Smith & Stephenson, 2013). And new forecast models are continuously bringing forward expectations of ice-free summers in the Arctic (Flake, 2013) creating a significant potential for previously impossible maritime activities. The diminishing ice cover has not only allowed for the utilization of the Arctic shipping lanes for intercontinental transport, but has also resulted in vast quantities of natural resources such as oil, gas and minerals to be extractible. This creates opportunities for various sectors of the maritime industry within: transport, offshoring, servicing, emergency response, surveillance, maritime equipment, new build and retrofitting vessels. The vast and remote Arctic Ocean entails significant challenges and hazards to companies seeking to operate in this environment. These challenges include first and foremost the cyclical ice cover and the drift ice this creates. However, the lack of population centers, suitable ports and the lack of developed infrastructure for search and rescue (SAR), poses even larger operational and environmental risks. Further, the need for ice reinforced vessels and specialized equipment impose significant investment costs needed to maintain maritime activities in the high Arctic. Currently only a limited number of companies are operating in the region, of which the majority of these are present in the Northern part of the Eurasian landmass.

Although accessibility for maritime activities has increased in the Arctic, the central part of the Arctic Ocean is still covered in ice throughout most of the year. The possibilities for the maritime industry are mainly divided into the two coastal regions of Arctic: Eurasia and arctic North America, although the waters of Greenland also provide significant possibilities for the sector. The Northern Sea Route (NSR), which runs along the Russian Arctic coast, is currently the most well developed, and has consequently seen the most extensive utilization. The North West Passage (NWP) in the Arctic Canada has seen limited development and maritime traffic. The next two chapters will present the opportunities, infrastructure and geography of both shipping routes along with their surrounding areas while. The last chapter will focus on the numerous challenges facing maritime operations in the remote Arctic.

2.1 THE NORTHERN SEA ROUTE

The NSR is the shipping route connecting Europe and Asia, north of the Eurasian landmass. The NSR has the potential to reduce the distance between Europe and Asia by up to 40 per cent, compared to the contemporary Suez Canal Route (SCR). The NSR is not a specific route but a multitude of passageways along the Russian Arctic and therefore covers a vast segment of the Arctic Ocean (Kronbak & Liu, 2010). The coastal versions of the NSR are currently the most trafficked, running along the Russian Arctic coast. From west to east, the route traverses the five marginal seas of the Barents Sea, the Kara Sea, the Laptev Sea, the East Siberian Sea and the Chukchi Sea, until reaching the Behring Strait between Siberia and Alaska. Although the opening of the NSR has mainly been connected to the shipment of goods between Europe and East Asia, vast quantities of proven oil, gas and mineral reserves are situated along the route. This creates a diverse range of opportunities for both the offshore, bulk and tanker sectors. The combination of

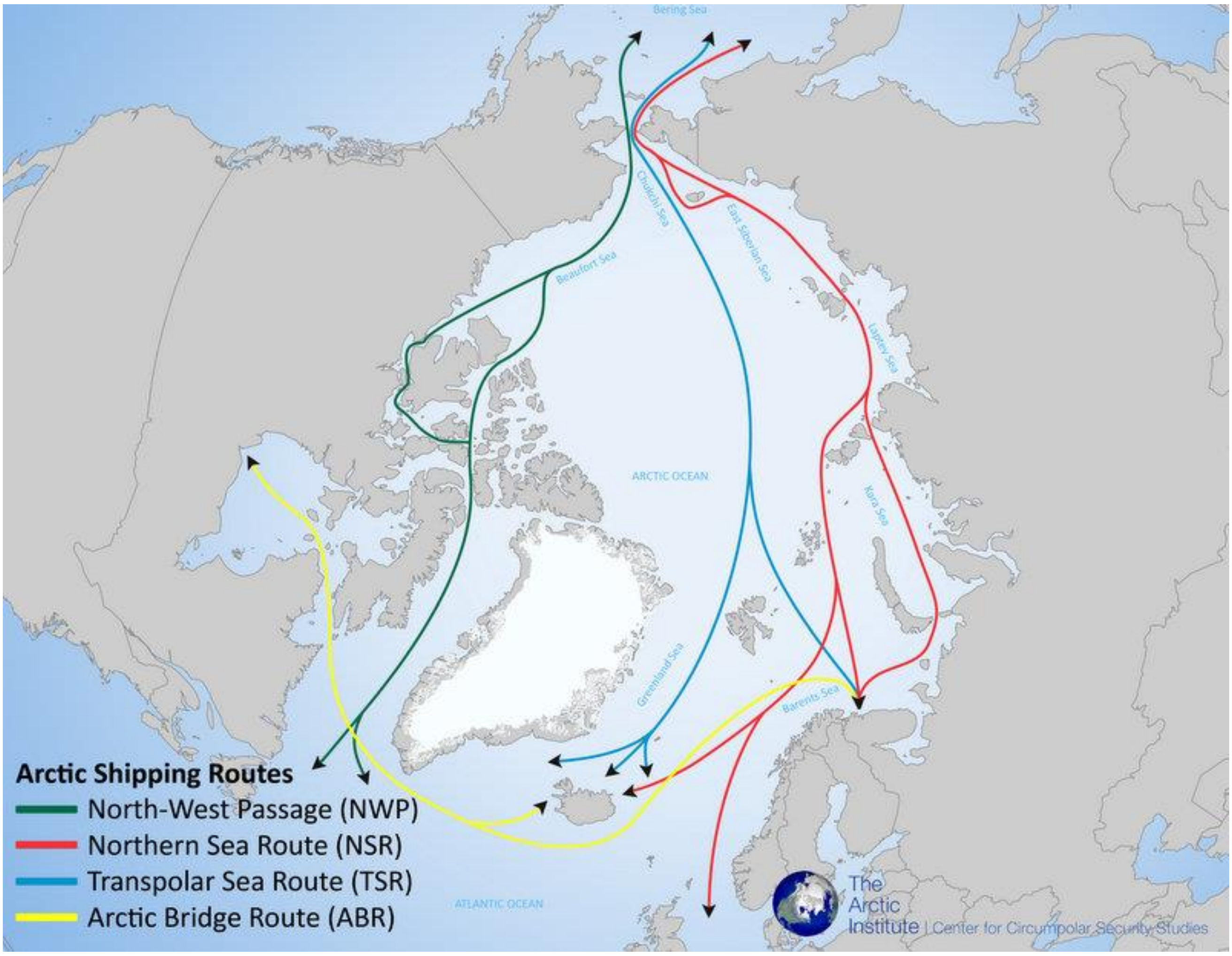

Figure 2.1: The Arctic Shipping Routes
Source: Humpert & Raspotnik (2012)

transport and resource extraction opportunities has sparked an influx of maritime activities in the waters of the NSR. In 2012 a total of 46 vessels operated along the route carrying a total cargo volume of almost 4 million tons of cargo. The number of commercial vessels operating on the route in 2013 increased to 71 vessels, with close to 30 of them transiting the entire route between Europe and the Pacific and some of the vessels yielding 60,000 gross tons or more. In 2014, however, the traffic declined to 53 transits, and data concerning the fraction of these vessels that navigated between Europe and Asia are currently unavailable (NSRA, 2015).

The coastal waters are generally shallow at a depth of less than 100 meters and the different marginal seas are separated by narrow straits, which are occasionally blocked by pack ice. Some of these straits also present draft restrictions on vessels navigating, the most severe being the Kara Gate, the Sannikov Strait and the De Long Strait. The Kara Gate, separating Novaya Zemlya from the Russian mainland, has a minimum depth of 21 meters while the De Long Strait, south of Wrangel Island, has a 20 meter restriction. The most severe draft restriction is encountered in the Sannikov Strait, between the New Siberian Islands archipelago, being only 13 meters deep. Navigating the Sannikov Strait therefore limits passing vessels to only 100,000 DWT or 4,500 Twenty-foot Equivalent Units (TEU) which is significantly less than a large section of the merchant vessels traversing the Suez Canal (Humpert, 2014). In order to bypass the shallow straits along the Russian Arctic coast it is possible to navigate along a more northern route passing over Novaya Zemlya, The New Siberian Islands and Wrangel Island. While allowing for vessels of far greater sizes, the more northern routes run periphery to the Arctic Basin. These routes are therefore subject to more severe ice conditions but reduce the distance between Europe and Asia. Even though a vessel may aim at predetermined course of the

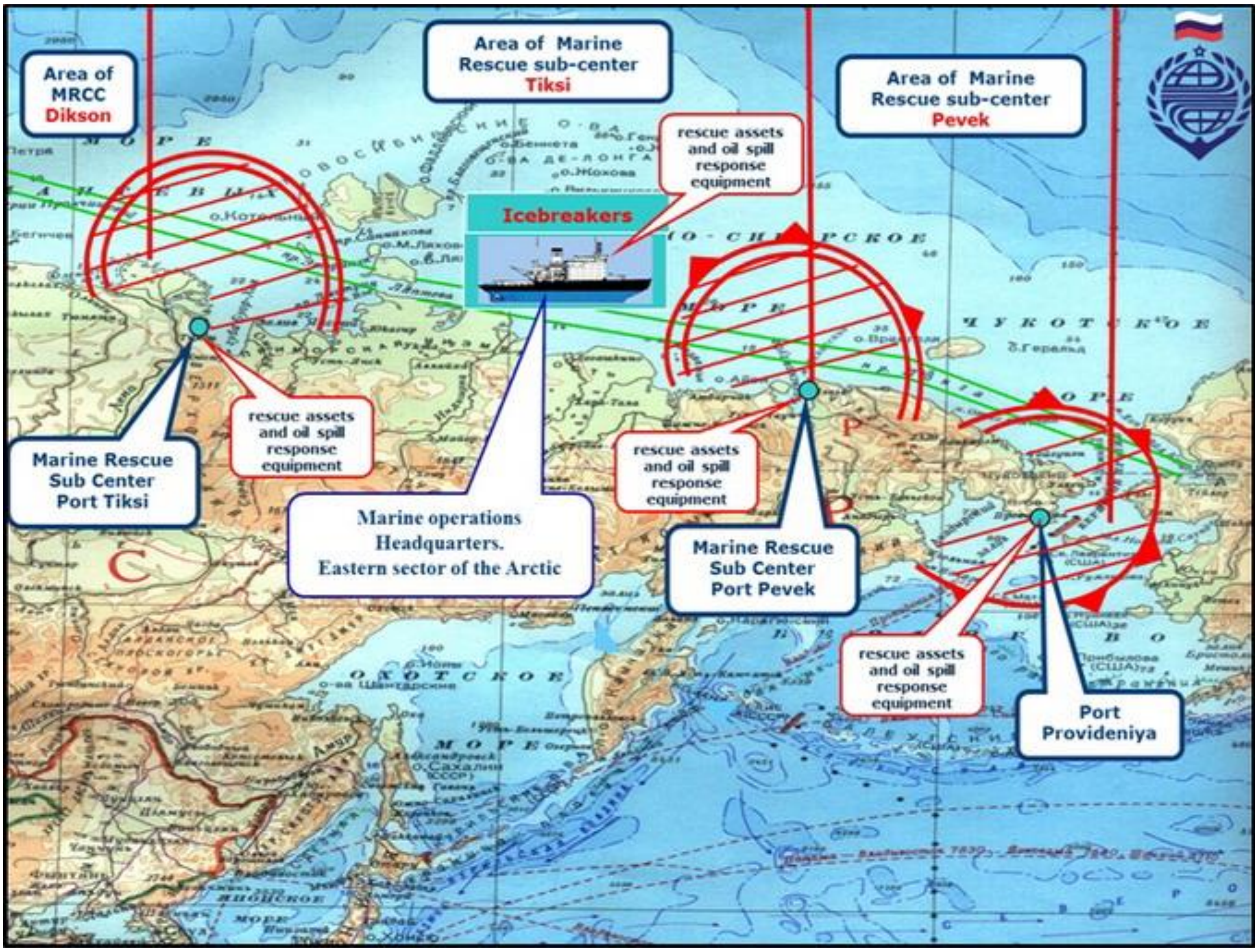

Figure 2.2: Search and rescue coordination areas in the eastern section of the NSR
Source: Gosmorspassluzhba (2013)

coastal or northern route, the ice conditions in the Arctic may force the shippers to alternate the route several times and the length of the Northern Sea Route therefore varies between 2,200 and 2,900 nautical miles (Østreng, et al., 2013, p. 13). The waters along the NSR between the Kara Gate to Cape Dezhnev is administered by the Russian Federal institution "Administration of the Northern Sea Route" (NSRA) with the main targets of "…*ensuring safe navigation and protection of marine environment from the pollution in the water area of the Northern sea route*" (NSRA, 2015).

The NSRA manages the Russian icebreaker fleet, which is currently the largest in the world[1], and evaluates if icebreaker escort is needed and also administers fees related to icebreaker escort service for vessels traversing the NSR. The NSRA provides short and long term ice cover forecasts, and from this determines the necessity for icebreaker assistance along the planned route, given the ice classification of the vessel traversing the NSR. The NSRA has established requirements of the ice strengthening capabilities of vessels navigation the NSR given the navigation season and general ice conditions at the time. To illustrate, it is allowed for a light ice reinforced vessel, class ICE3, to independently navigate the entire NSR in mild ice conditions during the period August to November 1st. However, in case of medium ice conditions, a minimum of class polar class 6 (Arc6) is required for vessels. Further, the Russian Federal Tariff Service recently announced an updated icebreaker tariff scheme for foreign vessels navigating the NSR coming into effect by 21 April 2014. Compared to the previous system this new tariff scheme presents an increased transparency of the system, lowering of the official price level, which makes cost projections of navigating the NSR more accurate for operators. This updated icebreaker escort tariff

[1] The fleet includes seven nuclear powered and multiple conventional ice breakers.

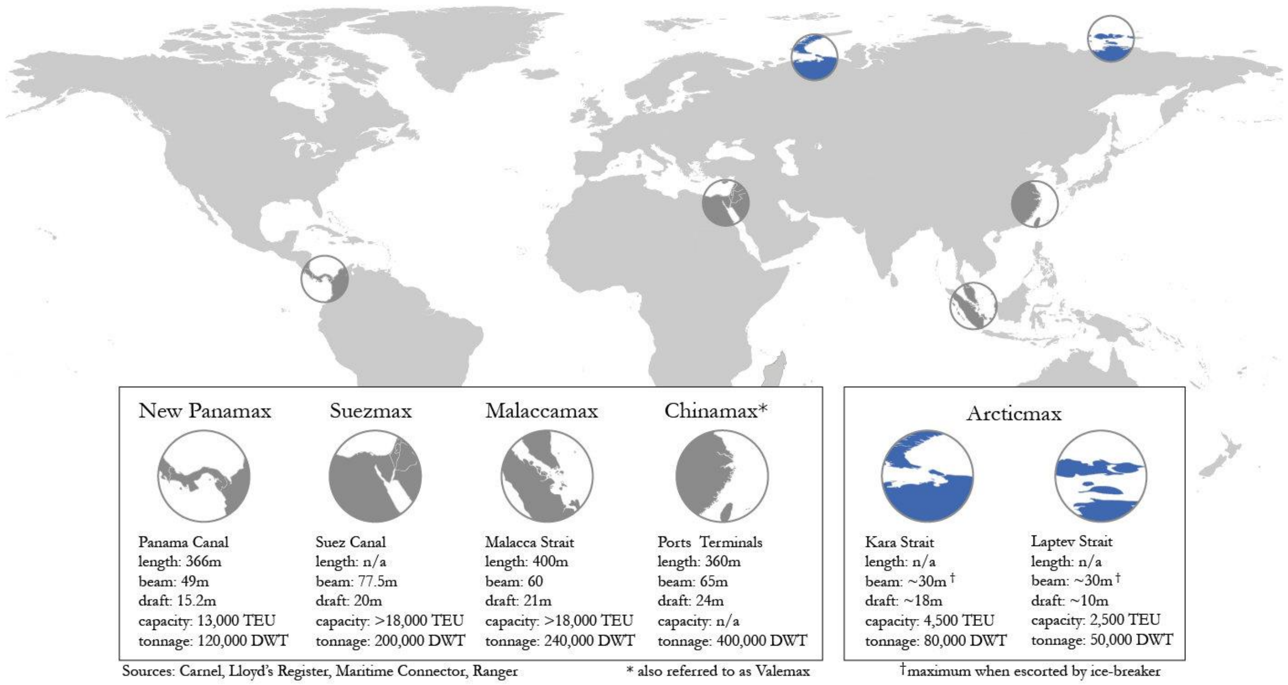

Figure 2.3: Global shipping choke points
Source: The Arctic Institute

is determined based on the following four voyage specifications:

- Total gross ton of the vessel seeking passage
- The ice classification of the vessel
- The season where the passage is to occur
- The areas where icebreaker assistance is needed

The base fee increases with the number of zones where icebreaker assistance is provided but is not directly affected by the lengths or time of the received escort service. This implies that the icebreaker assistance fee will remain the same regardless of receiving icebreaker assistance for 10 or 500 nautical miles within the of the zone along the NSR. Additionally the tariff fee only applies when actually receiving icebreaker escort, creating the potential for ice-reinforced merchant vessels to completely avoid transit fees in mild ice conditions. Previously the tariff was mandatory regardless of receiving icebreaker assistance or not, and it remains to be seen whether such a mandatory fee still applies. Russia has the most developed coastline infrastructures in the high Arctic, although the average distance between ports and SAR centers measures about 2000 kilometers. By far the largest port in the Russian Arctic is the port of Murmansk located on the Kola Peninsula, accessible throughout the entire year due to the Atlantic thermohaline current. Other smaller settlements with a moderate level of port facilities include Sabetta on the Yamal Peninsula, Tiksi at the Kara Sea and Pevek located near the New Siberian Islands. The infrastructure for SAR along the NSR has expanded in the last few years with two marine rescue operations headquarters located in Murmansk and Vladivostok. The operations headquarters in Murmansk is based on the federal state enterprise RosAtomflot, while the headquarters in Vladivostok is based on the Far Eastern Shipping Company. The SAR and the oil spill response assets along the NSR are managed in collaboration by with the headquarters by two marine rescue coordination centers and several marine rescue sub centers. The two marine rescue coordination centers are located in Murmansk and Dikson, while the sub centers are located in Archangelsk, Tiksi, Pevek and Port Provideniya. However, these centers are still separated by vast distances and the response time may easily be inadequate to prevent fatalities in case of an emergency. Although the infrastructure and traffic is scarce, the Russian Federation authorities have continuously emphasized that the NSR holds a great potential as a major international shipping lane, initiating several programs to further improve upon the current infrastructure and port facilities (Arctic Council, 2009).

2.2 THE NORTH WEST PASSAGE

The NWP is defined as the combination of shipping lanes connecting the Atlantic Ocean with the Pacific Ocean through the North American Arctic waterways. From east to west, the NWP passes through the Davies Strait, Baffin Bay and through the Canadian Arctic Archipelago to the Beaufort Sea. This then leads to the Chukchi Sea, finally opening up to the Pacific Ocean through the Behring Strait. In addition to holding vast reserves of minerals and petrochemicals, the waterways of the NWP has the potential to function both as an alternative to the Suez Canal and the Panama Canal. Potentially the distance between Northwestern Europe and Asia can be reduced by up to 30 per cent, as well as up to 20 percent between East Coast USA and East Asia. This Archipelago is a complex geographic area consisting of 36.000 islands spanning an area of 2.1 million square kilometers (Arctic Council, 2009). In similarity to the NSR, is not a specific route but a combination of several routes due to the multitude of different straits and waterways. Overall these routes follow a northern path through the Parry Channel, or a southern path passing south of Victoria Island. The northern route is relatively deep allowing for navigation of large sized vessels. These routes are subject to severe ice conditions, even during the summer, posing a navigational risk. The southern route can be used to mitigate this risk, as the Coronation Strait South of Victoria Island is better shielded from drift ice. On the other hand, this strait is extremely shallow and only allows for the passing of vessels with a draft of less than 10 meters.

The ice conditions in the Canadian Arctic are generally more severe than those along the NSR, and the straits remains frozen for a longer period throughout the year. Global warming has caused a reduction in the ice cover in the Canadian Arctic, the extent of summer sea-ice is volatile and several of the straits may still experience severe ice conditions even during summer. This was evident in 2007 most of the NWP waterways were completely ice free, while ice conditions in the following year were far more severe. In 2008 several of the Straits were covered in ice during most of the navigation season. During the summer months the Arctic Ocean current forces multiyear ice from the North Pole to drift into the NWP straits. This frequently clogs the straits, presenting a risk to all but the strongest icebreaking vessels operating along the NWP (Arctic Council, 2009). Because of the North Pole being covered in ice throughout the entire year - and will remain so in a foreseeable future - such flows of multiyear ice will continue to drift into the straits of the NWP, causing the navigation season to be less stable than that of the NSR.

Shipping in the Canadian Arctic is governed by the Canadian Coast Guard (CCG), which monitors vessel movements and provides radio services. Importantly ice and weather information is provided for vessels operating along the NWP through the NORDREG system. The CCG has divided the Canadian Arctic into various zones, where navigation is allowed depending on sufficient ice strengthening capabilities of vessels. (CCG, 2012).

Compared to the Russian Arctic the areas along the NWP are extremely underdeveloped – especially around the waterways of the Canadian Arctic. The largest and only well-developed port in the Canadian Arctic is Churchill, located in Hudson Bay close to the interior of the North American continent. The Hudson Bay shipping season lasts from mid-July to the beginning of November but the season could be lengthened significantly with the use of icebreaker support (Arctic Council, 2009).

Directly along the NWP lies Port Resolute, situated in the middle of the Archipelago on the banks of Cornwallis Island near the Barrow Strait. The Canadian Army has recently expanded the facilities at Resolute to enable the base to serve as a command post for SAR and disaster response operations (CAF, 2013). The port of Resolute is unsuited to accommodate vessels with a draft of more than 6 meters, but the Canadian Navy is currently constructing a deep water naval facility at Nanisivik, near the eastern entrance of the NWP, projected to become operational by 2018 (Sun, 2015).

Port facilities along the North American Arctic coast west of the passages are equally negligible. The closest well developed infrastructure is the west coast of Greenland, Nuuk being the largest and most significant port. The CCG currently maintains and icebreaker fleet of 17 vessels, six assigned to the Canadian North during the summer months. During the navigation season the CCG states it has an average response time along the NWP of 10 hours, under average ice conditions (CCG, 2013). Even though the CCG icebreaker fleet hosts a significant number of vessels, it is ageing with several of the vessels nearing retirement age. The Canadian Government has recently announced the investment of $CAD 720 million to replace the aging icebreaker flagship CCGS Louis S. St. Laurent but more funding is needed to maintain a significantly large fleet of icebreakers in the future (Arctic Council, 2009). Lastly, further development of maritime activities in the Canadian Arctic is hampered by Canadian legislation, as it provides an inadequate framework for transiting vessels. This results in uncertainties for the maritime sector investing in the NWP (NIRAS, 2014).

2.3 ARCTIC SHIPPING CHALLENGES

Although the opening of the Arctic Ocean has created a vast number of opportunities for the maritime industry, the remote and hostile Arctic Ocean still presents several major challenges for the industry. Some of these challenges include hazardous ice conditions, sub-zero temperatures and the lack of general maritime infrastructure. Further, an increase in maritime activities in the Arctic may adversely affect the sensitive environment, with oil spills being a major threat to the biodiversity of the Arctic Ocean.

There is a general consensus amongst researchers that the continuing reduction in the sea ice cover volume and area will continue to diminish in the future and that an ice free Ocean during September will appear somewhere within this century[2]. This dramatic decline in the ice cover provides the basis for an increase in maritime activities in the Arctic, as seasonal ice cover variations creates a fluctuating amount of possible navigation days and minimizes the risk of getting trapped in a sudden freeze during autumn. In the future, an ice free September Ocean will remove the presence of the thick multiyear ice; reducing risks even further (Arctic Council, 2009). The winter season ice cover is not expected to disappear in a foreseeable future, and navigation during the winter months will therefore not be possible. Summer weather in the Arctic is generally characterized by mild currents and wind conditions yet the weather patterns change during the autumn and winter with more severe conditions. More severe virulent wind systems appear[3] and temperatures often descending to -50 degrees, causing sea sprays to instantly freeze on vessels (Arctic Council, 2009). The Arctic Ocean is a hazardous operational environment for vessels and crews alike due to shallow unmapped seas along the continental coasts, low Arctic temperature, risks of encountering drift ice formations and the shrouded in darkness of the ocean for close to six months of the year. There is therefore a particular need for an expansion of shore side infrastructure for SAR operations as well as deep water ports, providing repair and refueling services (Arctic Council, 2009). At present, infrastructure for SAR

Source: Scanpix / Iris

[2] For more information regarding the future decline of ice cover see chapter 3

[3] These powerful weather systems are known as Arctic Lows.

is severely underdeveloped in large regions of the Arctic Ocean and the nearest assets may easily be located more than a thousand kilometers away from potential emergencies. The combination of slow speed of ships and the vast distances between facilities, results in a non-sufficient coverage to reach a distressed vessel. On top of this there is a general the lack of equipment: aircrafts, icebreakers and patrol vessels. In order to accommodate SAR operations as well as general escort operations through ice infested waters, the fleet of ships with a strong ice breaking classification needs to be expanded. Adding to the expansion, both the Canadian and Russian fleet are aging, requiring a general renewal of the fleets.

Technological infrastructure development is likewise also in need of heavy investment, for understanding local conditions and satellite communication. Given the sparse SAR capabilities better mapping of the ocean floor will provide safer transit of vessels, reducing the risk of groundings. To further reduce risk of ice and groundings, it is necessary to obtain better tools for forecasting ice movement, weather conditions and ocean currents. In providing this information, satellite communication systems are also inadequate. This is used for vessels maintaining contact with the relevant authorities and vice versa, but is however unavailable in large parts of the high Arctic. As the number of vessels operating in the Arctic increases, so does the risk of accidents and places pressure on the limited amount of infrastructure. Therefore the high Arctic coastal states have to carry out heavy investments, to provide a safer operational environment for its stakeholders.

The increase in maritime activities in the Arctic Ocean also provides a challenge to preserve the pristine and previously touched Arctic environment. Emissions from the engines of shipping, adversely affecting the environment, include carbon dioxide (CO_2,) Nitrogen oxide (NO_x), Sulphur Oxide (SO_x) and black carbon. Although these emissions are a product of shipping in all the World's oceans, black carbon darkens the surface of the ice-cover in the Arctic Ocean reducing the amount of sunlight reflected by the ice. Such a reduction in the reflection of the sun light (albedo) further increases melting and therefore enhances the already significant effects of global warming in the Arctic. Major oil pollution also has the potential to destroy Arctic environment. The 1989 Exxon Valdez oil spill in Prince Williams Sound Alaska, inflicted major damage to the environment with an estimated quarter of a million bird deaths. Fourteen years after the Exxon Valdez accident, oil was still found around Price Williams Sound. Due to the hostile climate and the lack of infrastructure, cleaning up oil spills poses a major operational risk (ACIA, 2004).

With the changing environmental conditions, and the challenges facing maximizing utilization of the Arctic, it is paramount to recognize the emergence of relevant legislation regulating the Arctic waterways and resources. National legislation regulates many aspects, as states themselves create standards for operations given the local conditions and priorities. This is an encumbrance for stakeholders in the Arctic, as they potentially operate within several national jurisdictions, thus making compliance with different national standards complex. Due to this complexity, the report seeks to provide an investigation into the multi-national governance structures in the Arctic (see part 8). These structures are important to understand, as these forums are potentially able to harmonize practices and create the best conditions for Arctic stakeholders. Findings by Arctic Marine Shipping Assessment in 2009 indicate that multilateral-governance will provide the best regulatory framework as this allows coordination between national entities. This coordination allows for the best protection of environmental concerns, because economic resources are better allocated (Arctic Council, 2009).

As with the emergence of landmasses, as the ice retreats, these multi-national organizations obtain certain broker positions within the Arctic community. In this framework the Arctic Council is important as the dominant state level forum for policy development and coordination. Based on a notion of applying the best science, the forum aims to create harmonized operational standards, optimal conditions for the development of local populations and to ensure environmental protection. Focusing on the political tensions, the United Nations Law of the Sea is similarly important being the only internationally recognized mechanism for defining the territorial boundaries. Growing economic interest in the regions natural resources, and the derived potential for benefits to the Arctic states, has increased the importance on how natural subsea structures define territorial boundaries. The overlaying and conflicting claims between states, have led to some tensions in the political positioning. The disputes will however not present a substantial challenge for the Arctic cooperation; as there is a high level of interdependency between the states in the long run.

2.3.1 Past studies on Arctic Shipping

The collapse of the Soviet Union in 1991 led to the subsequent opening of the Russian Arctic to foreign traffic. This produced a multitude of studies on the

Project	Time Span	Research Area	Participants
INSROP	1993-1999	*The Northern Sea Route*	*Japan, Norway and Russia*
Ice Routes – The Application of Advanced Technologies to the Routing of Ships through Sea Ice	*1997-1998*	*Ship efficiency in ice covered waters*	*European Union*
ARCDEV – Arctic Demonstration and Exploratory Voyages (1997-1999)	1997-1999	*Western Arctic Seas*	*European Union*
ARCOP – Arctic Operational Platform (2002-2006)	2002-2006	*The Northern Sea Route*	*Russia and Norway*
Northern Maritime Corridor (2000-2005)	2000-2005	*Barents, Kara and North Seas*	*European Union, Norway and Russia*
JANSROP (2002-2005)	2002-2005	*The Northern Sea Route*	*Japan*
Canadian Arctic Shipping Assessment (2005-2007)	2005-2007	*Canadian Arctic Waters*	*Canada*
AMSA – Arctic Maritime Shipping Assessment (2009)	2006-2008	*The Whole Arctic*	*The Arctic Council*

Table 2.1: National and multinational reasearch projects on Arctic shipping

possibilities of commercial activities in the Arctic. The rapid decline of the ice cover observed during the last decade, has increased the frequency of such studies as the probability of large scale maritime activities became more realistic.

These studies range from academic papers, books and commercial reports to large multilateral research programs aiming to assess the feasibility of maritime traffic in the increasingly ice free Arctic Ocean. These large research programs, listed in table 2.1, mainly explore the technical, environmental, infrastructure and political aspects, and do not have a focus on economic analyses and are therefore not further reviewed in this chapter.

In recent years, the focus of papers on Arctic shipping has changed to a micro economic foundation of quantitative studies on the feasibility of specific operations. The framework behind these studies varies between liner and bulk shipping, with both the feasibility of using NWP and the NSR as alternatives to the southern shipping lanes of the SCR and Panama Canal Route (PCR).

A brief review of recent studies on the economic feasibility of utilizing the Arctic shipping routes for commercial transport along with the methodology, framework and their assumptions behind is presented in table 2.2 below. These studies only include articles and studies published within the last decade. This is due to the unanticipated pace at which the Arctic sea ice is melting and the subsequent changes in the underlying assumptions of papers published prior to the change of the millennium[4].

[4] For a more extensive review of recent literature on the feasibility of Arctic shipping routes see Lasserre (2014).

Table 2.2: Review of economic studies on the feasibility of Arctic transport

Year	Authors	Objective	Routes analyzed	Origin and destination	Ship types	Navigation Season	Analysis Results	Weaknesses
2011	Xi, et al.	*To estimate the economic advantage of operating along the NSR during the navigation season (SCR the rest of the year) by calculating the cost savings compared to all year round SCR shipping.*	*NSR vs. SCR*	*Several combinations of port visits between North Western Europe and East Asia are examined. The vessel calls at four ports in both Europe and Asia regardless of the route*	*Conventional 10,000 TEU containership using both routes*	*One voyage equaling four weeks.*	*The results indicate that the annual fuel costs of a container fleet may be reduced by 3 – 5 percent by using the NSR during the summer navigation season.*	*The vessels examined in the analysis are not ice reinforced and may therefore not be allowed to operate in the Arctic. Further the analysis only includes the fuel cost savings leaving out the other critical cost components incurred by Arctic shipping.*
2008	*Somanathan, Flynn and Szymanski*	*To estimate the required freight rate of a transit of an ice-class ship from St. Johns, Newfoundland and New York to the port of Yokohama using the North West Passage compared to an ordinary vessel of the same size using the PCR.*	*NWP vs. the PCR*	*New – York to Yokohama and St. Johns, Canada to Yokohama*	*Unspecified Canadian Arctic Class 3 containership vs open water container ship of the same size.*	*All year round*	*From the simulations, they find that the route from St. Johns to Yokohama has a lower required freight rate relative to the PCR, although with a small margin. The authors conclude that further thinning of the ice cover on the North West Passage will reduce the costs relative to the Panama Canal Route and thereby make transit between New York and Yokohama via the Arctic economically feasible.*	*All year around shipping along the NWP is highly unlikely in the near future due to severe ice conditions.* *The market for new York – Yokohama alone may not be compatible to multiport visit routes.* *Far too few icebreakers in the Canadian Arctic to establish regular transits.*
2009	*Verny and Grigentin*	*To Establish the economic feasibility of regular container transport between North Europe and Asia by calculating cost per TEU.*	*NSR vs SCR vs Trans-Siberian Railway vs. air freight.*	*Hamburg to Shanghai*	*4000 TEU ice-class (undefined class) containership vs. 4000 TEU open-water containership as well as train and airplane*	*All year round*	*They find the cost per TEU using the NSR and Trans-Siberian railway to be roughly equal but both having significantly higher costs compared to the SCR. As the costs of freight by air are considerably higher than all of the above transport routes.*	*All year around shipping along the NSR is highly unlikely in the near future.* *The market for Hamburg to shanghai may not be compatible with no multiple port visits along the routes.*

Table 2.2 Continued:

Year	Authors	Objective	Routes analyzed	Origin and destination	Ship types	Navigation Season	Analysis Results	Weaknesses
2010	*Kronbak and Liu*	*To calculate and compare the yearly costs per TEU of transporting containers from North Western Europe to East Asia using the NSR during the navigation season (SCR the rest of the year) and the SCR given different scenarios of fuel price, navigation days and NSR transit fee.*	*NSR vs SCR*	*Rotterdam to Yokohama*	*4300 TEU ice-class 1B containership vs 4300 TEU open-water containership*	*Three scenarios analyzing 90, 180 and 270 days respectively*	*Firstly, a reduction in the icebreaker fee of 50 percent causes the NSR to be unprofitable compared to the SCR for all fuel price and navigation day scenarios. Secondly, a reduction in the icebreaker fee of 85 percent and a bunker fuel price of 700 and 900 USD per ton cause the NSR to become advantageous when the NSR is open for more than 91 days. Lastly, if the icebreaker escort is free of charge the NSR yields a higher profit for all bunker fuel prices and all navigation day scenarios.*	*The amount of TEU's transported per voyage may be over-estimated due to only one port visit per voyage.*
2013	*Furuichi and Otsuka*	*To calculate and compare the costs per TEU of transporting containers from North Western Europe to East Asia using the NSR and SCR given different fuel price, navigation days and ship sizes.*	*NSR vs. SCR*	*Hamburg to Yokohama*	*4300 TEU ice reinforced containership vs. 4000, 6000, 8000 and 15000 TEU ordinary container ships respectively.*	*Five scenarios analyzing 105, 135, 165, 195 and 225 days respectively.*	*Finds that an amount of five NSR trips per year (with eight SCR trips when the NSR is closed) makes the 4000 TEU ice-strengthened vessel advantageous to a 6000 TEU ordinary vessel for all levels of bunker fuel price examined. Additionally, the results suggest that a price of a ton of bunker fuel of 300 USD and 650 USD causes the NSR to be compatible to an 8000 TEU ordinary vessel.*	*The amount of TEU's transported per voyage may be over-estimated due to only one port visit per voyage.* *Additionally the NSR transit fee is based on old reporting's and therefore does not reflect the current pricing scheme.*
2014	*F. Lasserre*	*To calculate and compare the seasonal and annual costs per TEU of transporting containers from North Western Europe to East Asia using the SCR and either the NWP or NSR.*	*NSR and NWP vs SCR*	*Rotterdam to either Yokohama or Shanghai and additionally calling at Malta, Mumbai and Singapore when using the SCR.*	*4500 TEU 1AS ice classed container ship vs. a similar sized ordinary container ship.*	*6 months shipping season along both the NSR and NWP.*	*Cost per TEU is lower using the NSR between Rotterdam and Yokohama if the icebreaker tariff is reduced. The NSR will not be advantageous for cargo between Rotterdam and Shanghai unless the load factor is the same for both routes and the icebreaker fee is reduced considerably.* *Similarly, the NWP is advantageous compared to the SCR between Rotterdam and Yokohama but not between Rotterdam and Shanghai.*	*The NSR transit fee is based on old reporting's and therefore does not reflect the current pricing scheme.* *The cost comparison only runs for six months during the navigation season. The analysis does therefore not take the off season into account where the ice strengthened vessel sails at a large disadvantage.*

Table 2.2 Continued:

Year	Authors	Objective	Routes analyzed	Origin and destination	Ship types	Navigation Season	Analysis Results	Weaknesses
2011	*Schøyen and Bråthen*	*To calculate and compare the costs per megaton of nitrogen fertilizer and iron ore transported from North Western Europe to East Asia using the NSR, SCR and Cape Route*	***Fertilizer:** NSR vs. SCR vs. Cape of Good Hope **Iron Ore:** NSR vs. SCR for iron ore*	***Fertilizer:** Porsgrunn, Norway to Shekou, China **Iron Ore:** Narvik, Norway to Qingdao, China*	***Fertilizer:** Ice reinforced Handymax carrier with 40000 mt cargo capacity vs. open water Handymax carrier of the same size **Iron Ore:** Ice reinforced bulk carrier with 50,000 mt cargo capacity vs. an open water 68,000 mt cargo capacity Panamax bulk carrier*	*Single voyage examined.*	*They find that the cost of transporting one metric ton of fertilizer are higher on the NSR compared to the SCR, but is advantageous to the Cape of Good Hope Route. For the iron ore transport, however, they find the cost per metric ton to be advantageous on the NSR compared to the SCR, although at a small margin.*	
2010	*Det Norske Veritas (DNV)*	*To calculate the total costs of operating along the NSR compared to the SCR in 2030 and 2050 using projections on future ice distributions.*	*NSR vs. SCR*	*Rotterdam to Tokyo, Hong Kong or Singapore.*	***SCR:** 6500 TEU conventional container ship **NSR :** 5000 TEU and double-acting container vessel with ice breaking capabilities and 6500 PC4 ice classed container vessel in scenario one and two respectively.*	***First scenario:** All year navigation **Second scenario:** 100 days in 2030, increasing to 120 days in 2050.*	*Finds that seasonal transport between Rotterdam and Tokyo using the NSR may become economically attractive already in 2030 given the first scenario. In the second scenario, the NSR will not become favorable before 2050 unless the fuel price reaches an extremely high level.*	*The data and method is not published.*
2009	*Laujainen*	*Discussion of physical settings, traffic potential, route options and political issues of the Arctic Sea Routes*	*Both NSR and NWP vs. the SCR and PCR*	*N/A*	*N/A*	*N/A*	*Concludes that a reduced ice cover in the Arctic presents several opportunities of resource extraction and reduced transport times but argues that ship owners and ship builders may face managerial problems with diminishing route distances.*	*The paper discusses the topic but includes no quantitative analysis.*

3 ARCTIC SEA ICE – EXTENSION AND DECLINE

GLOBAL WARMING IS CAUSING THE ARCTIC SEA ICE TO RAPIDLY MELT, THEREBY INCREASING THE POTENTIAL FOR MARITIME TRAFFIC IN THE ARCTIC OCEAN. THE CRYOSPHERE IS, HOWEVER, A COMPLEX ENVIRONMENT AND SCHOLARS DISAGREE ON WHEN THE ARCTIC OCEAN MAY BECOME FREE OF ICE. THE FOLLOWING CHAPTER WILL REVIEW RECENT LITTERATURE ON THE SUBJECT IN ORDER TO PRESENT CURRENT PREDICTIONS ON HOW GLOBAL WARMING WILL AFFECT THE ARCTIC SEA ICE.

Global warming is causing the Arctic environment to change at a rapid pace. During the last few decades the Artic surface temperature has increased, at a rate almost twice that of the rest of the world, resulting in a thawing of glaciers and a drastic reduction in both sea-ice cover extend and volume. Consequently, the average sea ice extent, between 1979 and 2012, has seen a reduction of 3.8 percent per decade (IPCC, 2014). The most significant reduction of the sea ice extend has been observed during the September month with the 2012 September sea ice cover showing a reduction of 49 percent relative to the 1979 – 2000 average extend of 7 million square kilometers (Overland & Wang, 2013). Between 1979 and 2001, the September sea ice cover saw a reduction of 6.5 percent per decade. In 2005 this reduction increased to 8.5 percent per decade with a rise to 10.2 percent by 2007 and a further increase to a 12 percent by 2011 (Maslowski, et al., 2012). These observations have led to the consensus that an accelerating decline of ice cover on the Arctic Ocean will continue in the near future (IPCC, 2014). While there is a general agreement that these climatic changes, and the subsequent increasing decline in the Arctic ice cover, is caused by anthropogenic forcing's such as greenhouse gas emissions to the atmosphere, other factors may also contribute to these changes. As a consequence of the reduced ice cover on the Arctic Ocean, an increased amount of the solar radiation is absorbed into the ocean due to the considerable darker surface of the ocean, known as the positive feedback phenomenon (Walsh, 2013). This increased absorption of the solar radiation, during the summer season, further raises the surface temperature of the ocean contributing to the disappearance of the ice cover. As the summer sea ice cover, in the last few decades, has been rapidly receding north, the winter sea ice cover is not projected to disappear during the next century (Arctic Council, 2009). The cold climate of the Arctic winter will continue and during the last years the March Arctic ice cover has only receded by a few percent per decade. Although the Arctic sea ice will continue to cover the Arctic Ocean during winter, the average sea ice cover thickness has been reduced by 1.8 meters between 1978 and 2008 resulting in a drastic reduction in sea ice volume (IPCC, 2013) The figures 3.1 and 3.2 (next page) illustrates the Arctic ice cover during March and September for the years 1987 and 2012, respectively. While the March sea ice cover is almost identical during the 25 year span, the figures show the dramatic difference in the September sea ice cover during the same period. The September 2012 sea ice extent clearly shows the possibility of unhindered passage along the NSR and even the generally ice filled straits along the NWP are accessible. At present the Arctic Ocean is however covered in ice throughout most of the year. For Arctic shipping to become a serious contender, compared to the well-established shipping lanes, an additional reduction in the Arctic ice cover is needed. With the current level of human caused greenhouse gas emissions, a continuous warming of the Arctic is inevitable, but the resulting temperature increases and rate of declining ice cover is subject to debate. Several studies and projections of the future extend of the sea ice cover has been published with the most extensive being recently published fifth Assessment report, by the International Panel on Climate Change (IPCC).

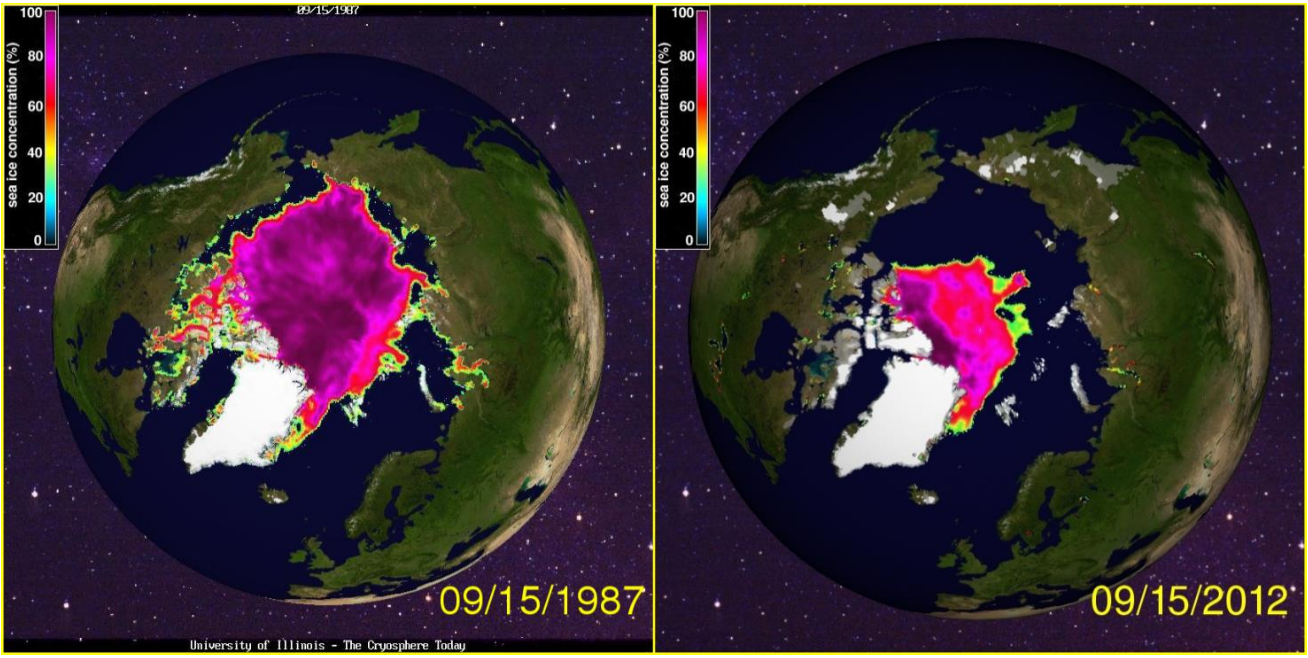

Figure 3.1: September sea ice concentration in 1987 and 2012
Left and right hand side image illustrates sea ice concentration in September 1987 and 2012 respectively. Darker colors indicate greater sea ice concentration.
Courtesy University of Illinois – The Cryosphere Today

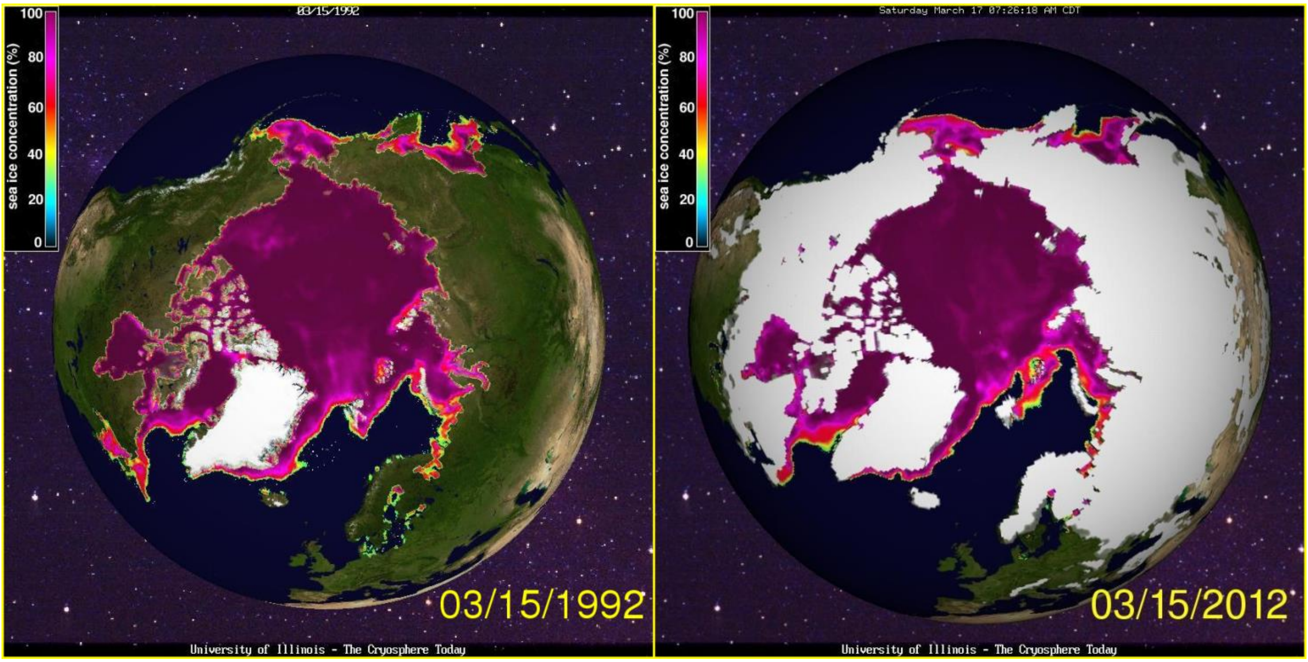

Figure 3.2: March sea ice concentration in 1987 and 2012.
Left and right hand side image illustrates sea ice concentration in March 1987 and 2012 respectively. Darker colors indicate greater sea ice concentration.
Courtesy of University of Illinois – The Cryosphere Today

This fifth IPCC report (AR5) provides the largest scientific study of the impacts of global warming comprising of contributions from hundreds of the world's leading scientists on the topic. According to the AR5 the temperatures in the Arctic may increase by up to 10 degrees Celsius at the end of the century relatively to that of the 1986-2005 level if human greenhouse gas emissions continue to increase (IPCC, 2014). The authors therefore conclude that the Arctic Sea ice cover is very likely to continue to diminish in the course of the 21st century as the global surface temperatures rise. The AR5 projects a reduction between 8 and 34 percent in the February sea ice extend in 2081 – 2100 compared to the 1986 – 2005 average and between 43 – 94 percent reduction in the September sea ice cover in the same period corresponding to a near ice free Ocean approximately midcentury given a high emission scenario. Figure 3.3 illustrate the February and September sea ice extend projections from a sampling of global climate models for medium and high emission scenarios, respectively.

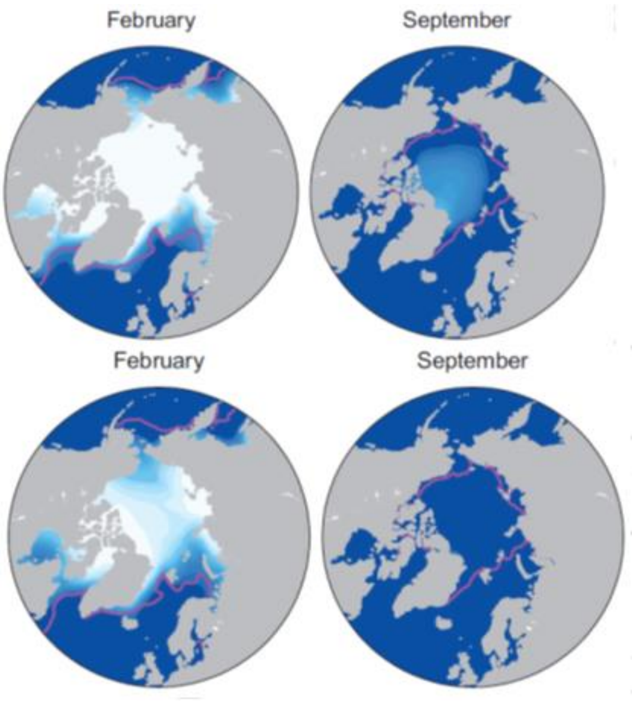

Figure 3.3: Projected Arctic sea ice concentration in 2080-2100

The top figures show a sea ice concentration given a medium future emission scenario (RCP 4.5) while the bottom two figures show the same for the high emission scenario (RCP 8.5). Light colors indicate a higher sea ice concentration.

Source: IPCC (2013), figure 12.29 pp. 1089

Climate projections by the IPCC are performed using a compilation of various global circulation models criticized for being far too conservative in their estimations of the reduction in the Arctic sea ice cover and volume (Wang & Overland, 2009); (Arctic Council, 2009); (Maslowski, et al., 2012). For example, the observed sea-ice extend reached a record low of 4.3 million km^2 in September 2007, a scenario which was not expected to reappear during the next 30 years according to IPCC estimates (Wang & Overland, 2009). By updating the IPCC models with these new observations, Wang and Overland (2009) approximates the time it takes to reach a September ice free Arctic Ocean and finds that such a scenario may be reached already by September 2037 with the first quartile being in 2028. Additionally the global climate models estimate the majority of the March sea ice to have a thickness of 2.5 meters when the September ices extend was 4.6 million km^2, which is reduced to only 1.2 meters when the September is ice free. It is important to note that since a completely ice free Ocean is not achievable within the next few decades, due to ice formations between the northern part of Greenland and the Canadian Archipelago. Most sources therefore define an ice free Arctic Ocean as an ice-cover of less than one million km^2, which will still leave the far majority of the Ocean navigable (Overland & Wang, 2013) (Wang & Overland, 2009). Regardless, an almost ice-free ocean just once a year will have profound implications for Arctic shipping. The disappearance of the hazardous multiyear ice and subsequent prevalence of only first year ice will make navigation in the Arctic easier for vessels with only moderate icebreaking capabilities, reduce the need for icebreaker escort and therefore lengthen the navigation overall navigation season. Maslowski, et al., (2012) argues that the modelled evolution of Arctic Sea ice volume is strongly correlated with the observed changes in the ice thickness after 1995, and estimates an annual reduction of the volume of sea ice of -1,120 km^3, which will result in an ice free September ocean as soon as 2016 although associated with a large uncertainty (standard deviation of 2.235 km^3). In a recent study, Smith and Stephenson (2013) use updated ice cover, climate and navigation models to simulate the optimal sailing routes for merchant vessels in the Arctic Ocean during the years from 2040 to 2059. They conclude that by midcentury the ice volume has been dramatically reduced such that ice reinforced vessels of polar class six will be able to navigate directly over the North pole using the Transpolar Sea Route during September, while ordinary open water vessels, without icebreaker assistance, will be able to navigate the NSR and NWP as well (See figure 3.4). As mentioned earlier the benefits of using the transpolar seaway, if the ice cover disappears, are significant, reducing the sailing distance through the Arctic Ocean and staying out of the currently defined Russian exclusive economic zone. Although scholars disagree on the pace at which the ice cover disappears and large scale maritime traffic in the Arctic may become feasible, all of the above mentioned research papers and reports agree that global warming is causing the ice cover to disappear at an alarming rate. It is therefore not a question of if the ice cover will disappear but how soon the world will experience an ice free Arctic Ocean, creating the possibilities for a continued increase in maritime activities north of the Arctic Circle.

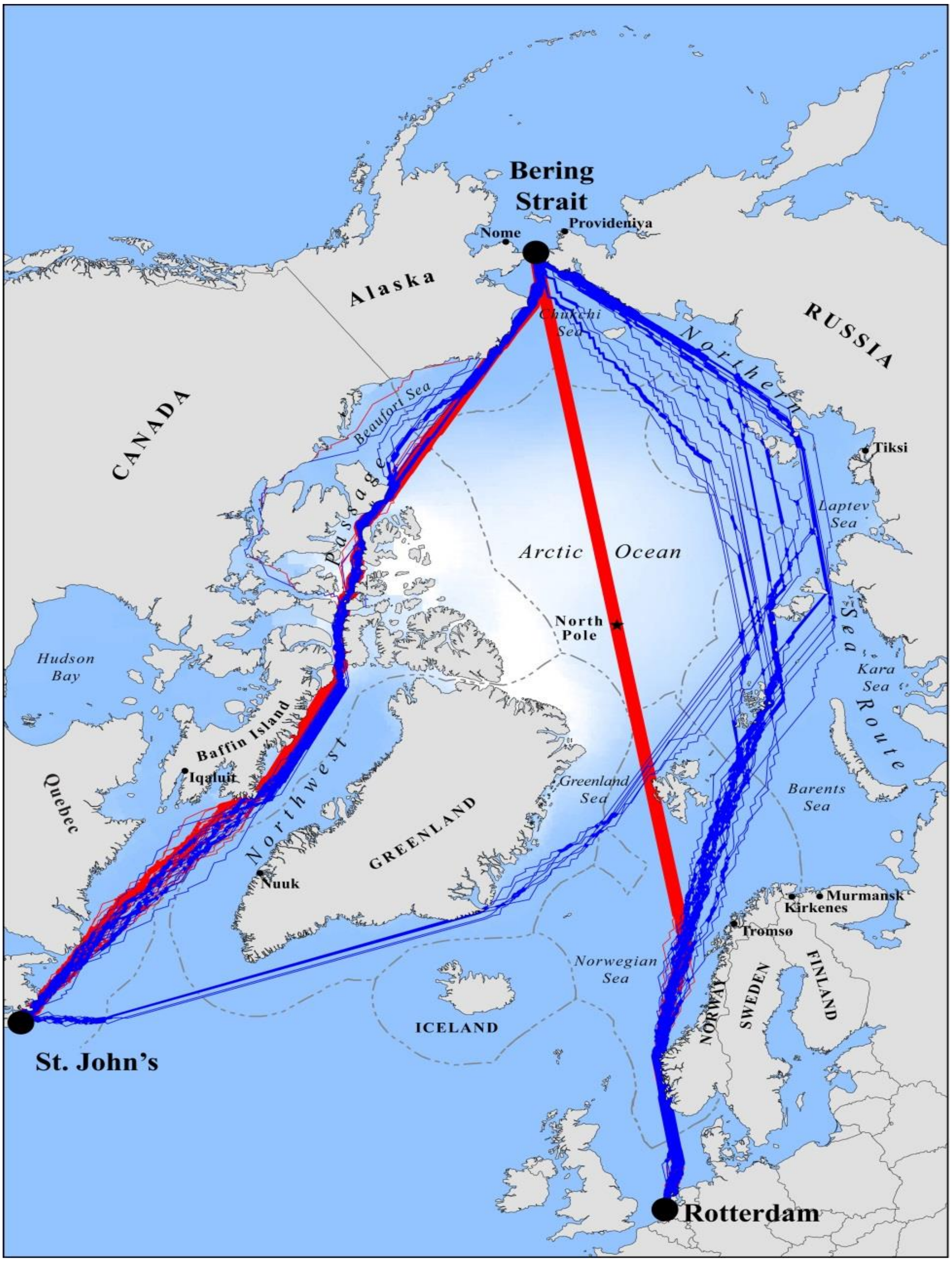

Figure 3.4: Projected Arctic shipping lanes from 2040 to 2059

Red and blue lines indicate the fastest route possible for a vessel of polar class 6 and ordinary open water vessels respectively.

Source: Smith and Stephenson (2013).

4 LINER SHIPPING IN THE ARCTIC – A POSSIBLE FUTURE?

USING ARCTIC SHIPPING ROUTES AS ALTERNATIVES TO THE SUEZ CANAL ROUTE WILL RESULT IN MAJOR DISTANCE AND COST SAVINGS. SEVERAL FACTORS SUCH AS A SHORT NAVIGATION SEASON AND SUDDEN CHANGES IN THE ICE CONDITIONS INHIBIT THE MAINTENANCE OF FIXED SCHEDULING AND TIMELY CARGO DELIVERANCE. ALTHOUGH MAINLY FOCUSING ON LINER SHIPPING, THE POSSIBILITIES AND CHALLENGES PRESENTED IN THIS CHAPTER MAY ALSO PROVIDE USEFUL INSIGHTS FOR THE BULK SECTOR.

The Liner shipping industry is the largest segment of the global shipping industry contributing an estimated 436.6 billion USD to the world economy and providing an estimated 13.5 million jobs worldwide (WSC, 2015). The dramatic increases in the price of oil over the last decade, has led to the liner shipping industry increasingly seeking new ways of reducing fuel consumption. This includes methods like utilizing the economics of scale by acquiring ever larger vessels, slow steaming to improve fuel consumption or improved hull designs. The rapid decline of the Arctic Ocean ice cover has increasingly created the opportunity of using the Arctic Ocean as transport corridor between the North Atlantic and East Asia. These passages reduce the distances by a significant amount compared to the contemporary shipping routes potentially lowering both fuel consumption and voyage time.

This chapter aims to inform the reader of the opportunities and challenges faced by the international liner shipping industry in Arctic operations. Liner traffic in both the NWP and the NSR will be investigated, the first section facilitating the opportunities and challenges. The second part aims to give a quantitative case study on the feasibility of utilizing the Northern Sea Route as an alternative to the Suez Canal Route.

4.1 TRANS-ARCTIC OPPORTUNITIES

The liner shipping industry mainly transports general cargo between ports located near the world's population centers. The opportunities and challenges of Arctic liner shipping presented in this study are therefore mainly concerned with trans-Arctic shipping. The Arctic routes of importance to the sector are the NSR the NWP and the Trans Polar Route (TSR)[5]. Both the NSR and NWP are considered as potential alternatives to the SCR reducing the voyage distance between Northwestern Europe and East Asia by up to 40 percent and 30 percent, respectively. Additionally the NWP also has the potential to save up to 20 percent of the distance compared to the PCR, for routes transporting goods between Eastern USA to East Asia.

The NSR is mainly a viable alternative to the SCR, a route with tremendous volumes of containerized goods. Along the SCR one can observe that the majority of the world's largest containerships are operating. In 2013, the amount the total containerized seaborne trade between Northern Europe and Asia amounted to 13.7 million TEU (WSC, 2015). Table 4.1 (next page) shows the potential distance savings, revealing the massive savings achievable by using the NSR compared to the SCR. This is especially when covering the areas in the north Eastern part of China, South Korea and Japan. It may even be viable for the NSR to cover the large ports of the southern China, with close to a 14 percent reduction in the distance between North Western Europe and Hong Kong. However, using the NSR for Singapore is not a viable option, as the route is 17 percent longer than the SCR. Solely measuring from distance this implies a breakeven point between the SCR and NSR, located somewhere along the southern coast of Vietnam. The economic breakeven point of the alternatives may however be located at significantly higher latitude depending on the costs of the NSR transit.

[5] The TSR is the most direct route through the Arctic Ocean, thus allowing for further distance and fuel savings (see Humpert and Raspotnik, (2012)). The ice conditions around the North Pole will, however, not allow regular transport in a foreseeable future and the rest of this chapter is therefore only concerned with the NSR and NWP.

Departure	Destination	Distance SCR (nm)	Distance NSR (nm)	NSR Distance Reduction (%)
North Western Europe	Tokyo	11,292	6,905	38.85
	Busan	10,827	7,248	33.06
	Shanghai	10,532	7,688	27.00
	Hong Kong	9,753	8,399	13.88
	Singapore	8,343	9,731	-16.64

Table 4.1: Distance savings of the NSR as an alternative to the SCR between North Western Europe and Asian ports

Source: Own calculations using Google maps and Sea-distances.org

Departure	Destination	Distance SCR (nm)	distance NWP (nm)	NWP Distance Reduction (%)
North Western Europe	Tokyo	11292	7798	30,94
	Busan	10827	8141	24,81
	Shanghai	10532	8581	18,52
	Hong Kong	9753	9292	4,73
	Singapore	8343	10624	-27,34

Table 4.2: Distance savings of the NWP as an alternative to the SCR between North Western Europe and Asian ports

Source: Own calculations using Google maps and Sea-distances.org

This implies that containerships servicing the North Western Europe (NWEU) to East Asia route may be able to cover a large fraction of the major ports located in China if the additional costs of transiting the Arctic Ocean are relatively modest.

In addition to the NSR, the NWP is also well suited to serve as a seasonal alternative for the Europe to Asia trade. Table 4.2 shows the potential distance savings of transporting goods between North Western Europe and East Asia using the NWP as an alternative to the contemporary SCR. It captures that in similarity with the NSR, the NWP has the largest potential for the Northwestern Europe to East Asia routes for the ports located in Japan, South Korea and the northern part of China. Respectively there is close to 31 and 25 percent saving in distance to the ports of Tokyo and Busan. The world's largest port of Shanghai achieves a distance saved above 18 percent. These savings diminishes to less than 5 percent for the port of Hong Kong, thus the SCR remains significantly more competitive for the ports located in the South China Sea. Although not being as competitive as the NSR for Europe to Asia transits, the NWP still has the potential to reduce the travel distances to several of the large East Asian ports compared to the SCR.

Travel along the NWP does not only form an alternative to the SCR on the Europe to East Asia trade. Navigating the NWP may also lower the voyage distance on the East coast USA to East Asia trade by functioning as an alternative to the PCR. In 2013, the containerized trade between North America and East Asia amounted to over 23 million TEU - this is almost double that of the trade between Northern Europe and East Asia in the same year although a large fraction of the cargo is shipped from the North American west coast and therefore not relevant in the context of the NWP (WSC, 2015). Table 4.3 (next page) illustrates the distance reductions achieved by using the NWP compared to the PCR for the New York – New Jersey – Baltimore area to East Asian ports. The distance savings achieved by navigating the NWP as an alternative to the PCR are close to 20 percent for most of the large ports located in North Eastern Asia.

Departure	Destination	Distance PCR (nm)	distance NWP (nm)	NWP Distance Reduction (%)
NY - NJ – Baltimore	Tokyo	9,623	7,764	19.32
	Busan	10,056	8,107	19.38
	Shanghai	10,577	8,547	19.19
	Hong Kong	11,148	9,258	16.95
	Singapore	12,421	10,590	14.74

Table 4.3: Distance savings of the NWP as an alternative to the PCR between East Coast USA and Asian ports
Source: Own calculations using Google maps and Sea-distances.org

The distance savings are therefore not as dramatic as those observed on the Europe to Asia trade, but interestingly, the NWP remains a viable option for reducing the total voyage distance to major South Asian ports relative to the PCR. For ports, such as Singapore for example, there is close to a 15 percent reduction in distance when using the NWP versus using the PCR.

From the above tables it is clear that utilizing the Arctic routes, between the coastal states of the North Atlantic and East Asia, allows for dramatic savings in distances compared to the established international shipping lanes. The dramatic reduction in distance between Western Europe and East Asia has not only the potential to improve fuel savings but may also allow better asset utilization. This can be achieved by increasing the amount of voyages possible for a vessel each year, thus leading to an increase in revenue during seasons of high market demand.

The feasibility of utilizing Arctic shipping lanes is not only determined by voyage distances. Other than the factors discussed in the previous chapter, also time scheduling and accessibility of the routes are highly important for containerized goods. The opportunities for liner shipping in the Arctic are therefore critically dependent on the future level of ice cover in the Arctic Ocean.

Sea ice will continue to be an integrated part of the Arctic Ocean for decades to come and the shipping lanes will be covered in ice throughout most of the year (see section 3). Only for a limited season each year are these shipping lanes sufficiently ice free. Presently, the annual amount of navigational days for the Northern Sea Route is limited to a few months and the volatile nature of drift ice in the Canadian Arctic results in an even shorter season. Such instabilities in the navigation season are especially apparent along the NWP, where the ice conditions vary dramatically, with some years being impossible to traverse even at the height of the navigation season.

Most liner shipping companies operate according to a strict time scheduling, with the potential for large compensations to the shippers in case of late deliveries of the cargo. Fixed time scheduling is easier to maintain for open water routes, along established shipping lanes, due to fewer fixed transport natural hindrances. The hostile natural conditions of the Arctic present challenges for this, as a fixed schedule may be impossible to follow. The highly volatile ice and weather conditions may cause a series of delays for transiting vessels. This can range from being temporarily stuck in the ice or needing the assistance of an icebreaker to cross a particular challenging section of the route. Although the NSRA assigns icebreakers along the NSR to assist vessels through ice infested waters, a transiting vessel may have to wait several hours or days for assistance in passage. This is due to icebreakers not assisting individual vessels but preferable whole convoys. Thus not only the environmental conditions of the Arctic pose a challenge, but also the actual assistance operations restrict vessel mobility compared to the SCR. Finally, the seasonal changes of the Arctic navigation season may complicate the stable time and route scheduling on which shippers of general goods rely. Common to all sectors of maritime industry operating in remote Arctic waters are the serious safety concerns of the crew, cargo and vessel. Parts of the Arctic shipping lanes are poorly charted, SAR infrastructure is severely lacking and moving drift ice may damage and in extreme cases cause the vessel to become stuck in the moving ice for several days.

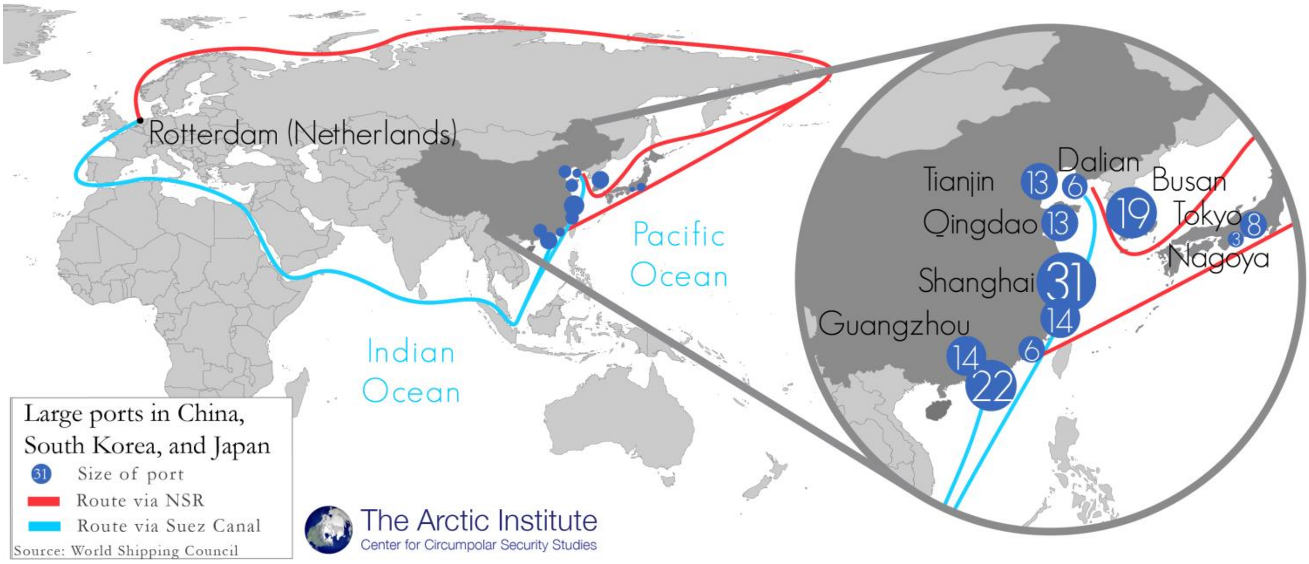

Figure 4.1: Major container ports in East Asia that are within reach of the Arctic Routes
Source: The Arctic Institute

This is especially apparent along the NWP where drift ice enters the narrow straits and where developed infrastructure and SAR facilities are underdeveloped. In order to secure safe navigation in the ice infested Arctic waters, several modifications to the vessel are required such as installments to prevent icing and a sufficient ice strengthened hull. The requirement of an ice reinforced hull has major implications for the feasibility of liner shipping operations in the Arctic, due to the increased building costs of the vessel and increased fuel consumption due to hull modifications (Kronbak & Liu, 2010). This implies that a sufficient amount of operational days must be spend in ice filled waters in order to compensate for the fuel consumption disadvantage when operating in open waters. Additionally, the operator must ensure that the vessel can be relocated to alternative markets during the winter in order to utilize vessels when the Arctic routes become inaccessible (NIRAS, 2014).

Another major barrier is the lack of population centers around the Arctic Ocean. The shipping lanes in the Arctic are lacking major ports along the route. The current large liner shipping routes between the Atlantic coastal states and Asia passes regions with large population centers and frequently stops at ports along the route to exchange cargo. This results in a vessel navigating the SCR being able to utilize their assets better by offering several transits, thus increasing the revenue of the liner shipping firm. Of the world's 50 largest container ports measured by the annual handling of containers, only 11 of these are located in the vicinity of the entrances to the NSR. Conversely, a containership operating along the SCR will pass 24 of the world's 50 largest container ports (Containerization International, 2013). For example, it will not be economically feasible for a vessel arriving through the Behring Strait, to call at Singapore, Hong Kong and Shenzhen, as these ports are situated too far to the south. Thus for a vessel on an eastbound voyage and designated to call at these ports, the SCR would be the rational choice. However, several significant ports with high growth rates are situated on Northern latitudes favorable for containerships arriving in the Pacific from the NSR. These include Shanghai, Busan, Ningbo and Qingdao, which are all amongst the ten largest ports in the world measured in annual container handling (Ibid.).

On the East Coast USA to East Asia trade, the PCR does not hold a significant advantage compared to the NWP when measuring the number of major container ports that the vessels pass along the voyage. Only the ports of Balboa, Panama and Savannah are amongst the 50 largest container ports located along the PCR between North Eastern USA and East Asia, and the NWP can therefore be seen as a viable option for trans-pacific voyages when taking into account the possibilities of cargo transfers in large ports along the route.

4.1.1 The NSR and China

In 2013, the Chinese 19,000 ton multi-purpose containership "Yong Sheng" became the first vessel in history to transit the NSR carrying containerized cargo (BO, 2013). The project was initiated by the Chinese state owned enterprise COSCO and departed from Dalian on 8 August and, after visiting Shanghai and Busan, continued on to navigate the Northern Sea Route. The "Yong Sheng" successfully entered the European port of Rotterdam on the 11th of September, using only 35 days to complete the voyage. Chinese interests in the region have increased in the last years, with the Chinese icebreaker "Xue Long" becoming the first Chinese vessels to complete a voyage over the NSR in 2012. High dependence on foreign trade has caused China to seek a diversification of trading routes to Europe in case of high political instability along established shipping lanes. This was exemplified by the sister ship of the "Yong Sheng" being attacked by pirates in the Gulf of Aden, while the "Yong Sheng" was transiting the Northern Sea Route (FT, 2013).

In response to the rapid melting of the ice cover in the Russian Arctic, the Polar Research Institute of China Maritime Transport has stated that the NSR will in the future play a major role in Chinese trade. It is suggested that between *5* and *15* percent of Chinas trade value (approximately $bn. 500) could pass through the Arctic already by 2020 (Guardian, 2014). The recent gas and trade deal signed between China and Russia further strengthens Chinese commitments to developing the NSR. The agreement covered an extended cooperation between Russia and China, to develop Russian transport infrastructure. This was agreed for the Chinese to ensure passage over the NSR, by partaking in the establishment of the needed infrastructure (CD, 2014).

Although such statements imply a strong Chinese interest in the Arctic region, several projects initiated by the Chinese government casts doubt on the future level of commitment to developing the NSR. For example, the Chinese government continues to invest in major expansions of logistics and port infrastructure along the SCR. Similarly, a majority of Chinese imports of raw materials is projected to come from suppliers located in the Southern hemisphere, and Chinese exports may increasingly target non-European countries (Humpert, 2013). Additionally, the Chinese premier Xi Jinping recently announced plans to develop an international railway, energy and logistics hub for a "*Silk Road Economic Belt*", seeking to establish new trade and transport links between China and Europe (WSJ, 2014a). In December 2014 a Chinese cargo train arrived in Madrid after completing a 13 thousand miles journey, departing from Yuwi in eastern China only 21 days prior the arriving in the Spanish Capital (CNN, 2014). The voyage lasted 6 days less than the 27 days spent by the "Yong Sheng". Such infrastructure projects could severely challenge the prospects and development of shipping along the NSR (Bennet, 2014). The above indicate that Chinese government officials are planning on further developments along the contemporary southern trade routes and alternatives. Such developments question the commitment by China to future shipping in the Polar region as Chinese traffic on the NSR may be reduced to a level solely reflecting the import of resources extracted from the Russian Arctic (Humpert, 2013).

Source: Scanpix / Iris

4.1.2 Uncertain Horizons

Arctic liner shipping holds great potential, offering huge distance and fuel cost savings to ship-owners, transporting containerized goods between the Atlantic coastal states and East Asia. A further reduction in the sea ice extend is, however, required for these routes to be viable as major liner shipping corridors with the NSR currently holding a far greater potential than that of the NWP. This is caused by the more advantageous ice conditions along the Russian Arctic coast, compared to the waterways of the Canadian Arctic. The NSR also has a relatively well developed infrastructure for search and rescue, along with a well-established icebreaker escort service. Both these services are severely lacking along the NWP. Common to both routes is that the Arctic navigation season is currently too short, and ice conditions are too unpredictable, for liner shipping to be feasible. Arctic liner shipping therefore only remains a viable alternative to the contemporary shipping lanes if global warming continues to melt the ice cover along the NWP and the NSR. In the next chapter this this report will aim to quantify when the ice conditions will allow for liner shipping along the NSR to become a viable alternative to the SCR.

5 FROM THEORY TO APPLICATION: A QUANTITATIVE OUTLOOK FOR THE NORTHERN SEA ROUTE

GIVEN THE DISADVANTAGEOUS CONDITIONS MENTIONED IN THE PREVIOUS SECTION, IT IS HIGHLY UNLIKELY THAT LARGE SCALE CONTAINERIZED CARGO TRANSPORTS WILL APPEAR IN A FORESEEABLE FUTURE. HOWEVER, THE QUESTION THEN ARISES; WHEN, IF EVER, THE ICE CONDITIONS WILL ALLOW FOR CONTINUOUS AND ECONOMICALLY FEASIBLE CONTAINER TRANSPORT ALONG THE NSR?

5.1 ANALYSIS FRAMEWORK

The aim of this case study is to examine the economic feasibility of transporting containerized goods using the NSR between Northern Europe and East Asia as an alternative to the contemporary SCR. More specifically this study will aim to determine when (if ever) the investment in an ice reinforced containership for operation along the NSR becomes favorable to an open water vessel solely navigating the SCR. In this study the vessel operating on the NSR has a capacity of 8000 TEU and is compared to three open water containerships operating on the Suez Canal Route with a container capacity of 8000 TEU, 10000 TEU and 15000 TEU, respectively. The ice reinforced vessel is assumed to operate along the NSR during the navigation season and the SCR when ice blocks entrance to the Arctic waters.

The feasibility of investing in an ice reinforced vessel for operation along the NSR is determined by comparing the total costs of the two types of ships. These costs include the capital costs of acquiring the vessel along with the fixed and variable costs encountered by operating the vessel until terminated. The analysis is calculated in discrete time with yearly intervals, such that each period denoting a year from 2016 until the vessel is either resold or scrapped. Thus period *0* equals the year *2016* such that $t = 1$ for *2017*, $t = 2$ for *2018* while the last operational year of the vessel is denoted as year n equalling $2016 + n$.

- ***Assumption I:*** *Variables changing value through time use the denotation t such that* $t = 0$ *is year 2016,* $t = 1$ *is 2017 and* $t = n$ *is year* $2016 + n$

This allows for gradual alterations in the annual navigation days and fuel price variables, thus creating the possibility of determining not only *what* conditions are required for navigation along the NSR to become advantageous, but also *when* such a scenario might occur. Such a critical point where the expected return on the investment in an ice reinforced vessel surpasses that of an ordinary vessel is investigated under two Arctic warming scenarios and three oil price scenarios. Such a scenario with a gradual increase in the annual amount of navigation days contrasts the framework of recent studies on the feasibility of transporting goods through the NSR where different scenarios are set up using static levels of fuel prices and navigation days (Kronbak & Liu, 2010; Verny & Grigentin, 2009; Furuichi & Otsuka, 2013).

The vessels examined in this study are of different container capacity and solely comparing the costs is therefore not sufficient to estimate the feasibility of the vessel relative to that of another. Further, it is reasonable to assume that the large amount of ports located in southern Asia, will result in an increased amount of cargo when the vessels are navigating the SCR. In order to take into account this difference in the container capacity and load factor, the total costs for each vessels is therefore divided by the total amount of TEU transported. This allows for a common denominator without the impossible task of projecting and incorporating the extremely volatile freight rate decades into the future. In order to exclude the freight rate from the calculations, the freight rate is assumed to be independent on the route used. Product differentiation opportunities are therefore excluded from the study, such as freight rate premiums for faster delivery rates using the shorter Arctic routes. In order to determine not only if the costs per TEU for the ice reinforced vessel are lower, but also when this scenario may occur, the value of the total costs per TEU for the investment in an ice reinforced vessel is compared to that of the open water vessels. This creates a feasibility ratio as a function of the investment year and the consecutive number of operational years, presented in equation 1.1. The ratio takes into account the differences in both container deliveries and cost components of both types of vessel under the assumption of a similar investment year and duration.

$$R_s = \frac{\frac{TC_s^{SCR}}{TEU^{SCR}}}{\frac{TC_s^{NSR}}{TEU^{NSR}}} \qquad (1.1)$$

$R_s = Ratio\ of\ total\ cost\ per\ TEU\ given\ \ investment\ year\ s$
$TEU = Total\ TEU\ during\ the\ operational\ phase\ of\ the\ vessel$
$TC = Total\ costs\ during\ the\ operational\ phase\ of\ the\ vessel$

In an attempt to illustrate the complexity of the cost structure and environmental constraints behind such a pioneering investment decision, a multitude of variables needs to be included and consequently investigated in the analysis. In the following section, the routes and scenarios are further examined and explained. This includes studying the pace at which the Arctic sea ice is receding, which can be translated into the annual amount of navigation days possible along the NSR. Additionally, the section will describe and quantify the various costs encountered when operating a vessel. The five major cost components of running a ship are divided into the operating costs, periodic maintenance, voyage costs, cargo-handling costs and capital costs, described as follows by Stopford (2008):

- Operating costs consists of crew costs, stores and lubricants, repairs and maintenance, insurance and general costs.
- Periodic maintenance consists of dry-docking of the ship every two years and a special survey every four years in order to verify the sea worthiness of the vessel.
- Voyage cost consists of the price for bunker fuel, oil, port dues and canal dues.
- Cargo handling costs consists of the loading and discharging of containers when visiting a port.
- Capital cost is the repayment of the debt incurred from financing the purchase of the ship as well as the interest payments of the debt.

Due to the scope of this analysis, some of the less significant operating costs are excluded. These consist of stores, lubricants, crew supplies and dry docking maintenance[6]. This leaves the cost components such as capital costs, all the voyage costs, cargo handling costs as well as the repairs and the following fixed costs of maintenance, insurance costs and crew salary. Several of these cost components diverge in value for ice reinforced vessels compared to normal open water vessels, which will be further elaborated later in the analysis. While these cost components may be subject to nominal price increases due to inflation, all cost included in this analysis are measured in constant 2014 USD and all price changes are therefore measured in real terms.

- ***Assumption II:*** *All prices are measured in 2014 USD such that price changes indicate real price changes and not changes caused by inflation.*

This analysis is divided into 3 parts. The first part outlies and quantifies the different environmental constraints, as well as the cost components (chapter 6.1.). The second part combines these constraints and variables to form the mathematical framework, needed to facilitate the analysis of the economic feasibility of operating along the NSR (chapter 6.2). The third and last part presents the results achieved from the mathematical model presented in part two. It will also provide a conclusion to the opportunities and challenges of Arctic liner shipping (chapter 6.3).

5.1.1 Theoretical Framework

In order to take into account the time value of the future costs the discounted cash flow method is selected[7]. By using this method, cost components located in future time periods are discounted to their present value in order to compensate for both inflation and the real rate of return of investments. This makes it possible to evaluate and compare the feasibility of alternative investment decisions.

The discounted cash flow method is used for evaluating an investment running over several future periods, where these future values are discounted for the opportunity costs of initiating the investment. The NPV of an investment is set to run over duration of *n* years, with year zero as the point of investment, illustrated in equation 1.2 below.

$$DC = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t} \qquad (1.2)$$

[6] The exclusion of these cost components may not alter the outcome of the analysis significantly as they all take moderate values and are present on voyages along both the NSR and SCR.
[7] This method is also known as the net present value method.

$CF_t = Total\ revenue\ in\ year\ t$
$r = Yearly\ depreciation\ rate$
$C_t = Total\ costs\ in\ year\ t$
$n = Investment\ duration\ (years)$

The annual depreciation rate consists of a nominal depreciation rate, as well as a fixed depreciation rate. Because of inflation, the value of 100 US dollars in one year is rarely worth the same as 100 US dollars in the present. Therefore the annual nominal depreciation rate is equal to the annual rate of inflation[8]. The real depreciation rate, meaning discounted for inflation, equals the opportunity cost of initiating the investment, which is denoted by δ. The opportunity cost is defined as the rate of return yielded by investing the capital alternatively. Denoting the yearly depreciation rate as $r = \pi + \delta$ and inserting into equation 1.2 yields equation 1.3, used in the analysis section of this paper.

$$DC = \sum_{t=0}^{n} \frac{CF_t}{(1 + \pi + \delta)^t} \qquad (1.3)$$

$\pi = Annual\ rate\ of\ inflation$
$\delta = Discount\ factor\ (real\ depreciation\ rate)$

In a normal scenario, the investment is deemed favourable if present value of the cash flows takes on a positive value. In this study, however, only the cost side of the cash flows is taken into account as the total amount of transported TEU serves as a proxy for the revenue (positive cash flow). The most favourable option is therefore determined by the lowest present value as this indicates the investment decision yielding lowest total cost per TEU.

Several other investment theories used for evaluating the feasibility of investments currently exists such as the annuity, internal rate of return and payback methods. Both the internal rate of return and the payback method are undesirable when comparing alternative investments and therefore not relevant given the framework of this study. The annuity method is a viable alternative to the discounted cash flow method for comparing investments, but requires more calculations without significantly changing the outcome of the investment feasibility.[9]

5.1.2 Route and Vessel Descriptions

In this section, the route used to transport containerized goods between North Western Europe and north Eastern Asia is specified. The SCR departs eastbound from Northwestern Europe and into the Mediterranean Sea, the Suez Canal, the Red Sea, crossing the Indian Ocean before crossing into the Pacific Ocean through the Strait of Malacca. The NSR is affirmed as consisting of several routes around the numerous islands and ice formations found in the Russian Arctic. Whether the vessel traverses the numerous islands in a north or southbound direction therefore significantly changes the voyage distance along the Russian Arctic Coast. A majority of previous studies on the economic feasibility of transporting containerized goods using the Northern Sea route have all examined a southerly route navigating south of the numerous Islands situated in the Russian Arctic, increasing the possible amount of annual navigation days due to less severe ice conditions of the coastal waters (Liu & Kronbak, 2010; Furuichi & Otsuka, 2013; Verny & Grigentin, 2010). The version of the NSR examined in this study, diverges from the southern route by navigating north of the Novaya Zemlya Peninsula and north of the New Siberian Islands. Thereby the vessel avoids the shallow and treacherous straits of the Kara Gate and Sannikov Strait. At the same time the route crosses south of the extremely northern and ice infested Severnaya Zemlya Islands. The northerly route chosen results in a lower navigation season, but avoids the severe draft limitations of 13 meters and consequently allows for the transit of larger vessels. Although receiving considerably less focus in literature, transits of larger vessels was achieved using this northerly route, including the “Stena Polaris” transit in the fall of 2013 (Stena, 2013) and the Dynagas LNG carrier “Ob River” in 2012 (Dynagas, 2015).

For calculative purposes the NSR is divided into three segments, similar to the method used in Xi, et. al (2011). The route and the different leg stretches of the route is presented in figure 4.2. The first leg stretches from the ports in northeast Europe to the Vilkitskiy Strait south of the Novaya Zemlya Islands (Green line). The second leg lies between the Vilkitskiy Strait and the De long Strait, south of Wrangel Island, on the border between the East Siberian Sea and the Chukchi Sea (red line). The third leg continues from there on to the final destination of the port cities in northeastern Asia (teal line). The icy waters of the second leg of the Northern Sea route covers a distance of 1214 nautical miles while the length of the first and third leg depends on the ports on which the vessel will call.

[8] It is important to note that inflation is not incorporated into the model and the nominal depreciation therefore takes the value of zero.
[9] For more on investment evaluation methods see (Hedegaard & Hedegaard, 2011).

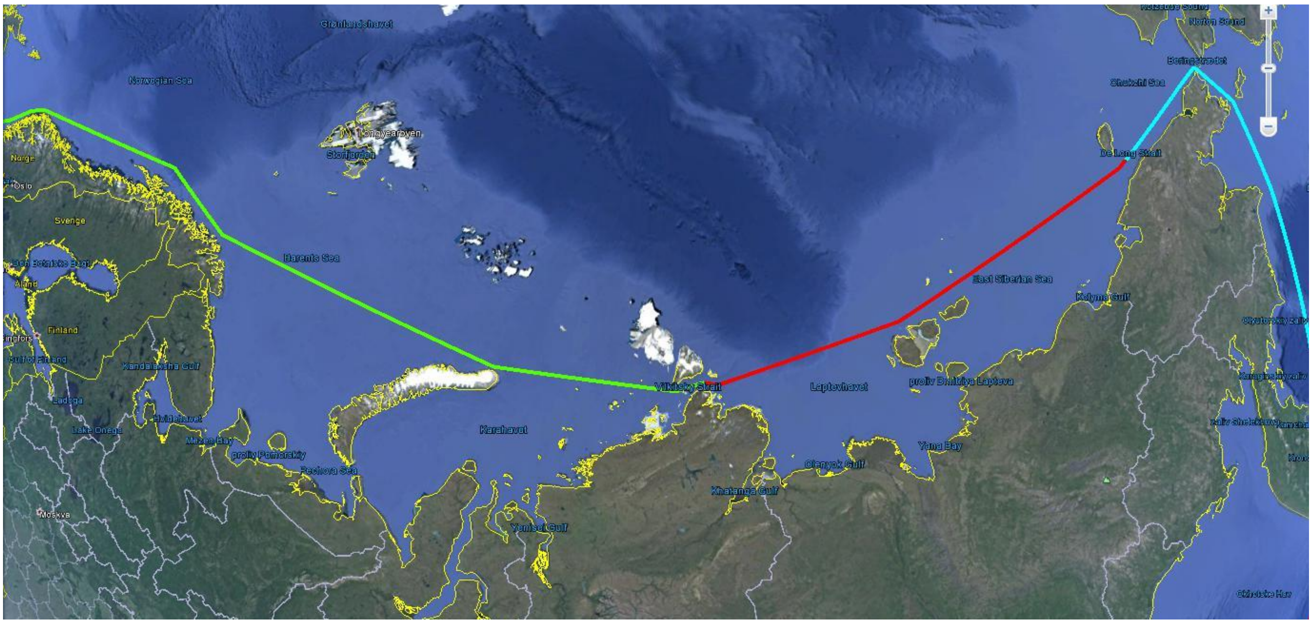

Figure 5.1: The version of the Northern Sea Route examined in this study
The green, red and teal line illustrates the route leg one, two and three respectively.
Source: Own calculations using Google Earth

On average, a containership servicing the Europe to East Asia trade, calls at between three and five ports in both the European and Asian segments of the voyage (Xu, et al., 2011). For simplification, the number of port calls per trip is reduced to three in both the Northwestern European segment and the north East Asian segment. The three ports visited in the North Western European cluster are the ports of Rotterdam, Hamburg and Antwerp while the three ports visited in the North East Asian cluster are the ports of Shanghai, Qingdao and Busan. The Suez Canal Route allows for additional ports visits along the way, as it transits more populous areas and will therefore call at Singapore and Hong Kong along the way. This increases the potential load factor, and consequently company revenue.

It is assumed that the vessel will call at each of the three ports just once when the vessel is operating in one of the clusters. This means that the vessel will discharge the cargo destined for that port while also loading new cargo for the destination ports on the other side of the Eurasian landmass. The vessel arriving at the Northern European cluster from East Asia, using either route, will consequently only call Antwerp, Rotterdam and Hamburg once.

During the winter the ice-reinforced vessel will transit along the SCR, and the distance is therefore the distance between Hamburg in Europe and Busan in Asia (via the six ports called at in between). The round voyage distance for the SCR is set to 22,826 nautical miles with a total of 10 port calls. During the summer navigation season, the ice reinforced vessel is solely operating on the NSR. In this period the voyage distance is therefore between Antwerp in Europe to Shanghai (via the four port called at in between). A round trip using the NSR calls six ports, with a total voyage distance of 15,762 nautical miles. The routes, distances and port calls are illustrated in figure 5.2.

This analysis denotes a voyage as a single east or west bound trip between North Western Europe and East Asia. Voyage distances and port visits are therefore calculated by taking the average of a west – and eastbound voyage for each of the two routes, respectively. This is due to the differences in the distance sailed, depending on the voyage destination and number of port visits. Although this will result in differences between the actual voyage distances and port visits, it is reasonable to assume that the total amount of both east – and westward voyages will converge in the long run, thus significantly reducing deviations. Further, such a measure of voyage distance and port visits results in complexities in estimating the exact distances for the ice reinforced vessel due to the two annual alterations in the route during the annual opening and closure of the NSR.

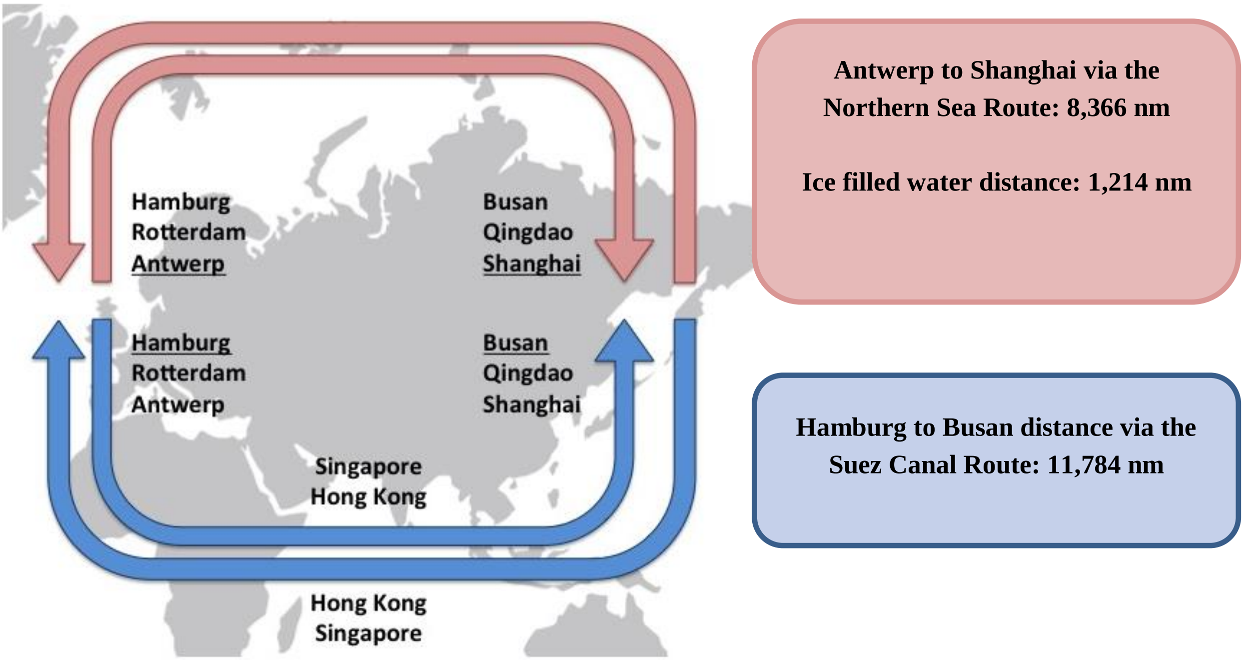

Figure 5.2: Voyage distances and port visits along the Northern Sea Route and Suez Canal Route
While only calling at each of the ports located in Europe and East Asia once, the vessel will call at both the port of Shanghai and Hong Kong on each voyage along the Suez Canal Route. The voyage distances are calculated as the averages of entire roundtrips.

These two transition phases, deriving from the opening and the closure of the NSR, results in a distance saving of either 432 or 826 nautical miles depending on whether the vessel initiates the next voyage from the European or Asian cluster. These small distance distortions are disregarded for simplicity, although these distances may cause the results of the analysis to be slightly biased towards the ice reinforced vessel.

5.1.3 Vessel Specifications and Acquisition

The requirement of being equipped with a reinforced double hull of sufficient ice classification along with numerous other technical requirements in order to get permission to enter the NSR are one of the major challenges for a ship-owner planning to operate in the Russian Arctic waters (see chapter 2.1). This part seeks to explain the size and dimensions of the case study container vessel, including the new build costs and finance aspects.
Previous studies on the economic feasibility of utilizing the NSR as an international container transport lane have investigated the most southern version of the NSR, effectively limiting the capacity of the container ship to 4300 TEU (Arcticmax). A containership of such a limited size is not able to leverage the same economics of scale as the ultra large containerships being added to the world’s liner fleet, leading to higher costs per TEU. The positive economics of scale linked to the increases in containership sizes have contributed to an increase in the size of the world’s liner shipping fleet with the largest containerships in 1980 of 3,000 TEU to the introduction of vessels larger than 18,000 TEU in 2013 with expectations of further increases in size in the coming decades (Kremer, 2013)[10]. Although huge distance savings are possible by using the NSR, an Arcticmax class containership is not economically competitive compared to an ultra large vessels operating on the Europe to East Asia trade (Furuichi & Otsuka, 2013). In order for liner shipping through the Arctic to become more than a niche market, conditions must allow larger vessels to operate along the NSR. Since the examined version of the NSR used for transiting goods between Europe and Asia lies on the more northern latitudes of the Russian Arctic, an ice-reinforced container ship with a capacity of 8000 TEU is selected for

[10] GMA GCN Recently launched the 18,900 TEU “*Marco Polo*”, currently holding the title as the largest container ship in the World.

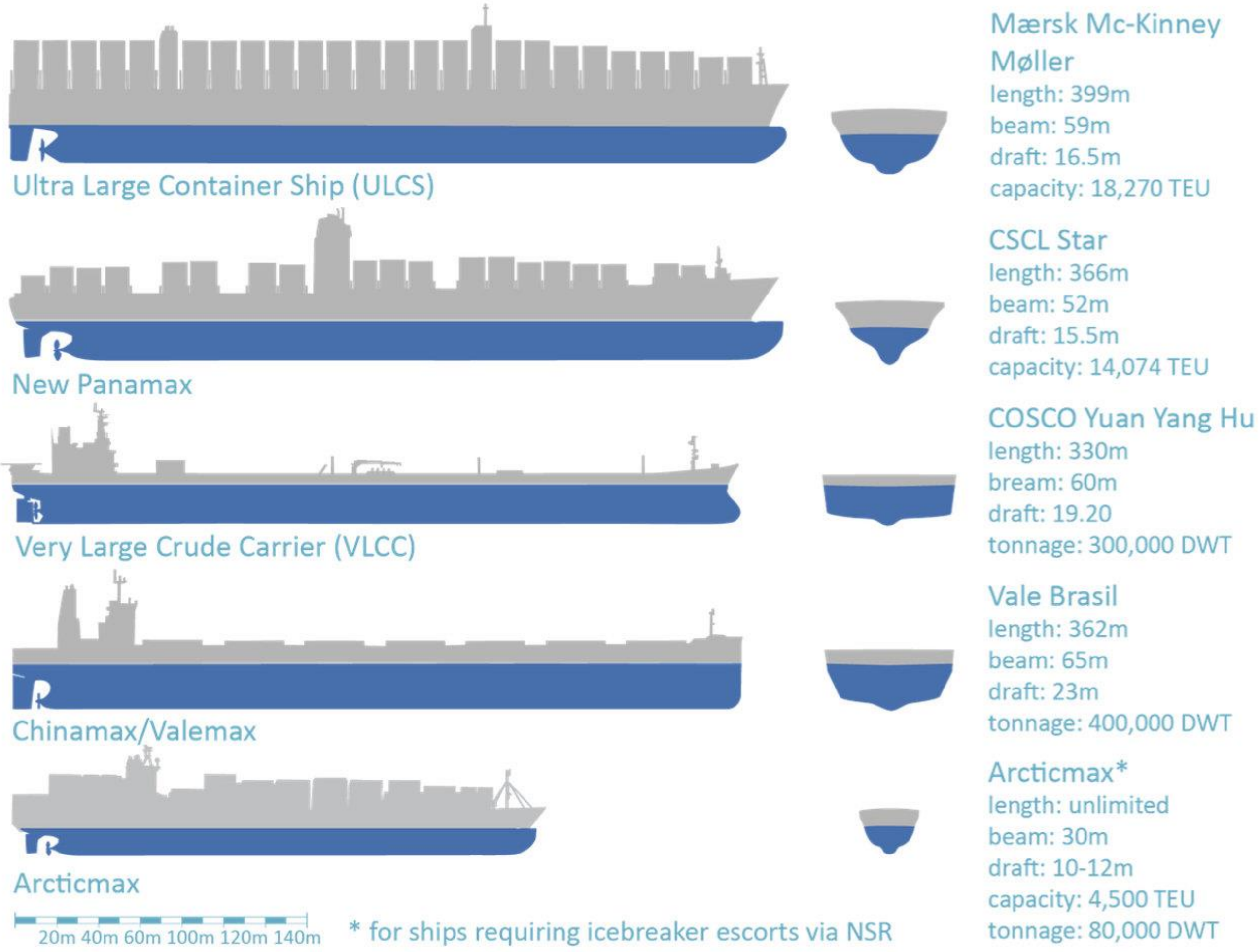

Figure 5.3: Size comparison of Arcticmax and large open water vessels
Source: The Arctic Institute

the purpose of this study. This consequently makes it possible to better compare the economic feasibility, comparing the NSR to the larger vessels operating along the standard SCR. Ultra large carriers are not able to operate in the Russian Arctic, due to the necessity of seasonal icebreaker escorting along the route. This is caused by the limitations of the icebreaker escorts, which have a limited breadth restricting the breath of the transiting vessel. The largest of the Russian icebreakers currently operating along the NSR have a beam of 30 meters, while that of the new generation of icebreakers, projected to enter service within the next decade, are increased to 34 meters (NSRA, 2015). According to Liu & Kronbak (2010) the maximum beam of the transiting vessel are not to exceed the beam of the icebreaker escorts while Furuichi & Otsuka (2013) argue that the maximum breadth possible is between 33 – 49 meters. The NSRA, however, does not list any beam restrictions and it therefore remains unclear if such restrictions exists. Transits of vessels with a beam far greater than that of the Russian icebreakers has been reported numerous times; “Arctic Aurora”, “Zaliv Amurskiy”, “Propontis” and “Zaliv Baikal” with a beam of 44.23, 42, 44.06 and 42.02 meters respectively (NSRA, 2015). For the sake of this study, it is assumed that an 8000 TEU vessels can navigate the Northern Sea Route given a calculate breadth of 42.91 meters (DSA, 2014). This lies within the bounds of the previously largest vessels transiting the Northern Sea Route. The open water vessels operating solely along the Suez Canal Route, used to compare the economic feasibility, are in this study set to be of a container capacity of 8000 TEU, 10000 TEU and 15000 TEU. Despite the thicker hull of the ice-strengthened vessels, the assumption is that the vessels operating solely using the SCR are subject to the same dimensions as the NSR vessels. Table 5.1 lists the dimensions of the containers ships used in this study.

	8000 TEU Open Water	8000 TEU Ice-reinforced	10000 TEU Open Water	15000 TEU Open Water
DWT	95.782	95.782	95,782	168,000
Draft (m)	14.33	14.33	14.73	15.73
Breadth (m)	42.91	42.91	45.51	52.01
Length (m)	325.5	325.5	349.39	399.6
Total volume (m^3)	264.157	264.157	338,594	499,149
Gross Tonnage	81.476	81.476	105.165	156.715
New Building Price (Mill. USD.)	87.9	105.48	122.5	159.4

Table 5.1: Vessel dimensions and building costs

Source: Calculations based on ship specifications spreadsheet from Danish Ship Owners Association and Furuichi & Otsuka (2013)

5.1.4 Capital Costs

The capital costs of acquiring the vessels, used to operate along the different routes, is a major cost component in this study due to the debt service spanning several years. Especially the large cost increase in new build ice reinforcing the vessels compared to ordinary open water vessels, results in the need for significant reduction in the operational costs to be economically feasible. The containership used to operate the Northern Sea Route is assumed to have an ice classification of polar class 6, being a reasonably strong classification to reduce the time spent receiving icebreaker assistance. Vessels of the Polar Class six classifications are able to sail through first year ice of up to 120 cm without an icebreaker escort (Smith & Stephenson, 2013). The new building cost is between 20 – 30 percent higher than compared to open water vessel depending on the level ice reinforcement (Kronbak & Liu, 2010). 20 percent is assumed for the purpose of this study, given the vessel examined only being able to penetrate moderately strong first year ice, thus still dependent on ice breaker assistance in more harsh conditions.

The newbuilding price adopted in this study are compiled from Furuichi & Otsuka (2013), as it provides new-building prices for container ships of several sizes. They estimate that an 8000 TEU container ship costs 87.9 million USD, while the price for a 15000 TEU container ship is 159.4 million USD. Given the volatility of ship prices, such figures may easily be subject to large fluctuations, but are assumed to be constant for the purpose of this study. Table 5.1 presents the new building prices for the different containerships forming the framework of this study.

- ***Assumption III:*** *Throughout this paper, demand and supply of ship building services are assumed constant and the prices encountered are therefore not subject to shipping cycle fluctuations.*

The acquisition of container ships is assumed to be financed by 70 percent debt and 30 percent of the capital cost to be covered by the investor's reserves (Kronbak & Liu, 2010). The debt is amortized over 15 years, with a 7 percent annual interest rate, calculating the annual debt service using equation 1.4 below.

$$C = B \cdot \frac{r}{1-(1+r)^{-n}} \qquad (1.4)$$

$C = Yearly\ Capital\ Cost$

$B = Initial\ payment$

$r = Yearly\ interest\ rate$

$n = Number\ of\ years\ the\ debt\ is\ serviced$

According to Stopford (2008) the average lifetime of a transport ship is 25 years. A building time of one year is assumed, with an initial shipbuilding payment to be transferred at the end of the first year of the investment. Therefore an investment is assumed to run for a span of 26 years, building the vessel in year 1, with 25 years operational years, before the vessel is sold as scrap. The demolition of transport ships is usually carried out in India, Bangladesh or Pakistan with the scrap metal used in local markets (ibid). With a negligible scrap-value of 425 USD per ton in 2012, the total scrapping revenue is approximately 40.000 USD for an 8000 TEU container ship (Bloomberg, 2012). Due to the multimillion costs and revenues associated with an investment in a containership, the income of the sale to a scrap yard is disregarded.

- ***Assumption IV**: The investment is assumed to run for a duration of 26 years of which the first year is used for the acquisition of the containership, thus being operated for 25 years before demolition.*

- ***Assumption V:** The vessel is assumed to be operated by the same company for the duration of the operational period and therefore not resold or time chartered forward.*

5.1.5 Navigation Days

The continuous decline of ice cover in the Arctic Ocean is one of the deciding factors that determine whether it is economically viable to transport goods through the NSR. Even though several Arctic climate studies have been published with various results, the future extent of the ice cover along the different sections of the NSR is impossible to forecast in a precise manner. A critical assumption of this study is the continuous expansion of the yearly navigation season along the NSR due to the melting of ice cover. The exact amount of navigational days forecasted here is therefore loosely based on the underlying trends of the sophisticated global climate forecasts mentioned earlier in this paper.

The annual navigation days along the Russian Arctic differs significantly between the marginal seas that form the NSR (Rodrigues, 2008). While the Barents and Chukchi Seas remained ice-free for more than 100 days in both 2006 and 2007, the Laptev Sea and East Siberian Seas proves the biggest barriers to maritime transport. The short season of these chokepoints can be mitigated by the use of icebreaker assistances and the Russian NSR administration generally allows for traffic on the NSR from the beginning of July to the middle of November given a sufficient level of ice-protection (NSRA, 2015). Significant variations in the ice cover results in difficulties when estimating the exact length, and for the purpose of this study, the navigation season of year 2016 is set to 120 days which is a realistic assumption for an ice strengthened vessel given the official navigation season listed by the NSRA. As this study will take departure in a dynamic analysis of the feasibility of transport using the NSR, a projection of the annual navigation days is required. Global Circulation Models are currently not capable of precisely projecting the future navigation period, and continuously underestimate the observed decline of sea ice cover in the Arctic Ocean (Stroeve, et al., 2012).

The only forecast in the hands of the authors are those of Khon, et al., (2010), who projects the annual amount of navigation days on the NSR based on the IPCC A1B global warming. They find the navigation season scenario to be approximately 90 days by midcentury (see figure 5.4). In the study days where navigation is possible are defined as water with a maximum sea ice concentration of 15 percent, although ships with a sufficient ice classification easily may be able to navigate in higher concentrations. The navigation season is further expanded with the aid of the Russian icebreakers as they allow for a significant increase in operational days along the NSR.

Given the general uncertainty of the speed at which the navigation season is increasing, both a low and a high navigation scenario is examined in this study. In the low and high global warming scenario, the average annual increase in the amount of navigation days are set to be 1.5 and 3 days, respectively (equation 1.5). These two

Marginal Sea	1979	2006	Difference	2007
Barents Sea	194	251	57	294
Kara Sea	41	77	36	110
Laptev Sea	22	51	29	75
East Siberian Sea	7	46	39	103
Chuckchi Sea	52	109	57	153

Table 5.2: Past observations of the annual number of ice free days along the Marginal Seas of the Arctic Ocean
Source: Rodrigues (2008)

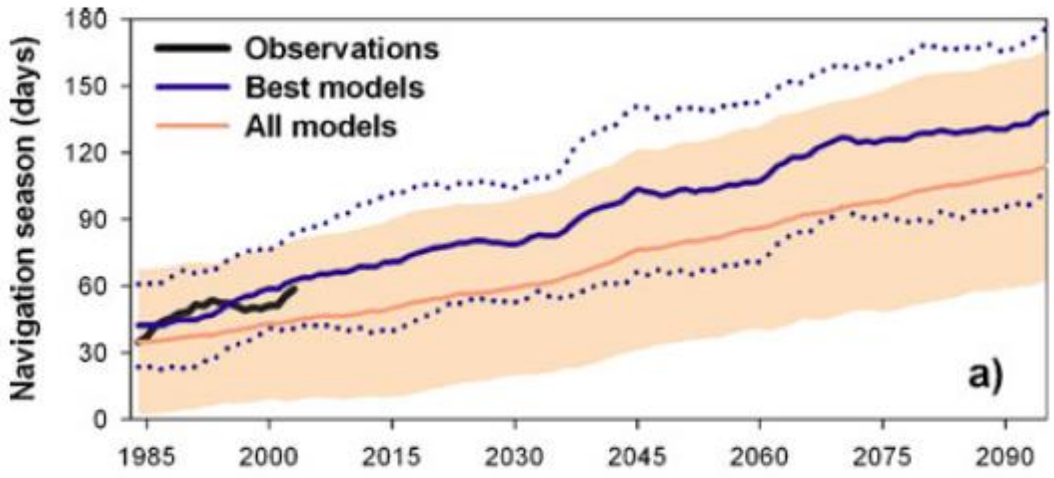

Figure 5.4: Length of the navigation season along the NSR from the Kara Strait to the Behring Strait
The black line illustrates past observations. The blue solid and dotted lines denote the mean and intermodal standard deviation of the selected best models using the A1B IPPC emission scenario while the orange line and the orange shading illustrate the same for all the models.
Source: Khon, et al., (2010)

scenarios will result in a navigation season expanding to approximately 170 and 220 days by the middle of the century. Consequently, the NSR will still be closed during the height of the winter period in both scenarios.

$$\tau_{t,j} = 120 + \sigma_j \cdot t \qquad (1.5)$$

$\tau_t = Navigation\ days\ on\ the\ NSR\ \ in\ year\ t$
$\sigma_j = Annual\ navigation\ day\ increase\ in\ warming\ scenario\ j$

A crucial assumption of this analysis is that the yearly navigation time on the NSR covers a continuous time span each year, such that no sudden NSR closures affect the vessel transit time. Given the volatility of the Arctic weather systems even in the summer, such a continuous navigation season may not be realistic but is assumed for simplicity.

- ***Assumption VI:*** *In the low and high Arctic warming scenario the annual navigation season increase is assumed to be 1.5 and 3 days, respectively.*

- ***Assumption VII:*** *The annual navigation time along the NSR covers a continuous time span from the opening of the route in spring/summer to the closure in autumn*.

Even during the navigation period in the Arctic Ocean, certain stretches along the NSR still experiences occasional pack ice, forcing vessels to operate at drastically reduced speeds despite ice-strengthening. Therefore, the need for icebreaker assistance will rise - especially around the late and early weeks of the yearly navigation period.

For simplicity the amount of nautical miles of which the vessel is forced to operate at reduced speed, due to either severe ice conditions or icebreaker assistance, is divided equally on each passage of the NSR. Kronbak and Liu (2010) assume an average distance of 700 nm of ice water per trip, when the NSR is navigable for 91 days, and 100 nm average when navigable for 274 days.

Due to the increased length of the navigation season, the amount of nautical miles with reduced operation speed is set equal to 1214 nautical miles. This is the distance of the ice-filled waters of the second leg, presented in chapter 4.2.3. This distance is assumed to be the average of the entire navigation season, despite fluctuates of ice cover, which reaches an annual low in September and high levels during the start and ending of the season. The assumption is therefore that a given vessel has to operate with slower speeds for 1214 nm one each voyage, regardless of the impact of the global warming.

- ***Specific notations:*** *Throughout the rest of this paper, variables with values that differ between types of Arctic warming scenarios are denoted with the letter j, such that X_j is the variable X given Arctic warming scenario of type j.*

5.1.6 Travel Time and annual voyages

The voyage duration depends on the speed of the transiting vessel. The SCR route allows the vessel to maintain a constant speed for the majority of the time, only interrupted by weather conditions or port calls. While operating along the NSR however, the shifting ice conditions does not allow for the same stability. Due to the scope of this study, it is not possible to realistically simulate the above-mentioned uncertainty and therefore two sailing speed aggregates are used instead. A multitude of different transit speeds are presented by scholars on the subject, with Verny and Grigentin (2009) using an average operating speed of 17 knots along the SCR and 15 knots along the NSR. Furuichi and Otsuka (2013) use an average speed of 20 knots in open water and a speed of 12-15 knots in ice water. Liu and Kronbak (2010) assume an average vessel speed of 18 knots in open water and an average speed of 10 knots in ice water, regardless of receiving icebreaker assistance or not. These voyage speeds are adopted as vessel speeds for this study.

- ***Assumption VIII:*** *While in open – and ice waters, the vessels are assumed to operate at constant speeds respectively, and are therefore not affected by changes in wind and ocean currents.*

After establishing the lengths of the routes and the average navigation speeds – both in open and ice covered waters - it is possible to estimate the average time needed for a voyage between the port cluster of Northwestern Europe and North East Asia for each of the routes examined.[11] In addition to the time spent navigating the routes, the vessels spends time calling at each port visit (berthing) as well as waiting for permission to transit either the Suez Canal or receive icebreaker assistance in the ice covered waters in the Russian Arctic.

The time spent for each port call is assumed to take an average of *one* day regardless of the size and traffic near the respective port. The average waiting time for the Suez Canal transits is assumed to be 4 days (Kronbak & Liu, 2010). The average waiting time along the NSR is assumed to be eight days, for potential icebreaker assistance. This is reasonable at the present ice conditions, yet with the retreat of the Arctic ice cover it is expected to be reduced in the future. Therefore the average waiting time along the Northern Sea Route is set to decrease by 0.1 day annually such that the average waiting time for a NSR trip is reduced to approximately 4 days at the middle of the century. The linear relationship between average waiting days and time is illustrated by equation 1.6 below.

$$W_{NSR,t} = 8 - 0.1 \cdot t \qquad (1.6)$$

$W_{NSR,t} = Average\ waiting\ time\ on\ the\ NSR\ in\ year\ t$

When transporting goods between two points, the amount of trips is realistically measured in whole numbers. By solely considering whole numbers, in discrete time, risks the exclusion of a significant amount of revenue generating days from the analysis. Since it is always possible to sail along the SCR, the annual amount of trips is assumed as a fractional value. Due to the risk of sudden closures of the NSR while on voyage is not considered to be plausible in this scenario, the annual number of voyages along the NSR is assumed to only take whole numbers.

The vessel transiting the SCR is assumed to operate between Hamburg and Busan. The operating speed is assumed to be 18 knots, with a voyage length of 11,784 nautical miles, and an average of five port visits per voyage. The travel time is calculated using equation 1.7 below[12].

$$\phi^{SCR} = \frac{D_{SCR}}{V_{OW} \cdot 24} + W_{SCR} + W_{SCR}^{Port} \qquad (1.7)$$

$\phi^{SCR} = Travel\ time\ for\ the\ Suez\ Canal\ Route\ (days)$
$D_{SCR} = Distance\ of\ the\ Suez\ Canal\ Route\ (nm)$
$V_{OW} = Speed\ in\ open\ water\ (knots)$
$W_{SCR} = Average\ waiting\ time\ on\ the\ Suez\ Canal$
W_{SCR}^{Port}
$= Average\ time\ spent\ berthing\ on\ a\ Suez\ Canal\ Route\ voyage$

The total amount of annual voyages for a vessel solely operating along the Suez Canal route is therefore calculated using equation 1.8.

$$Q^{SCR} = \frac{365}{\phi^{SCR}} \qquad (1.8)$$

$Q^{SCR} = Yearly\ trips\ when\ using\ only\ the\ SCR$

This gives an average travel time along of the SCR, regardless of the vessel size, of 36.27 days allowing 10.1 annual voyages along the SCR.

[11] A trip is set to be one transit between the two end ports regardless of the direction or route used.

[12] When calculating the average voyage time, only the time spent calling at five ports is included due to only calling at each of the ports in Europe and East Asia once.

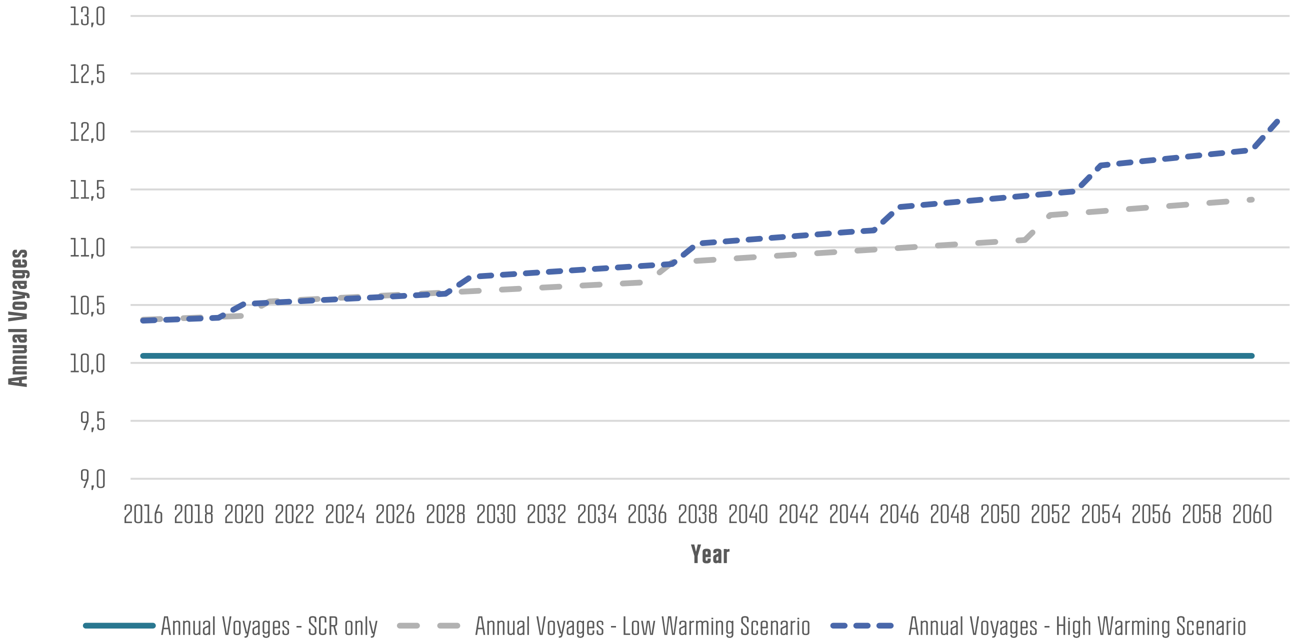

Figure 5.5: Annual number of successful voyages
The solid (teal) line illustrates the annual amount of successful voyages for the vessels solely operating along the SCR. The striped (gray) and dotted (blue) lines illustrate the annual amount of successful voyages of both routes in the low and high warming scenario respectively.

The travel time using the NSR varies due to changes in the time spent waiting for icebreaker escort and is subject to periods of slow speed even when icebreaker assistance is not required. The length of a NSR voyage between Antwerp and Shanghai is calculated by modifying equation 1.7 to include the distance traveled in ice covered waters with reduced speed, presented by equation 1.9 below.

$$\phi_t^{NSR} = \frac{(D_{NSR} - \omega_t)}{V_{OW} \cdot 24} + \frac{\omega_t}{V_{IW} \cdot 24} + W_{NSR} + W_{NSR}^{Port} \qquad (1.9)$$

$\phi_t^{NSR} = Travel\ time\ using\ the\ NSR\ \ in\ year\ t\ (days)$
$D_{NSR} = Open\ Water\ NSR\ Distance\ (nm)$

$\omega_t = Ice\ Water\ distance\ in\ year\ t\ (nm)$
$V_{OW} = Speed\ in\ open\ water\ (knots)$
$V_{IW} = Speed\ in\ ice\ water\ (knots)$
$W_{NSR} = Average\ waiting\ time\ on\ the\ NSR\ (days)$
$W_{NSR}^{Port} = Time\ at\ port\ on\ a\ NSR\ voyage\ (days)$

This yields a voyage time of 32.6 days in year 2016, while the annual reduction in the ice cover reduces the travel time to 29.1 days in year 2050.
In addition to the ice water distance variable, the amount of voyages also depends on the number of days the Arctic Sea is open to navigation. The total number of voyages using the NSR in year t, conditional on the warming scenario j, is calculated by dividing the navigation period by average travel time per trip. In employing absolute numbers, this is rounded down to the lowest integer denoted by the equation 1.10 below.

$$Q_{t,j}^{NSR} = \left\lfloor \frac{\tau_{t,j}}{\phi_t^{NSR}} \right\rfloor \qquad (1.10)$$

$Q_{t,j}^{NSR} = Number\ of\ NSR\ trips\ in\ warming\ scenario\ j\ in\ year\ t$
$\tau_{t,j} = NSR\ navigation\ days\ in\ warming\ scenario\ j\ in\ year\ t$

When the NSR is not open for navigation, the ice-strengthened container ships will sail the SCR for the rest of the year. The amount of SCR trips is calculated using equation 1.8, substituting 365 days with the number of days not used navigating along the NSR. Days where Arctic navigation is allowed, but not spent sailing on the NSR, is calculated using Euclidian division witch finds the remainder of the whole number from a division. The annual amount of trips using the SCR conditional on the amount of NSR trips possible is calculated using equation 1.11.

$$Q_{t,j}^{(SCR|NSR)} = \frac{365 + \tau_{t,j}\ mod(\phi_t^{NSR}) - \tau_{t,j}}{\phi^{SCR}} \qquad (1.11)$$

$Q_{t,j}^{(SCR|NSR)} = Number\ of\ SCR\ trips\ for\ the\ NSR\ vessel$

$$in\ year\ t\ given\ warming\ scenario\ j$$
$$\tau_{t,j}\ mod(\phi_t^{NSR}) = Arctic\ navigation\ days\ not\ spent\ on\ the\ NSR\ in\ warming\ scenario\ j\ in\ year\ t$$

It is important to note that the annual amount of trips using the NSR may actually be higher than illustrated in figure 5.5. By dividing the length of the navigation season with the total voyage time for the NSR, the total amount of nautical miles may be overestimated. This is due to the fact that the vessel only needs to travel two thirds of the distance before the closure of the NSR. This is exemplified by a vessel departing from Western Europe only having to reach the Behring Strait before the closure of the NSR and the results found in this analysis may therefore moderately underestimate the potential of Arctic shipping.

5.1.7 Fuel Costs

Being the single largest operational cost component, fuel costs have a large impact on the feasibility of transporting cargo through the Arctic. The total fuel cost per voyage depends on the price of bunker fuel, voyage distance and bunker consumption per nautical mile. The price of crude oil has shown a significant volatility during the last decade, translating into large fluctuations in the price of bunker fuel. Due to such fluctuations and the large time span investigated in this study, a projection of the future price of bunker fuel is therefore needed. This study will adopt the projected prices of residual fuel oil in the transportation sector until 2040 from the Energy Information Administration (EIA). The projections made by the EIA are divided into several scenarios dependent on various macroeconomic growth cases and given the major uncertainty attached to the future level of the price of oil. Of these alternatives, three different fuel oil price scenarios are incorporated in this study in order to investigate how different oil price scenarios will affect shipping along the NSR. These scenarios are low oil price, a reference case and a high oil price scenario.

The low oil price scenario assumes a low demand for petroleum products in the non-OECD countries, due to low economic growth, and the world therefore experiences an excess supply of oil. This result in a moderate price increase of bunker fuel by 2040 compared to the present. In the high oil price scenario, a high economic growth in the non-OECD countries is assumed, and consequently a high demand for oil products. This creates a high demand for oil, resulting in drastic bunker fuel price increases. The reference case assumes the world's real GDP to grow at an average annual rate of 2.4 percent until year 2040, causing moderate price increases of bunker fuel to approximately 800 USD per barrel by 2040. The reference case is therefore situated between the low and high oil price scenario, and is used by the EIA as general case for all of its forecasts (EIA, 2015). The projected prices of residual fuel oil for the low, high and reference case scenario are illustrated in figure 5.6. From the illustration, it is evident that the residual fuel oil price projections in the three scenarios are widely different. The low fuel price scenario

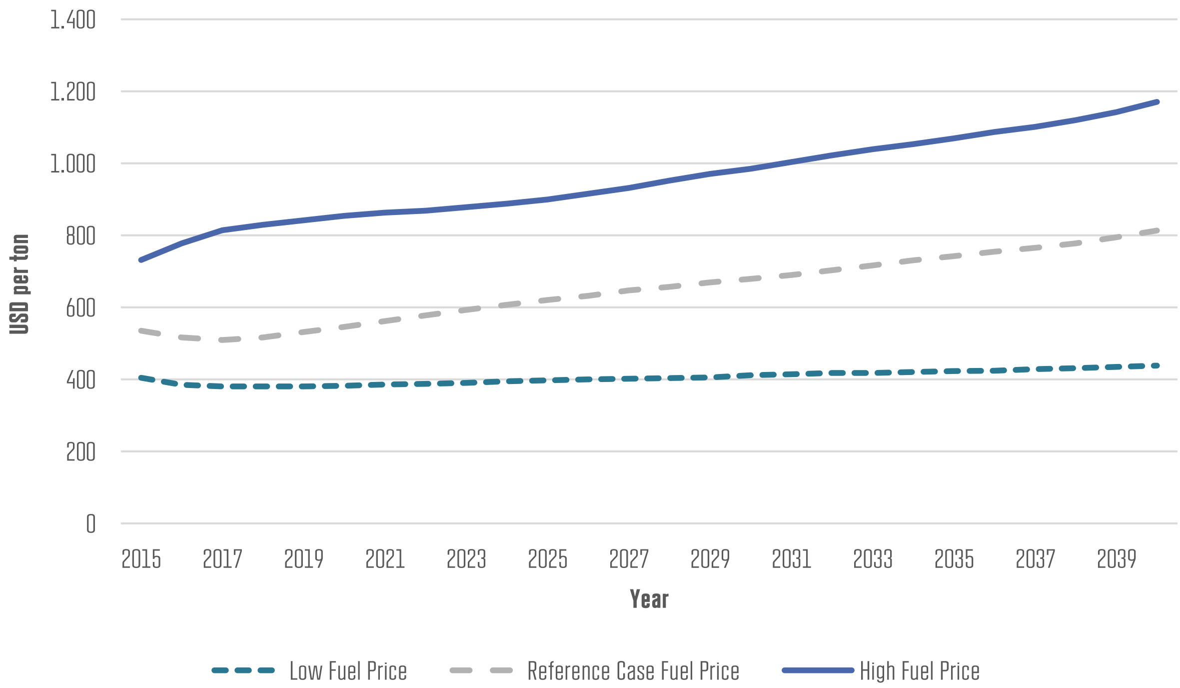

Figure 5.6: EIA residual fuel oil price projections
Prices are measured in 2014 constant USD and converted from price per barrel to price per ton using a conversion factor of 7.33 barrel per ton.
Source: EIA

remains approximately constant between the present time and 2040, and the high price scenario illustrating a vast increase in price during the same period[13]. Since the time period examined in this study continues to the year 2060, the price projections need to be extended. The annual price change between 2020 and 2040 is relatively constant for each of the three scenarios and uncovering this underlying price trend is possible by running an ordinary least squares regression on the projected price data in each of the three scenarios. From the calculations of each of the three scenarios, the annual real price increase for a barrel of residual fuel oil is found to be 2.7 USD in the low scenario, 12.4 USD in the reference case and 16.4 USD in the high demand case.

As with all economic projections, one must take into account the large degree of uncertainty attached to such forecasts. A multitude of factors are determining the price of oil, and it is therefore impossible to accurately project the price for bunker fuel so far into the future. Additionally, the price of bunker fuel varies from port to port, resulting in even greater difficulties in projecting the fuel costs encountered by the vessels operator.

However, the fuel costs examined in this study are estimated in order to illustrate the effect of different fuel prices on the feasibility of Arctic liner shipping. It seeks to provide a relative, and not absolute, quantification of the future. This is further elaborated in the analysis section. Having established the future level of bunker fuel prices, the fuel consumption of each vessel needs to be defined. The consumption of bunker fuel depends on several factors including ship size, speed, water currents and wind conditions. As previously mentioned the vessel aggregate speeds are set to be 18 knots in open water, and 10 knots when operating in ice filled waters or receiving ice breaker assistance along the NSR. The ship characteristics spreadsheet of the Danish Ship-owners' Association provides information of standard ship types, given the container capacity of vessels. Table 5.3 (next page) lists the calculated fuel consumptions for each of the containerships used in the analysis section, given the two speeds examined. External variables, like weather and ocean currents, will cause fluctuations in speed and fuel consumption. This will have a high impact on fuel consumption. Thus, the speeds used are averages, given that they cannot be maintained in the real world, causing the calculated fuel consumption to also be aggregated. Although the vessel may still operate at the average speeds defined in this study, the fuel consumption correlates exponentially with speed and the total fuel consumption, may therefore be negatively biased. For simplicity it is therefore assumed that the vessels will not deviate from the above mentioned speed making the fuel consumption constant.

- ***Assumption IX****: The vessels will not deviate from the two sailing speeds making both levels of fuel consumption constant.*

Although the values of fuel consumption calculated in this study have the potential to be negatively biased, it is clear that this is the case for both the SCR and NSR vessels. Due to the comparative nature of this study, it is therefore of limited impact to the conclusion. Having established the values of the fuel prices and fuel consumption, it is possible to calculate the total fuel costs for a voyage using both routes. The fuel cost is calculated from multiplying the route distance with the fuel consumption of the vessel and then the price fuel. Equation1.12 and 1.13 illustrated the fuel costs for a SCR voyage using the ordinary and ice reinforced vessels, respectively.

$$C^F_{t,i,k,SCR} = D_{SCR} \cdot \vartheta^{SCR}_k(V_{OW}) \cdot P^F_{t,i} \qquad (1.12)$$

$C^F_{t,i,k,SCR}$
$= Year\ t\ voyage\ fuel\ costs\ for\ a\ vessel\ of\ size\ k\ in\ oil\ scenario\ i$
$\vartheta^{SCR}_k = \text{Fuel}\ consumption\ for\ an\ open\ water\ vessel\ of\ size\ k$
$P^F_{t,i} = fuel\ price\ in\ oil\ price\ scenario\ i\ in\ year\ t$

$$C^{F,NSR}_{t,i,SCR} = D_{SCR} \cdot \vartheta^{NSR}(V_{OW}) \cdot P^F_{t,i} \qquad (1.13)$$

$C^{F,NSR}_{t,i,SCR}$
$= Year\ t\ \ voyage\ fuel\ costs\ for\ a\ \ NSR\ vessel\ in\ oil\ scenario\ i$
$\vartheta^{NSR}(V_{OW}) = Open\ water\ fuel\ consumption\ for\ the\ NSR\ vessel$

In order to calculate the fuel costs for a voyage using the NSR, the ice cover water distance and the corresponding reduction in speed and fuel consumption needs to be included. This is presented in equation 1.14

$$C^F_{t,i,NSR} = \omega \cdot \vartheta^{NSR}(V_{IW}) \cdot P^F_{t,i} + (D_{NSR} - \omega) \cdot \vartheta^{NSR}(V_{OW}) \cdot P^F_{t,i} \qquad (1.14)$$

$C^F_{t,i,NSR}$
$= Fuel\ costs\ for\ a\ NSR\ voyage\ in\ year\ t\ with\ fuel\ scenario\ i$
$\omega = Average\ ice\ water\ distance$
$\vartheta^{NSR}(V_{IW}) = \text{Ice water}\ fuel\ consumption\ for\ the\ NSR\ vessel$

[13] The recent drop in the price of oil is not incorporated into the EIA fuel price estimations. Regardless, the EIAs projects that the oil price will converge to the previously high level in the next few years.

	8000 TEU Open Water	8000 TEU Ice Reinforced	10000 TEU Open Water	15000 TEU Open Water
Speed in open water (knots)	18	18	18	18
Speed in ice water (knots)	Na	10	Na	Na
Fuel consumption in open water (ton/nm)	0.192	0.236	0.212	0.256
Fuel consumption in ice water (ton/nm)	Na	0.118	Na	Na

Table 5.3: Vessel navigation speed and fuel consumption

Source: Own calculations based on the ship specification spreadsheet from the Danish Ship-Owners Association,

- ***Specific notations:*** *Throughout the rest of this paper, variables with values that differ depending on the fuel price scenarios are denoted with the letter i, such that* X_i *is the variable X given the fuel price scenario of i.*

5.1.8 Port Dues

As mentioned earlier, the vessel visits an average of six and eight ports during a round trip when navigating the Northern Sea Route and the Suez Canal Route respectively. Due to the vessel only visiting each port in both the North Western European and the East Asian cluster once per visit, the average number of ports per voyage is actually reduced to three and five port visits, respectively. The total cost of entering a port, including port entry, berthing and line-handling charges is assumed to be 0.428 US dollars per gross ton for each port entry. The cost for the handling of container is assumed to be 100 USD per TEU, including both the discharge and loading of containers (Furuichi & Otsuka, 2013). The total port related costs per voyage along the NSR or the SCR are presented by equation 1.15 and 1.16, respectively.

$$C^P_{SCR} = u_{SCR} \cdot 0.428 \cdot G_j + \epsilon_{SCR} \cdot L_k \cdot 100 \qquad (1.15)$$

$$C^P_{NSR} = u_{NSR} \cdot 0.428 \cdot G + \epsilon_{NSR} \cdot L \cdot 100 \qquad (1.16)$$

$C^P_{k,SCR} = Port\ related\ costs\ for\ a\ vessel\ of\ size\ kvoyaingthe\ SCR$

$C^P_{NSR} = Port\ related\ costs\ for\ a\ vessel\ voyaing\ in\ the\ NSR$

$G_k = Gross\ ton\ of\ a\ vessel\ of\ size\ k$

$L_k = Container\ capacity\ of\ vessel\ k$

$u_{SCR} = Average\ number\ of\ port\ visits\ during\ a\ SCR\ trip$

$u_{NSR} = Average\ number\ of\ port\ visits\ during\ a\ NSR\ trip$

$\epsilon_{SCR} = Average\ load\ factor\ along\ the\ SCR$

$\epsilon_{NSR} = Average\ load\ factor\ along\ the\ NSR$

5.1.9 NSR Transit Fee

In April 2014, the NSRA released an updated tariff scheme for receiving icebreaker escorting along the Northern Sea Route. Compared to the previous tariff system, where the transit fee was negotiated between the vessels operator and Russian authorities, the updated version has increased the transparency. The new tariff system is based on a fixed pricing scheme with the fee varying depending on the size, ice classification and season of navigation. It also considers the amount of NSR zones in which the transiting vessels receives ice breaker escort (see chapter 2.1). For a vessel transiting the NSR during the navigation season, it is reasonable to assume that the ice conditions around the opening and closure of the navigation season are far more severe compared to the during the middle of the season. It is therefore assumed that on the first and last voyages on the NSR during the navigation season, icebreaker assistance is required along a majority of the second leg of the route. This stretch measuring 1214 nautical miles covers a total of four of the NSRA designated icebreaker escort zones thereby causing an increased cost associated with transiting the Northern Sea Route. For the remaining annual transits along the Northern Sea route, an average of icebreaker assistance through two zones is assumed. In this case study no transit will therefore be completed without the aid of icebreaker escorts. With the present state of ice conditions along the Northern Sea Route, such an assumption is reasonable, although future transits during September may be possible without the aid of icebreaker escort. This is contingent on vessels having a sufficient ice classification.

From the NSRA homepage it is possible to extract tariffs for vessel between 40,000 and 100,000 gross ton of polar class of four. During the summer/autumn season the cost per gross ton is 357.47 Rubles, which provides icebreaker assistance in 4 zones. In comparison during the mid-season, an operator can pay 268.11 rubles per gross ton for only 2 zones. The average exchange rate between for the last five years is 32.187 Russian Rubles for one USD. Using this rate to convert the tariff into dollars (and deflating into 2012 USD) results in the costs of icebreaker assistance to be approximately 904 and 677 thousand constant 2012 USD for the escort through 4 and 2 zone respectively.

5.1.10 Suez Canal Fee

The Suez Canal toll is based on the calculations of the Suez Canal net tonnage and the Special drawing rights, and it is not easily comparable to general cargo capacity measurements (Stopford, 2008). The toll is approximated by the gross ton of the vessel, according to Suez Canal Authorities, using the Leth Agencies Suez Canal toll calculator for a laden containership. This yield the Suez Canal tolls measured in constant 2014 USD for the four different vessels of this study are estimated to be approximately: 450.800, 547.300 and 682.400 for the 8000, 10000 and 15000 TEU vessels, respectively.

5.1.11 Fixed operation costs

This section will introduce the annual operation costs included in this case study. These fixed costs include insurance, maintenance and crew wages. Contrary to the variable operation costs introduced in the previous section, these costs are not directly linked to the annual amount of voyages performed by the vessel. They can therefore, for the purpose of this study, be described as fixed cost components. As previously mentioned some of the minor fixed cost components are excluded from this study, like lubricants, crew supplies and administration costs. Additionally, the expenses and time span associated with the mandatory annual dry docking, required by the International Maritime Organization (IMO) are excluded although both the direct and opportunity costs of such operations may be significant.

The annual repair and maintenance costs are set to be 1.095 percent of the new building costs (Furuichi & Otsuka, 2013). It is reasonable to assume that maintenance and repairs of a vessel operating in the Arctic are significantly higher compared to a normal open water vessel. The higher new building price of an ice reinforced vessel will result in maintenance and repair costs being 20 % higher than those of the normal open water vessel. It is further assumed that the amount of repairs and maintenance does not increase with the age of the vessel and therefore remains fixed during the entire operational time span of the vessel.

- ***Assumption X**: The annual repair costs remain constant throughout all the operational years of the vessel regardless of the investment year.*

The insurance cost of the vessels consists of the two forms of insurance required for operating the containership. The Hull and Machinery (H&M) insurance is obtained from a marine insurance party, which protects the owner from the physical loss or damage to the vessel. The second insurance covers damage to cargo, collision damage, pollution and general damage affecting third party liabilities. This is obtained from Protection and Indemnity (P&I) Clubs (Stopford, 2008). A high degree of uncertainty is linked to maritime activities in the Arctic and it is likely that insurers will hesitate to provide insurances to such endeavors, and if so a significant premium for ships operating along the NSR will be required. Despite these uncertainties, the numerous successful transits over the Northern Sea Route performed by non-Russian companies indicate that Arctic shipping is indeed insurable. Insurers are currently working on helping to improve safety and raising awareness of Arctic shipping routes (Emmerson & Lahn, 2012). The basic insurance premium is assumed to be 0.343 percent of the new building cost per year for both H&M and P&I insurance. An additional insurance premium surcharge of 10 USD per gross ton per year is charged for Arctic shipping (Furuichi & Otsuka, 2013). Similar to the maintenance and repair costs the annual insurance costs are assumed to be constant, although an increase in successful transits along the NSR and improvements in infrastructure may eventually cause a reduction in the Arctic insurance premium.

- ***Assumption XI**: The annual insurance premium is assumed to be constant throughout all the operational years of the vessel regardless of the investment year.*

Lastly, the salary of the crew working on the vessel is assumed to be 1.2 million USD annually (Verny & Grigentin, 2009). Although the size of the crew varies depending on the regulatory policies of the flag state and the vessel type, this sum is assumed to be constant regardless of the size of the vessel.

Combining the three above mentioned cost components yields the annual fixed operation costs presented in the equation 1.17 and 1.18 for the open water and ice reinforced vessels respectively.

$$FC_k^{SCR} = I_k^{SCR} + C^{Crew} + M_k \qquad (1.17)$$

$FC_k^{SCR} = Annual\ fixed\ costs\ for\ a\ SCR\ vessel\ of\ size\ k$
$C^{Crew} = Annual\ crew\ costs$
$M_k = Annual\ maintenance\ costs\ for\ vessels\ of\ size\ k$
$I_k^{SCR} = Insurance\ costs\ for\ a\ SCR\ vessel\ of\ size\ k$

$$FC^{NSR} = I^{NSR} + C^{Crew} + M^{NSR} \qquad (1.18)$$

$FC^{NSR} = Annual\ fixed\ costs\ for\ a\ NSR\ vessel$
$I^{NSR} = Annual\ Insurance\ costs\ for\ a\ NSR\ vessel$

5.1.12 Load Factor

The load factor is defined as the percentage of the container capacity of the vessel which is loaded. Major fluctuations in the load factor will seriously affect the cash flows of the investment and therefore the cost per TEU.
The demand for the freight of containers is highly volatile and depends on several world macroeconomic factors (Stopford, 2008). Additionally, the demand for westbound cargo is considerably higher than that of eastbound cargo resulting in a difference load factor depending on the destination (Kronbak & Liu, 2010). Since the liner ship will complete an equal amount of east and westbound voyages in the long run, an average of the two load factors is used in this study. Furuichi & Otsuka (2013) use an average load factor of 70 percent while
Kronbak & Liu (2010) define an average load factor of 60 percent for a voyage between Rotterdam and Yokohama. When vessels operate on the Suez Canal Route they call at both the port of Singapore and Hong Kong, which are not called on the NSR. Therefore an increased amount of cargo is to be assumed for the SCR, thus increasing the load factor compared to that of the NSR. For the purpose of this study the average load factor, regardless of direction, is assumed to be 70 percent when voyaging along the SCR and 60 percent when on the NSR.

- ***Assumption XII****: The annual average load factor is assumed to be constant at 60 and 70 percent for the NSR and SCR respectively*

As mentioned above, the load factor is subject to large fluctuations following the developments of shipping cycles causing a constant load factor to be highly unlikely. Further, seasons of capacity shortages due to a high demand for freight may easily cause the load factor to reach 100 percent on both routes. This will positively affect the feasibility of the NSR and the results of this analysis may therefore be positively biased towards the SCR.
The annual amount of TEU transported is calculated by multiplying the load factor with the annual number of voyages and the container capacity of the vessel. This is presented by equation 1.19 and 1.20 for the open water and ice reinforced vessels, respectively.

$$U_{t,k}^{SCR} = Q^{SCR} \cdot \epsilon_t^{SCR} \cdot L_k^{SCR} \qquad (1.19)$$

$$U_{t,j}^{NSR} = (\,Q_{t,j}^{(SCR|NSR)} \cdot \epsilon_t^{SCR} + Q_{t,j}^{NSR} \cdot \epsilon_t^{NSR}) \cdot L^{NSR} \qquad (1.20)$$

$U_{t,k}^{SCR} = TEU\ transported\ on\ a\ SCR\ vessel\ of\ size\ k\ in\ year\ t$
$U_{t,j}^{NSR} = TEU\ transported\ on\ NSR\ vessel\ in\ ice\ scenario\ j\ in\ year\ t$
$\epsilon_t = Load\ factor\ in\ year\ t$
$L_k^{SCR} = Container\ capacity\ of\ an\ open\ water\ vessel\ of\ size\ k$

5.2 COMBINING THE COSTS

After having defined the variables and constraints, the different cost components are combined to form the basis for the economic feasibility study. The voyage costs are defined as the cost components associated directly with the annual amount of voyages. They are thus calculated as the sum of the fuel costs, berthing fee, container handling charges and route related fees. The costs of one voyage along the SCR, using the open water vessel are calculated by combining equations 1.12 and 1.15 into equation 2.1 below.

$$C_{t,i,k}^{SCR} = C_{t,i,k}^{F} + C_k^{S} + C_{SCR,k}^{P} \qquad (2.1)$$

$C_{t,k}^{SCR} = Total\ costs\ for\ one\ SCR\ trip\ \ vessel\ in\ year\ t$
$C_{t,j,j}^{F} = Voyage\ fuel\ cost\ in\ oil\ price\ i\ for\ vessel\ size\ k\ in\ year\ t$
$C_k^{S} = Suez\ Canal\ fee\ for\ a\ vessel\ of\ size\ k$
$C_{SCR,k}^{P} = Port\ related\ costs\ for\ a\ vessel\ of\ size\ k\ voyaing\ the\ SCR$

The costs of one voyage along the SCR, using the open ice reinforced vessel are calculated by combining equations 1.13 and 1.15 into equation 2.2 below.

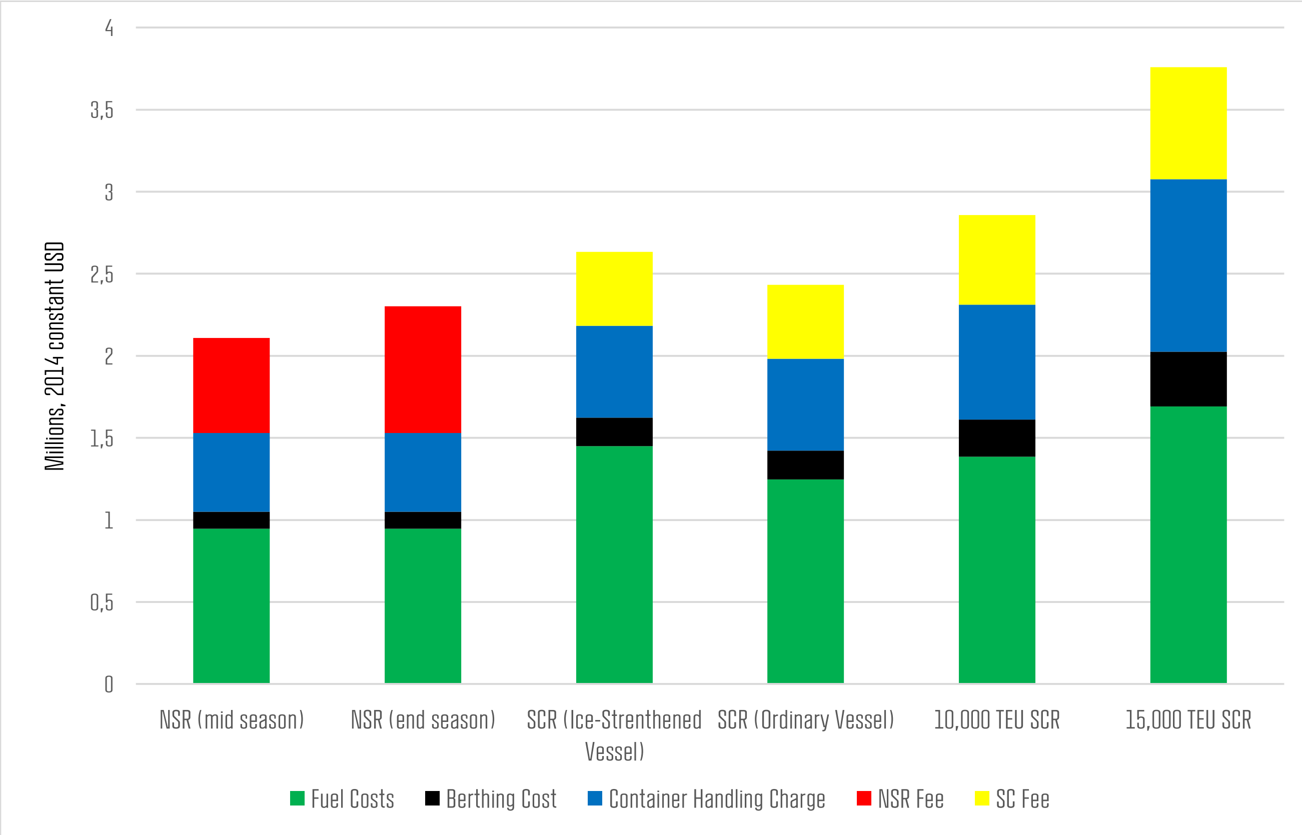

Figure 5.7:Voyage cost component breakdown
The Costs are based on a one voyage in 2016 in the reference case oil price scenario. NSR / SCR denotes the route used while mid – and end season denotes the amount of zones where icebreaker assistance are required.
Source: Own Calculations

$$C_{t,i}^{(SCR|NSR)} = C_{t,i,SCR}^{F,NSR} + C_{NSR}^{S} + C_{SCR}^{P} \qquad (2.2)$$

$C_{t,i,SCR}^{F,NSR}$
$= Year\ t\ SCR\ voyage\ fuel\ costs\ for\ a\ \ NSR\ vessel\ in\ oil\ scenario\ i$
$C_{NSR}^{S} = Suez\ Canal\ fee\ for\ a\ vessel\ of\ size\ k$
$C_{SCR}^{P} = Port\ related\ costs\ for\ a\ NSR\ vessel\ voyaing\ the\ SCR$

The cost for one voyage using the NSR is calculated by substituting the Suez Canal fee and SCR fuel costs in equation 2.1 with the icebreaker fee and NSR fuel cost from equation 1.14 and 1.15.

$$C_{t,i}^{NSR} = C_{t,i}^{F} + C^{N} + C_{NSR}^{P} \qquad (2.3)$$

$C_{t,i}^{NSR} = NSR\ voyage\ cost\ with\ oil\ price\ i\ in\ year\ t$
$C^{N} = NSR\ transit\ fee$
$C_{t,i}^{F} = Voyage\ fuel\ cost\ with\ oil\ price\ i\ ice\ scenario\ j\ in\ year\ t$
$C_{NSR}^{P} = Port\ related\ costs\ for\ a\ vessel\ voyaing\ in\ the\ NSR$

The cost component breakdowns for the different vessels examined are illustrated in figure 5.7. Looking at the voyage costs for the 8000 TEU vessels, it is clear that the reduced distance of the NSR results in a major reduction of bunker fuel costs. Although the fuel costs of transiting the NSR are considerably lower, the ice strengthened hull causes the vessel to operate at a disadvantage when navigating the SCR. These fuel cost differences, prove the importance of the number of annual Arctic navigation days.

An ice-reinforced vessel have to complete several NSR transits in order to offset the fuel cost disadvantage of operating along the SCR, in order to be economically competitive to the open water vessel in the long run. The other major cost component affecting the NSR transits are the icebreaker assistance costs taking up a significant part of the voyage costs compared to the Suez Canal fee. This is especially evident during the start and end season transits, where the icebreaker fee takes on close to one third of the total voyage costs. This makes the voyage costs almost as high as that of an open water vessel navigating the SCR. Additionally, figure 5.7 reveals the significant cost reductions achieved by operating larger vessels. It is evident that the NSR voyage costs per TEU is not competitive compared to the costs of the larger SCR vessels. This demonstrates the significant economies of scale incurred with increases in the container capacity. For example the total fuel costs for the 15000 TEU vessel is only approximately 15 percent higher than that of the ice reinforced vessel using the SCR although the container capacity is almost twice as high.

The total variable costs each year for each of the vessel type can be identified by multiplying the annual amount of trips with the voyage costs. Thus, multiplying equation 2.1 and 2.2 with the annual amount of SCR and NSR trips respectively, given the ice-cover scenario, yields the variable costs in year *t* for the SCR and NSR vessels. These annual variable costs are presented in equation 2.4 and 2.5 below.

$$VC_{t,i,k}^{SCR} = Q^{SCR} \cdot C_{t,i,k}^{SCR} \qquad (2.4)$$

$VC_{t,i,k}^{SCR} = Variable\ costs\ for\ a\ SCR\ vessel\ with\ of\ size\ k\ in\ year\ t$

$Q^{SCR} = Yearly\ trips\ for\ a\ vessel\ using\ only\ the\ SCR$

$$VC_{t,j,i}^{NSR} = Q_{t,j}^{(SCR|NSR)} \cdot C_{t,j,i}^{(SCR|NSR)} + Q_{t,j}^{NSR} \cdot C_{t,j,i}^{NSR} \qquad (2.5)$$

$VC_{t,j,i}^{NSR}$

$= Variable\ costs\ for\ a\ NSR\ vessel\ in\ ice\ scenario\ j\ in\ year\ t$

$Q_{t,j,i}^{(SCR|NSR)} = Annual\ SCR\ trips\ in\ ice\ scenario\ j\ in\ year\ t$

$Q_{t,j,i}^{NSR} = Annual\ NSR\ trips\ in\ ice\ scenario\ j\ in\ year\ t$

In addition to the variable operation costs of the vessels, both the annual fixed costs and the capital costs need to be taken into consideration. The annual fixed costs consist of the insurance premium, the maintenance costs and salaries to the crew, while the capital costs consist of the debt payment of the vessel. Equation 2.6 and 2.7 denote the yearly fixed costs of the container ship used for the SCR and NSR, respectively.

$$FC_k^{SCR} = I_k^{SCR} + C^{Crew} + M_k^{SCR} \qquad (2.6)$$

$FC_k^{SCR} = Annual\ fixed\ costs\ for\ a\ SCR\ vessel\ of\ size\ k$

$C^{Crew} = Annual\ crew\ costs$

$M_k^{SCR} = Annual\ maintenance\ costs\ for\ a\ SCR\ vessels\ of\ size\ k$

$I_k^{SCR} = Annual\ insurance\ costs\ for\ a\ SCR\ vessel\ of\ size\ k$

Source: Scanpix / Iris

$$FC^{NSR} = I^{NSR} + C^{Crew} + M^{NSR} \qquad (2.7)$$

$FC^{NSR} = Annual\ fixed\ costs\ for\ a\ NSR\ vessel$
$I^{NSR} = Annual\ Insurance\ costs\ for\ a\ NSR\ vessel$
$M^{NSR} = Annual\ maintenance\ costs\ for\ a\ NSR\ vessel$

Denoting the capital costs in year *t*, conditional on the investment year *s*, as $A_{(t|s,k)}$, the total costs for an ice reinforced or open water vessel of size *k*, given Arctic warming scenario *j*, in year *t*, are presented for an NSR and an SCR vessel in equation 2.8 and 2.9 respectively

$$TC_{t,k,i}^{SCR} = Q_t^{SCR} \cdot C_{t,k,i}^{SCR} + FC_{t,k}^{SCR} + A_{(t|s,k)}^{SCR} \qquad (2.8)$$

$TC_{t,k,i}^{SCR}$
$= Total\ costs\ of\ a\ SCR\ vessel\ of\ size\ k\ with\ oil\ price\ i\ in\ year\ t$
$A_{(t|s,k)}^{SCR}$
$= year\ t\ CAPEX\ for\ a\ SCR\ vessel\ of\ size\ k\ with\ investment\ year\ s$

$$TC_{t,j,i}^{NSR} = Q_{t,j,i}^{(SCR|NSR)} \cdot C_{t,j}^{SCR} + Q_{t,j,i}^{NSR} \cdot C_{t,j}^{NSR} + FC_{t,j}^{NSR} + A_{(t|s)}^{NSR} \qquad (2.9)$$

$TC_{t,j,i}^{NSR} = Total\ costs\ for\ a\ NSR\ vessel\ in\ year\ t\ in\ ice\ scenario\ j$
$A_{(t|s)}^{NSR} = Capital\ cost\ in\ year\ t\ conditional\ on\ investment\ year\ s$

Figure 5.8 and 5.9 (next page) illustrate the annual total cost component breakdown for the investment for the ordinary and ice-strengthened 8000 TEU vessel respectively in year 2015. As previously stated, the investment runs for 26 years where the first year is used for building the vessel and the subsequent twenty-five years used for the transport of goods.
From the figures, it is evident that the fuel cost is by far the largest cost component ranging between forty and sixty percent of the total annual cost during the years operating the ships. For the ship solely operating the SCR the fuel cost accounts for a slightly larger share of the total costs. The higher capital costs and icebreaker assistance costs encountered by the ice reinforced vessel explain this difference. Over time the cost allocated by the Suez Canal toll relative to the NSRA icebreaker fee is reduced due to the increasing amount of annual voyages along the NSR. The other major cost variable components are those of the container handling charges and the berthing costs. They comprise between 15 and 25 percent of the total costs, taking up a larger share of the costs for the open water vessel due to the increased number of port visits and load factor of the SCR. Lastly, the berthing fee and the yearly fixed costs contribute marginally to the overall costs of operating the vessels although the insurance premium for the ice reinforced vessel is significantly higher than that of the open water vessel.

Source: Novatek.ru

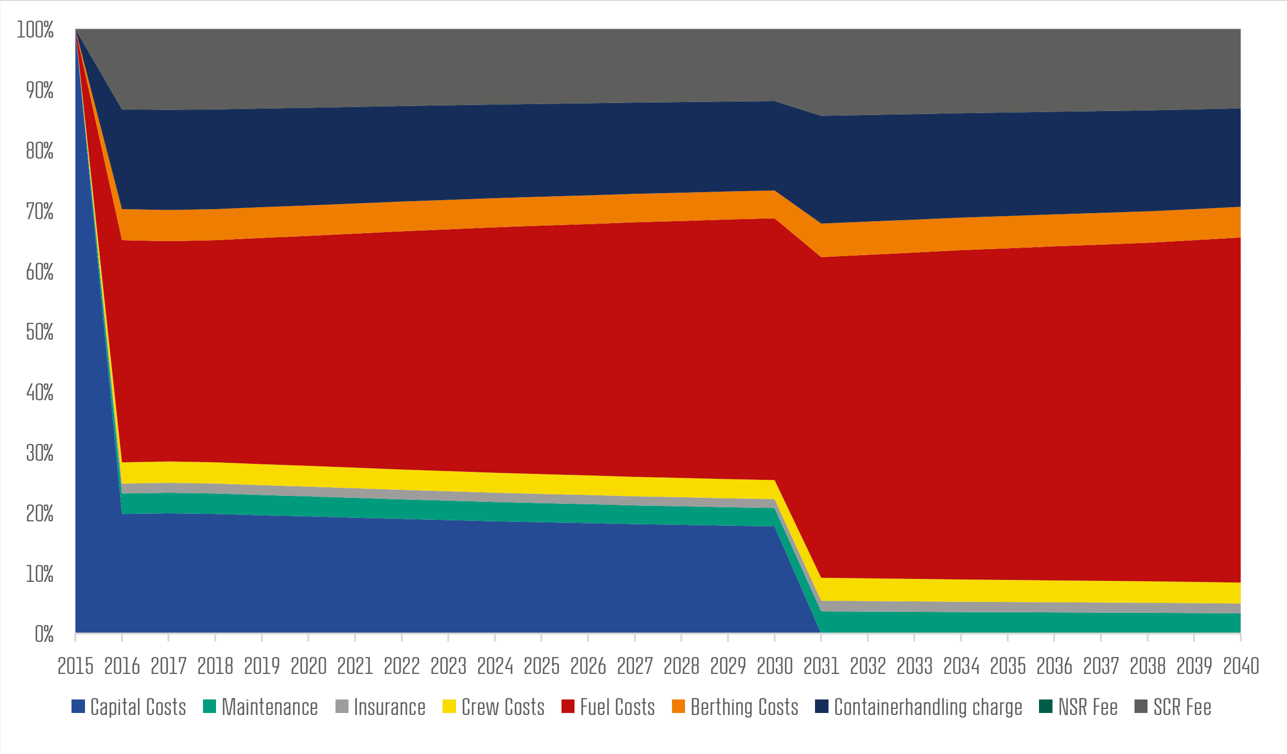

Figure 5.8: Total cost component breakdown for the 8000 TEU open water vessel
The costs are based on the investment in an ordinary 8000 TEU vessel in 2015 and 25 years of service given the reference case oil price scenario.
Source: Own Calculations

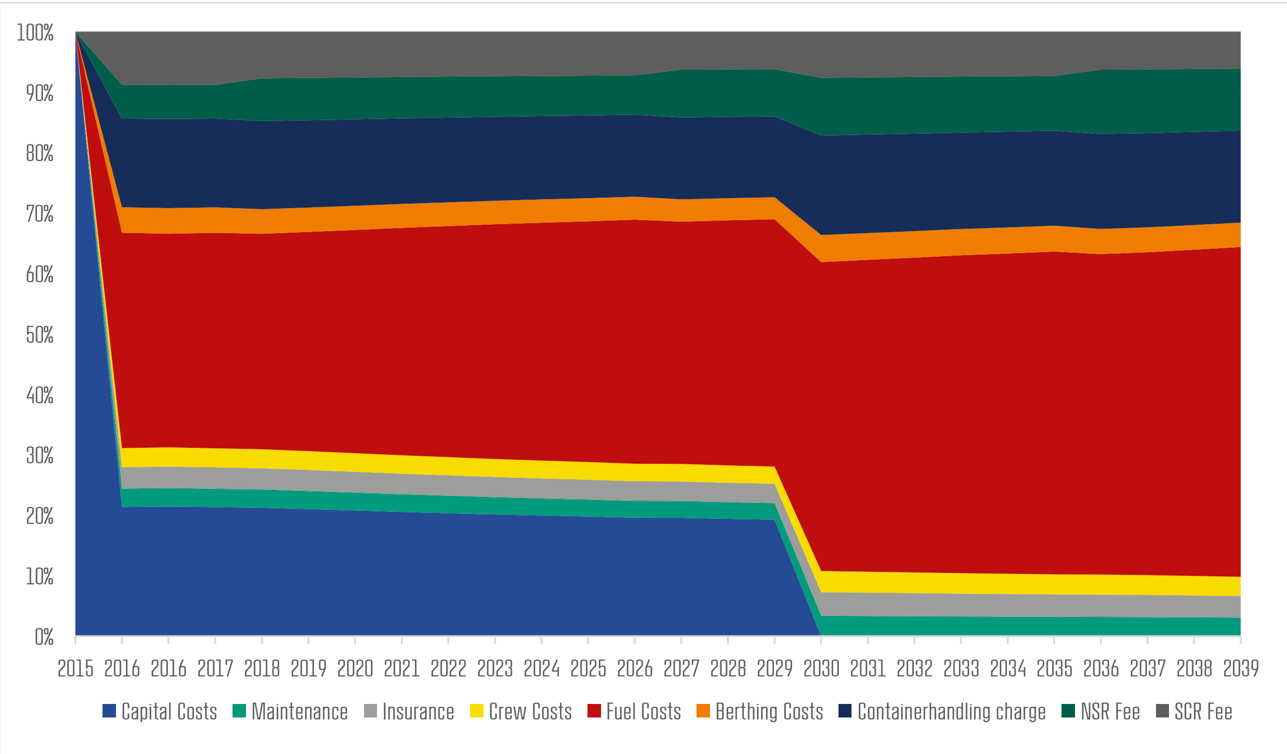

Figure 5.9: Total cost component breakdown for the 8000 TEU ice reinforced vessel
The costs are based on the investment in an ordinary 8000 TEU vessel in 2015 and 25 years of service. The costs are calculated in the high Arctic warming scenario and the reference case oil price scenario.
Source: Own Calculations

5.3 RESULTS

The purpose of this analysis is to determine the year where the investment in an ice strengthened vessel becomes favorable to the investment in a normal open water vessel. The ice strengthened vessel will operate on the NSR when open for traffic and on the SCR when not, while the open water vessel will operate solely on the SCR. The point at which the investment is advantageous is determined by estimating the ratio of the total cost per TEU between the two alternative investment decisions. The total cost per TEU is calculated by dividing the total discounted costs with the total amount of transported TEUs. This is illustrated in the equations below, where the investment initiated in year *s*, with fuel price scenario *i*, Arctic warming scenario *j* and an open water vessel of size *k*. Equitation 3.1 illustrates the total discounted costs per TEU for the open water vessel while equation 3.2 illustrates the same for the ice strengthened vessel.

$$DC_{s,i,k}^{SCR} = \frac{\sum_{t=s}^{s+25} \frac{Q^{SCR} \cdot C_{t,i,k}^{SCR} + FC_k^{SCR} + A_{(t|s,k)}^{SCR}}{(1+\delta)^t}}{\sum_{t=s}^{s+25} Q^{SCR} \cdot \epsilon_t^{SCR} \cdot L_k} \qquad (3.1)$$

$$DC_{s,j,i}^{NSR} = \frac{\sum_{t=s}^{s+25} \frac{Q_{t,j}^{(SCR|NSR)} \cdot C_{t,j,i}^{SCR} + Q_{t,j}^{NSR} \cdot C_{t,j,i}^{NSR} + FC^{NSR} + A_{(t|s)}^{NSR}}{(1+\delta)^t}}{\sum_{t=s}^{s+25} \left(Q_{t,j}^{(SCR|NSR)} \cdot \epsilon_t^{SCR} + Q_{t,j}^{NSR} \cdot \epsilon_t^{NSR} \right) \cdot L^{NSR}} \qquad (3.2)$$

$L = Vessel\ container\ capacity$

$\epsilon_t = Load\ Factor\ in\ year\ t$

$\delta = Real\ rate\ of\ depreciation$

$s = Year\ in\ which\ investment\ is\ initiated$

Dividing the discounted costs per TEU of the investment in an open water vessel, with that of the investment in an ice reinforced vessel yields the ratio of the total discounted costs per TEU. If the ratio takes a value of above one, the investment of a NSR vessel has a lower cost per TEU than the investment in an ordinary SCR vessel. If the value is between zero and one, the SCR vessel is still the most lucrative investment. It is important to note, that when comparing the investment in an ice strengthened vessel compared to that of an open water vessel, both investments must be initiated in the same year. For a comparison between the two investment types, the costs also need to be discounted to the same year (all cash flows in this analysis are discounted to 2014 USD). The discounted cost ratio for vessels of size *k*, oil price scenario *i*, and Arctic warming scenario *j*, given an investment start in year *s*, is calculated using equation 3.3 below.

$$Ratio_{s,i,j,k} = \frac{DC_{s,i,k}^{SCR}}{DC_{s,j,i}^{NSR}} \qquad (3.3)$$

$Ratio_{s,j,i,k} = Total\ discounted\ costs\ per\ TEU\ ratio$

The discounted total costs per TEU ratios for the ice-strengthened and open water vessels of the same size, are illustrated in figure 5.10 and 5.11 for the low and high navigation scenario, respectively.

From both these figures it is evident that the investment in an ice reinforced vessel will not become advantageous to the investment in a similar sized open water vessel during the span of this analysis. Investing in an ice reinforced vessel by 2035, the projected cost per TEU for the ice reinforced vessel exceeds those of the open water vessel by a large margin in both Arctic warming scenarios. Not surprisingly, the high warming scenario yields the largest cost ratio, with the total cost per TEU for the ice reinforced vessel being approximately 10 percent higher than that of an open water vessel in the high oil price scenario given an investment year of 2035.

Both figures show an increasing trend in the cost ratio, as a function of investment year. This is explained by the gradual reduction return of the cost per TEU of the NSR vessel, as the Arctic sea ice is receding. This clearly illustrates the effect of the increasing number of navigation days on the NSR have on the economic feasibility, as an alternative to the SCR. Further, the results reveal the impact of the oil price on the viability of the NSR. A low oil price reduces the fuel savings potential of utilizing the shorter NSR, as the larger capital and transit costs of the ice reinforced vessel causes the SCR to remain highly favorable. A high oil price scenario causes a reduction in the extra costs of the ice reinforced vessels relative to that of a normal vessel.

This implies that the NSR will may become competitive to an open water vessel of the same size in the near future, given a continued decrease in the ice cover. The positive economics of scale achieved by the larger open water vessels results in cost ratios much lower than observed in figures 5.10 and 5.11. Consequently, the graphs illustrating the cost ratios between the ice-strengthened vessel and the larger 10,000 and 15,000 TEU vessels are located in appendix A.

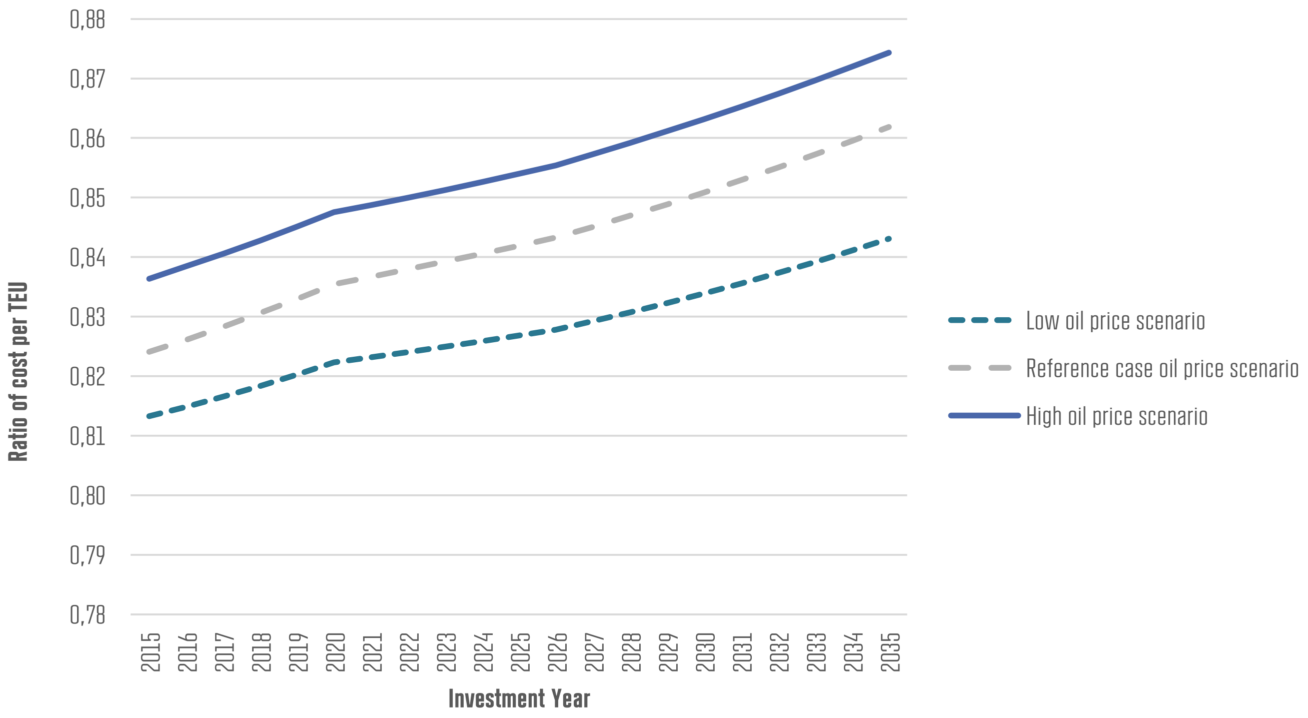

Figure 5.10: Cost per TEU ratio in the low navigation scenario
The total cost per TEU ratio of the investment of an ice strengthened vessel to an open water vessel, as a function of the investment year. The ratio is calculated in the low Arctic warming scenario with a discount factor of 7 percent and both vessels having a container capacity of 8000 TEU. A ratio above one indicates that the investment in the ice reinforced vessel is favorable.
Source: Own Calculations

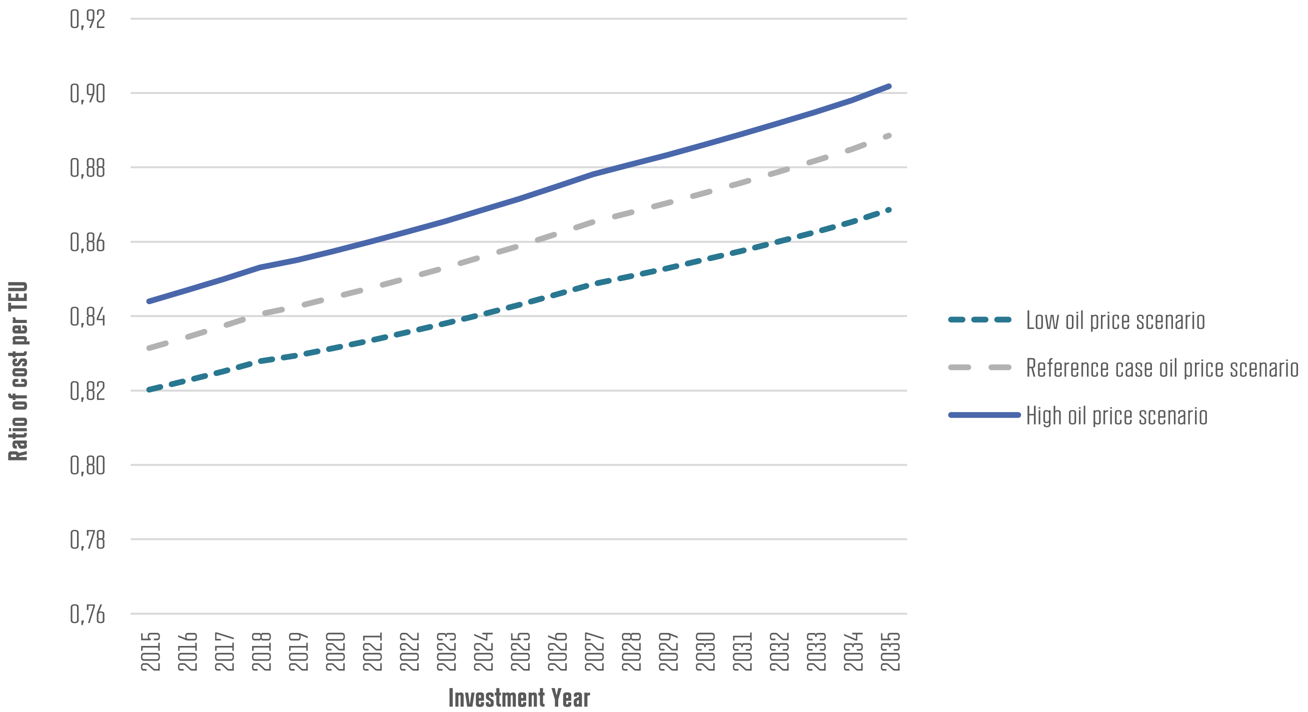

Figure 5.11: Cost per TEU ratio in the high navigation scenario
The total cost per TEU ratio of the investment of an ice strengthened vessel to an open water vessel, as a function of the investment year. The ratio is calculated in the high Arctic warming scenario with a discount factor of 7 percent and both vessels having a container capacity of 8000 TEU. A ratio above one indicates that the investment in the ice reinforced vessel is favorable.
Source: Own Calculations

5.3.1 The viability of super slow steaming

One of the advantages of following a route with a reduced distance is the possibility of operating at lower speeds compared to the alternative route, while still maintaining the annual amount of completed voyages. Such a strategy may be attractive in a scenario where the demand is low, and an increase in annual voyages therefore will only result in a lower profitability per voyage. From the results posted in the previous section it is evident that the investment in an ice reinforced container ship would not be advantageous to that of an ordinary vessel within the next decades. This was in large part due to the significant fuel consumption stemming from the hull alterations of vessels operating in ice filled waters. It is therefore worth investigating whether a reduction in the voyage speed, when operating along the NSR, will increase the cost ratios for an ice reinforced vessel.

By reducing the average speed when navigating in the open water sections of the NSR to 15 and 12 knots, the voyage time is increased to approximately 35 and 40 days, respectively. This lowers the voyage fuel costs, due to the exponential nature of fuel consumption as a function of speed. Figure 5.12 illustrates the costs per trip in 2016, when the ice reinforced vessel uses super slow-steaming at a speed of 12 knots during operations along the NSR.

From the figure it is clear that the costs for a trip using the NSR has been drastically reduced, compared to the costs voyage costs when operating at 18 knots, illustrated previously in figure 5.7 (page 46).. The costs of a NSR voyage are now reduced by approximately 20 percent, making the NSR voyages significantly more attractive. However, operating at lower speeds also reduces the annual number of possible voyages and consequently; a reduction in the number of TEU's transported. Thus the ice strengthened vessel will have fewer NSR trips to offset the higher fuel cost along the SCR as compared to ordinary open water vessels.

Figure 5.13 and 5.14 illustrates the total cost per TEU ratios for the NSR when traveling between North-western Europe and East Asia using the NSR when operating at a speed of 15 and 12 knots, respectively.

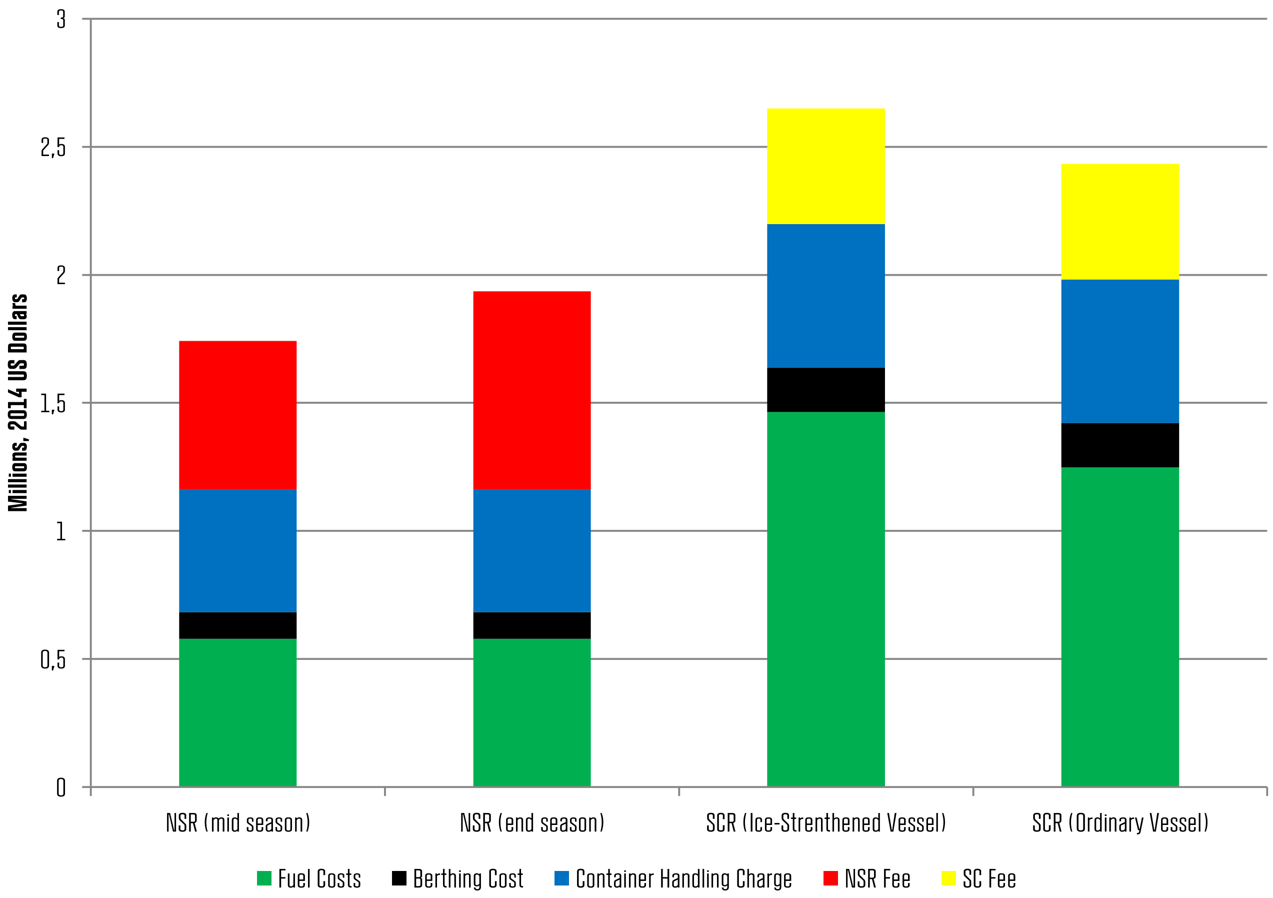

Figure 5.12: Voyage cost component breakdown when super slow steaming on the NSR

The Costs are based on a one voyage in 2016 in the reference case oil price scenario with a voyage speed of 12 knots on the open water sections of the NSR. NSR / SCR denotes the route used while mid – and end season denotes the amount of zones where icebreaker assistance are required.

Source: Own Calculations

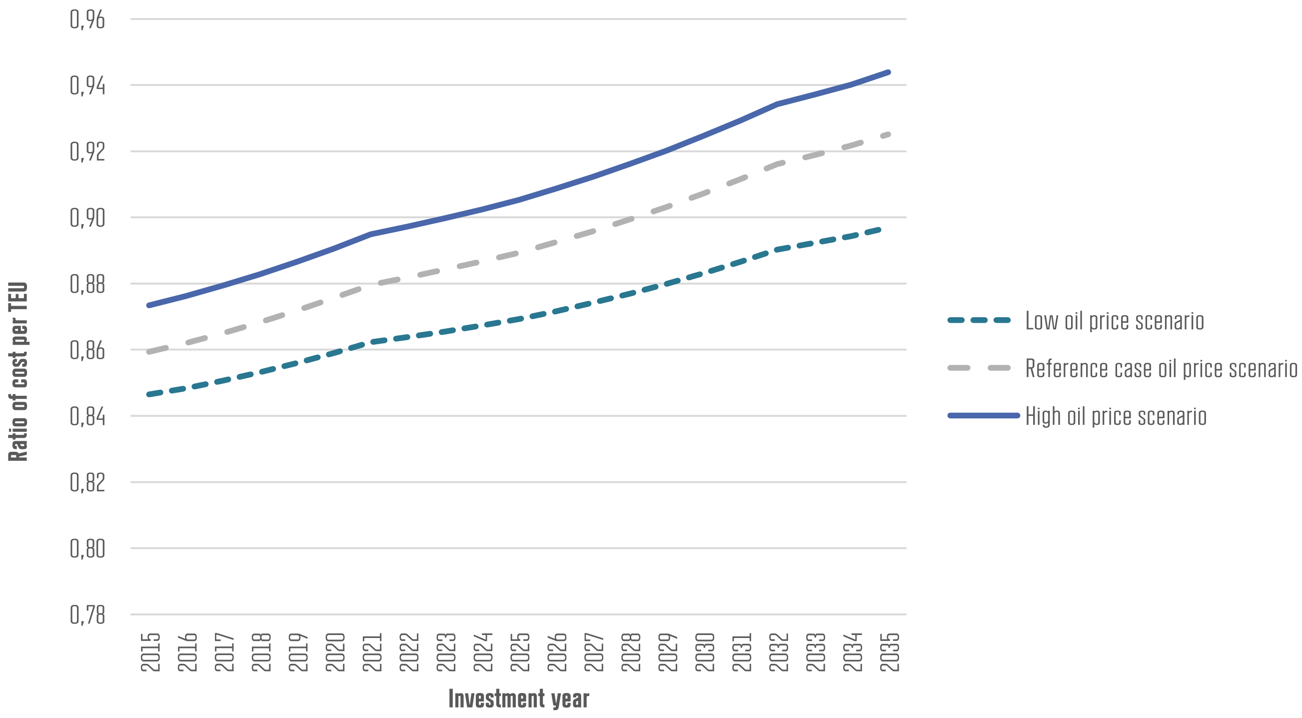

Figure 5.13: Cost per TEU ratio with a voyage speed of 15 knots along the NSR
The total cost per TEU ratio of the investment of an ice strengthened vessel to an open water vessel, as a function of the investment year given a voyage speed of 15 knots along the open water section of the NSR between Europe and Asia. The ratio is calculated in the high Arctic warming scenario with a discount factor of 7 percent and both vessels having a container capacity of 8000 TEU. A ratio above one indicates that the investment in the ice reinforced vessel is favorable. Source: Own Calculations

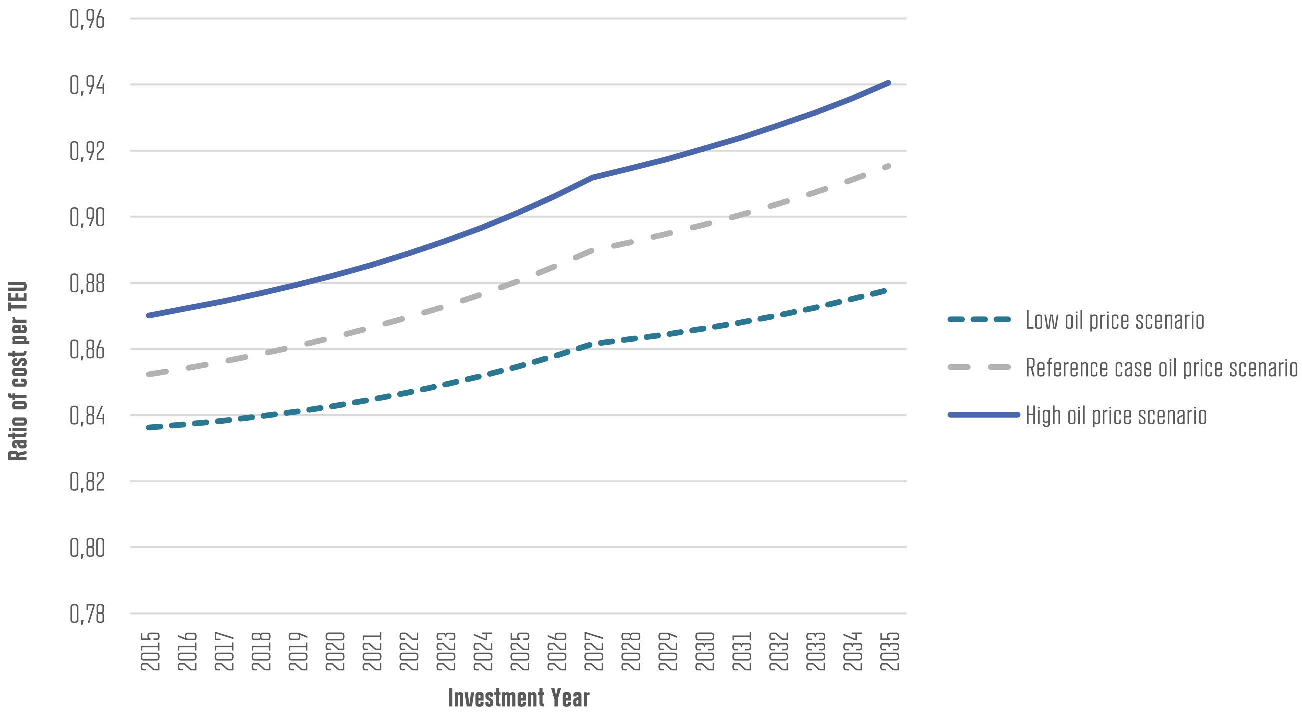

Figure 5.14: Cost per TEU ratio with a voyage speed of 12 knots along the NSR
The total cost per TEU ratio of the investment of an ice strengthened vessel to an open water vessel, as a function of the investment year given a voyage speed of 12 knots along the open water section of the NSR between Europe and Asia. The ratio is calculated in the high Arctic warming scenario with a discount factor of 7 percent and both vessels having a container capacity of 8000 TEU. A ratio above one indicates that the investment in the ice reinforced vessel is favorable. Source: Own Calculations

From figure 5.13 and 5.14 it is clear that super slow steaming operations along the NSR moves forward the point at which the investment in an ice reinforced vessel becomes favourable, relative to an ordinary container ship of the same size using the SCR. Recalling the results from the previous section, it was evident that the investment ratio was not favourable in the time span of this analysis. By altering the NSR speed to 12 and 15 knots, the investment in an ice reinforced vessel becomes more attractive; although only at a small margin. At both speeds the total cost per TEU is approximately 6 percent higher for the ice strengthened vessel compared to the open water vessel if the investment is initiated in 2035 under the high oil price scenario. Interestingly, the total cost per TEU is slightly lower when the vessel operates at 15 knots on the NSR compared to the lower speed of 12 knots. This indicates that operating at the lowest speed possible does not necessarily reduce the total costs per TEU, and that an optimal speed along the NSR is situated at approximately 15 knots.

5.3.2 Case Study discussion and conclusion

The Arctic Sea ice-cover is continuously disappearing, creating the opportunities of using the NSR as an alternative maritime shipping lane to the SCR. Transporting goods via the NSR reduces the travel distance by up to 35 percent, resulting in significant reductions in voyage time and fuel costs. In this case study, a cost analysis was performed on the feasibility of transporting containerized goods between North Western Europe and East Asia using the NSR as an alternative to the SCR. Throughout the case study, the total costs per TEU of operating an 8000 TEU vessel using the NSR was compared to three ordinary open water vessels; all investigated under two different sea-ice projections and three fuel price projections. By performing a discounted cost analysis, this case study finds that the investment in an 8000 TEU ice reinforced containership using the NSR will not be preferable to an investment in an ordinary 8000 TEU (or larger) open water vessel in the near future. This is considering all the global warming and fuel price scenarios. The greatest potential for the ice reinforced container ship was found in the high global warming scenario and fuel price scenario. Here a total cost per TEU was identified as only being approximately 10 percent higher than the open water vessel of the same size operating along the SCR. This emphasizes that the feasibility of liner shipping is highly dependent on the annual number of navigation days along the NSR. The results also imply that the prospect of Arctic liner shipping may become feasible around 2040, with a rapidly expanding navigation season and a fuel price following the high price scenario.

Further, this reveals that the vessel operating along the NSR is relatively less affected by increasing fuel prices compared to that only navigation the SCR. This is only the case if the navigation season is sufficiently long to offset the increased fuel consumption of the ice reinforced vessel. Lastly, it can be concluded that by navigating at reduced speed along the NSR, the total cost per TEU is reduced, thereby advancing the point at which an ice strengthened vessel becomes an advantageous investment to an ordinary vessel of the same size.

The possibility of regular traffic along the NSR to become competitive to the SCR as soon as 2040 rests upon several crucial assumptions which are all subject to major uncertainties. These uncertainties include the topics of vessel sizes, icebreaker availability, entry deterrence, fuel prices port availability and the future decline in sea ice. Although the cost ratio difference between the ice-reinforced and open water vessel was close to one, it is important to take into account the lower costs per TEU of the larger vessels operating along the SCR due to the economics of scale. In order for the NSR to be truly competitive to the SCR, the vessels operating in the Arctic therefore have to increase considerably in size to become competitive. This is impossible at present, due to the shallow Arctic waters and the limited size of the icebreakers. The Arctic Ocean spans a vast area and is subject to extreme weather and large floes of drift ice. In the analysis it was assumed that the yearly navigation period is continuous, and that icebreaker assistance is always available. In a real scenario however, a sudden change in the weather pattern may cause the NSR to close, severely increasing the voyage time and thus loss of revenue. Additionally, icebreaker assistance might not always be readily available, and the average waiting time on an NSR trip could easily exceed those adopted for this study.

As mentioned in the previous section, multiple port visits along the voyage hedges the ship operator against local demand slumps. This has the potential to increase the amount of goods transported per trip, positively affecting the overall revenue. One of the assumptions throughout this paper was that a voyage along the NSR only included three port visits at each cluster, which is reasonable to assume given the sparsely populated Russian Arctic. In contrast to the NSR, numerous major port cities are situated along the SCR. This creates the potential for a much larger annual amount of TEUs than calculated in this paper, and consequently it might overestimate the competitiveness of the NSR. These major population centers along the SCR also provide different challenges to the ships operating in these waters. Two examples of this are large scale piracy off the horn of Africa and the acute problem of large scale refugees crossing the Mediterranean Sea in need of rescue as mariners are compelled to bring the distressed humans to safety.

In this paper, the developments of bunker fuel prices are projected using a forecasting model under the critical assumption of no major geopolitical shocks. Looking forty years into the past, it becomes clear that such dramatic events occur frequently. In recent years shale gas and oil extraction in the Dakotas, has changed the world oil price, which is currently lower than seen during the financial crisis of 2007. The assumption of no such global events occurring is in itself contrary to the background of this paper. The Arctic has the potential to change the transport infrastructure of the world, providing alternatives to the Suez Canal, which is currently the fastest shipping lane between Europe and East Asia. With a contemporary sharp decline in the number of pirate attacks in the bay of Aden (Stavridis, 2013), the Suez Canal is still one of the world's most important transport routes. Unlike the Russian Federation, Egypt does not need to maintain a ready icebreaker fleet nor create a maritime infrastructure in a remote and sparsely populated part of the world. As the incumbent provider of the world's most trafficked shipping lane, the Suez Canal authority has the potential to use policies of entry deterrence in order to postpone the prospect of Arctic shipping. By lowering the Suez Canal transit fee, the total costs per TEU calculated in this paper are lowered and thereby reduce the ship-owners' incentives to use the NSR. Even the expectation of the Egyptian authorities lowering the future Suez Canal tariff may increase the projected opportunity costs of investing in a vessel designed for the NSR and thereby maintain its role as the most important route between Europe and Asia. Although the Suez Canal presently maintains its dominant bottleneck position, the retreating Arctic Sea ice-cover along the NSR is declining, making the NSR more attractive in the future. Transporting goods through the Artic, as an alternative to the SCR, results in a dramatic reduction in the travel distances, which is still a major determining factor in the cost of maritime shipping. As the ice-cover along the NSR diminishes, the Russian Arctic infrastructure will most certainly become more effective in the future, making the NSR more attractive. Further research is needed and should incorporate more advanced fuel price forecasts, shipping cycles and navigation day projections. This will certainly enhance the predicting power of a future case study, to create a better economic foundation for when to operate in the high Arctic.

Source: Rosatomflot

6 ARCTIC OFFSHORING AND BULK OPPORTUNITIES AND CHALLENGES

AS BOOMING COMMODITY PRICES HAS EXPANDED THE EXTRACTION OF RESSOURCES TO THE ARCTIC A NEED FOR MARITIME TRANSPORT AND SERVICES HAS FOLLOWED. THIS HAS CREATED A WIDE RANGE OF OPPORTUNITIES FOR THE OFFSHORING AND BULK SECTOR WHICH ALREADY FORMS THE MAJORITY OF MARITIME ACTIVITIES IN THE ARCTIC. THE FOLLOWING CHAPTER AIMS TO MAP THE ONGOING AND FUTURE ARCTIC RESSOURCE EXTRACTION SITES OF RELEVANCE TO MARITIME ACTIVITIES IN ORDER TO GIVE AN OVERVIEW OF THE OPPORTUNITIES FACED BY THE SECTOR.

The area north of the Arctic Circle hosts an abundance of oil, gas and minerals, which were previously deemed impossible or non-economically feasible to extract. The rapidly diminishing ice cover on the Arctic Ocean, combined with a major expansion of several large developing countries' economies, has fueled a rise in demand for such commodities. The recent years have seen a surge in oil and gas extraction activities in the Arctic parts of the Eurasian continent. To meet this surge in demand, several resource extraction sites in the high Arctic are either in the construction or planning phase, creating major opportunities for the maritime industry. A large majority of the maritime activities in the Arctic are associated with resource extraction activities and several major projects requiring a significant expansion of bulk shipping capabilities are currently under way (see section 6.2.1). Therefore the opportunities for Arctic shipping in these sectors will mainly be concerned with the transport of such commodities from extraction points in the Arctic and maritime support for the resource extraction facilities.

Although bulk shipping linked to such resource extraction activities are faced with the biggest potential, it is worth mentioning the recent and successful trans-Arctic bulk voyages along both the NSR and NWP. These voyages indicate that the reductions in distance of the Arctic Sea Route also benefit the bulk sector, thus making Arctic bulk shipping sector with a wide range of opportunities.

Trans-Arctic bulk voyages are being subject to the same limitations as those mentioned for the liner shipping sector, such as a short navigation season and the general risks of operating in the remote areas of the Arctic. However, bulk operations rarely operate under the strict time scheduling observed in the liner shipping sector, reducing the financial risks of such voyages (Schøyen & Bråthen, 2011).

The following parts of this chapter include a more in depth review of the present and future activities important to the bulk sector in relation to the extraction of both petrochemicals and minerals in the Arctic. The first part will provide a brief introduction to the multiple roles of the shipping sector in Arctic resource extraction activities. Then the paper will then review the activities and describe the opportunities for the tanker sector, given the present and future extraction possibilities. In the third part, the focus shifts to the activities and opportunities for the dry bulk sector by reviewing the current and future Arctic mining activities with importance to the maritime sector.

6.1.1 The role of Arctic Shipping for resource extraction

A large fraction of the Arctic landmasses consists of islands or areas far away from existing infrastructure. Therefore, the maritime industry plays a decisive role in the prospect of extracting minerals and hydrocarbons from the Arctic. Sea transport is thus necessary both for transporting commodities away from extraction points, but also for providing supplies and machinery for the mining process. This includes all resources needed for the establishment of sufficient infrastructure on site, like fuel, water, food and general supplies. Additionally standby ships may also be needed for towing and support operations. In the case of off shore extractions specialized vessels might be required for SAR operations or oil spill containment. The seasonal ice cover and harsh environment in large parts of the Arctic further complicates maritime operations. Although large areas of water previously inaccessible to vessels have been exposed, the Arctic navigation season still provides a limited window of opportunity for the transport. This results in potential severe disruptions to the supply chain, which forces the companies to seasonally stockpile the products when the arctic waters are inaccessible to transport vessels.

Mines and facilities for the extraction of hydrocarbons located north of the Arctic Circle are numerous, yet only a few of these are situated in areas solely dependent on maritime transport for in- and outbound logistics. A majority of the mining sites located in the Arctic parts of Scandinavia, Russia and North America are connected permanently to ice-free ports by railway. Most of the hydrocarbon extraction facilities use pipelines to transport oil and gas directly to ports and markets further south, which significantly reduces their dependence of Arctic shipping. If development of resource extraction in the Arctic continues to expand to more remote and isolated areas, the need for logistic maritime assets arises creating further opportunities for the sector. These developments could be in areas such as Greenland, the Canadian Arctic Archipelago and Arctic Siberia, where pipeline transportation would be impossible.

6.2 PROSPECTS FOR LIQUID BULK AND OFFSHORING

Although the Arctic Circle only covers 6 percent of the Earth's surface, the area may account for as much as 20 percent of the world's undiscovered recoverable oil and gas resources (Ernst & Young, 2013). The US Geological Survey estimates the total mean of undiscovered conventional oil and gas resources in the Arctic to be 90 billion barrels of oil, 47 trillion cubic meters feet of natural gas and 44 billion barrels of natural liquid gas. Of these the largest amount of undiscovered oil, set at 29 billion barrels of oil, is expected to be located in Arctic Alaska. The largest gas fields are estimated to be located in the Western section of the Russian Arctic (USGS, 2008). To transfer these resources to economic growth centers further south, an extended infrastructure is required. Multiple types of infrastructure are needed, adapted to the conditions at each site, including: pipelines, oil terminals, gas terminals and bulk tankers. Although the maritime transport of hydrocarbons is a major industry on a global scale, a large fraction of the oil and gas produced north of the Arctic Circle is currently transported south by the use of pipelines, either directly to the costumers or to accessible ports located in more advantageous climate areas. Installing pipelines to extraction facilities are both technically difficult and expensive, resulting in the need for tankers and LNG carriers to transport the hydrocarbons (NIRAS, 2014). Consequently, the liquid bulk maritime sector has seen a recent surge in the number of transports along the vast expanses of the NSR. This increase in oil and gas maritime activity has not only been fueled by the need for inter-Arctic logistic transport, but also by numerous trans-arctic transits between Europe and Asia. The number of trans-Arctic tanker voyages along the entire distance of the NSR has amounted to 13, 18 and 19 in 2011, 2012 and 2013, respectively (NSRA, 2015). Compared to the number of tanker vessels operating partially along the NSR, with 10 in 2012 and 20 in 2013, it is clear that tanker traffic is dominated by traffic between Europe and Asia. It is, however, important to note that several of the transits were carried out by smaller vessels departing or arriving in the port of Murmansk and Western Russia. They did therefore not travel directly to the large population centers of East Asia and Europe.

The majority of the tanker vessels navigating the Arctic are owned and operated by Russian shipping companies, notably Sovcomflot and the Murmansk Shipping Company. Sovcomflot is Russia's largest shipping company and one of the world's leading tanker ship owners. The company is an active participant in the Russian oil and gas extraction activities in the Arctic, operating a large amount of ice classed LNG and petroleum carriers. Murmansk Shipping Company provides transport of dry bulk, general cargo and tanker shipping along the NSR and operates the Russian nuclear icebreakers, used for the escort of cargo ships along the NSR (MSCO, 2013). Both Sovcomflot and the Murmansk Shipping Company have a long history of operating in the Russian Arctic, but in recent years several non-Russian shipping companies have also navigated the NSR. Non-Russian companies having used the NSR comprise of the Swedish Stena Line, Greek Dynagas and the German Reederei Group.

Dynagas provides specializing in navigating in Arctic weather and ice conditions using its expanding fleet of ice reinforced LNG carriers (Dynagas, 2015) made history in 2012 when the tanker "OB River", chartered by Gazprom, was the first LNG tanker to successfully transport LNG via NSR from Hammerfest, Norway to Tobata, Japan. The voyage was carried out during November, outside of the navigation season, with the aid from Rostomflot icebreakers (Gazprom, 2012). Another Dynagas LNG carrier; the "Arctic Aurora" carrying 66.866 tons of LNG completed a similar voyage in 2013[14], while also backhauling through the NSR (NSRA, 2015). In the same year Stena Line, in cooperation with Hyundai Glovis, also traversed the NSR transporting 43000 tons of Naphtha from Ust-Luga, near Skt. Petersburg to South Korea (Stena, 2013). Between 2012 and 2013, the German Reederei Nord completed two transits carrying gas condensate from the port of Murmansk to Incheon, South Korea and Malacca, Malaysia. Several other non-Russian companies have navigated the waters of the NSR, transporting oil and gas between Europe and Asia. This indicates a broader interest in utilizing the Arctic as a viable transport route for liquid bulk. Additionally, several oil and gas companies operating in the Arctic without access to the pipeline network are acquiring their own vessels to transport goods.

6.2.1 Arctic oil and gas extraction activities by region

The reserves of the five Arctic nations are unevenly distributed. This part of the paper provides a brief review of extraction operations relevant to the maritime industry. It will provide an oversight of current and planned extraction sites in: Norway, Russia, US and Canada

Norway: Norway maintains the largest reserves of oil and gas in Western Europe, standing at 2.1 trillion cubic meters of gas and 7.5 billion barrels of oil (BP, 2015). The country is currently the third largest exporter of gas in the world after Russia and Qatar (EIA, 2014). A majority of the Norwegian production occurs outside of the Arctic in the North Sea, but extraction occurs in the Barents Sea north of the Arctic Circle. The gas and oil pipeline network in the North Sea is extensive, connected to the European central network. However, northern Norwegian oil and gas fields are only connected to the mainland, thus requiring transport south to reach other markets by rail or ship. The Norwegian part of the Barents Sea is ice free throughout the winter, and can therefore use normal open water tankers to markets in Europe and Asia. Snøvit is the first Norwegian gas field developed in the Barents Sea, where gas is transported to land using a 143 kilometer pipeline to the on-shore LNG terminal at Melkoya near Hammerfest for liquefaction (Statoil, 2014). Melkoya is the most northern LNG facility in the world, and is used as an export terminal to transport the LNG to consumers. In 2012, 65 percent of the LNG produced in Norway was exported to European and Eurasian countries, but shipments of LNG from Norway also have Asian markets as a destination (EIA, 2014). The two LNG carriers “Ob River” and the “Arctic Aurora” mentioned above, departed from the Melkoya terminal to deliver gas to the Japanese market.

The Goliat oil field in the Norwegian part of the Barents Sea is scheduled to begin production in 2015. It is expected to hold oil reserves of up to 174 million barrels of oil and close to 8 billion cubic meters of natural gas (ENI, 2015). Located far offshore, where pipelines are non-feasible, oil from the field will be transported to the markets using two newly acquired 123 thousand dead weight tons (DWT) shuttle tankers. They are owned and operated by Knudsen NYK Offshore Tankers, having acquired the vessels specifically to work in Arctic waters (WMN, 2011). Future development in the Norwegian Arctic may include the newly discovered Johan Castberg field, situated north of the Snøvit field, which is estimated to hold between 400 and 600 million barrels of oil. According to Statoil the field is too small for the development of land based facilities near the Castberg field (BO, 2014b) and the oil will therefore need to be transferred by ships. Although the future of the project seemed bright since the discovery in 2011, recent declines in the oil price has forced Statoil to postpone the decision phase at Castberg until 2016. This is due to estimations of a breakeven point of a 100 USD per barrel in the field, non-feasible at the current world price (Stangeland, 2015).

Russia: Of the 61 large oil and gas fields that have been discovered within the Arctic Circle, two thirds are located in the Russian part of the Arctic (Ernst & Young, 2013). Almost a quarter of the world’s proven gas reserves are located in Russia, with close to 90 percent of these reserves located in the Northwestern part of the Russian Arctic. Gas fields located in the Barents and Kara Sea region currently supply almost 70 percent of the Russian gas production (Østreng, et al., 2013). The gas and oil pipeline infrastructure is well developed in the Western part of the Russian Arctic, with under 20 percent of the produced oil being transported using by ships, railways or roads. Several oil export terminals are located in the Russian part of the Arctic, with a majority of these located in the ice free waters of the Barents Sea. Of these Murmansk is the largest terminal, serving as a hub for the transport of oil to markets around the world.

Oil produced at the Timan-Pechora field, is transported to Archangelsk, and then shipped to the Belokamenka floating storage unit in Kola Bay. From the Belokamenka unit, the oil is further shipped to customers in Europe and the US, amounting to as much as 11.2 million barrels of oil

[14] On the voyage in 2013 the destination port was Futtsu, Japan.

The Belokamenka floating oil platform
Source: Scanpix / Iris

in 2008 (Rosneft, 2015). The Russian company Lukoil owns and operates the Varandey terminal in the Pechora Sea, currently the northernmost continuously operating oil terminal in the world. Varandey is a fixed-offshore ice resistance off-loading terminal located 22.6 kilometers from the coast, where oil produced at the nearby Timan-Pechora oil field is loaded on to oil tankers for further transport (Lukoil, 2015a). Lukoil exports all its oil from Russia by sea, which amounted to 4.2 million tons of crude oil in 2012, of which the 3.2 million was through the Varandey terminal (Lukoil, 2015b).

Located 60 kilometers north of Varandey, in the Pechora Sea, lies the ice reinforced drilling platform Prirazlomnoye capable of operating year-around in the harsh Arctic climate. It is the world's first stationary platform extracting oil in the Arctic shelf. The Prirazlomnoye oil field is estimated to hold 72 million tons of oil and Gazprom, the operator of the platform, expects the annual production to reach 6.6 million tons after production from the field was initiated in December 2013 (Gazprom, 2015). Located far from shore the drilling platform is not connected to land by pipelines and the oil extracted is therefore transported by sea and on May 1st 2014 the first shipment consisting of 67 thousand barrels of oil arrived at the port of Rotterdam by the Sovcomflot ice strengthened oil carrier "Mikhail Ulyanov". Since then several transits has been completed and Gazprom plans to increase annual production to 5 million tons by 2020 (BO, 2015a).

Unlike the transport of oil, Russia only exports natural gas extracted in the Arctic by pipeline and the only liquidation plant located on the Sakhalin Island in the Russian Far East far well away from the Arctic Ocean (EIA, 2014). A major LNG terminal is currently underway on the Yamal Peninsula near the Kara Sea by Novatek, Total AG and CNPC (Novatek, 2014). Here gas will be extracted from the large South-Tambeyskoye gas field, transferred to the Sabetta seaport. It is estimated the port will export up to 16.5 million tons of LNG annually by 2021, making it the busiest port in the Arctic. The contracting companies have signed a slot reservation agreement with Daewoo Shipbuilding & Marine Engineering Company for the construction of up to 16 Arc-7, 172,000 m^3 LNG carriers. These ships are ordered to ship LNG to international markets through the Barents Sea to Europe in the winter and by the NSR to Asia during the summer. Nine of the 16

LNG carriers have already been ordered by two joint ventures. The first 6 of these have been ordered by a joint collaboration between Teekay and China LNG, while the last 3 have been ordered by a joint venture between OSK Lines and China Shipping (SW, 2015).

Another major project in the development phase is the Shtokman Field in the Barents Sea, estimated to hold up to 3.9 billion m^3 of natural gas. From the planned deep sea rig, the gas is planned to be transported to the port of Teriberka on the Kola Peninsula to a planned liquefaction terminal for the maritime transport of LNG to costumers (Gazprom, 2015). A combination of the American shale gas boom and high production costs has, however, resulted in uncertainty for the Shtokman field. According to Andrey Kruglov, Gazprom Deputy Chairman, further development of the project may be postponed "*for future generations*" (Novosti, 2013).

USA and Canada: While the North American Arctic is projected to hold vast reserves of conventional oil and gas resources, liquid extraction has been limited due to missing production facilities and pipeline network. The Alaskan North Slope has proved reserves of 4.2 billion barrels of oil, but is estimated to contain at least 27 billion barrels of oil and 1 trillion cubic meters of gas (Østreng, et al., 2013). Alaskan oil is mainly produced at the Greater Prudhoe Bay area and is transported by pipelines to the ice-free port of Valdez, in the subarctic region of Alaska. From here oil is shipped to refineries along the western coast of America (EIA, 2014). Due to the road connectivity, the Alaskan oil and gas sector is therefore of negligible significance to the Arctic tanker sector.

Canada is already amongst the world's largest oil and gas producers but production mainly comes from the Alberta oil sands, the Western Sedimentary Basin and offshore oil fields in the Atlantic Ocean. All these extraction points are all well away from the Canadian Arctic (EIA, 2014). With the US importing close to all of Canadian oil and gas exports, these products are transferred using a well-developed pipeline network. Shipping prospects for Canadian fossil fuels is therefore also insignificant, unless major development of the remote Arctic reserves is initiated. Arctic Canada is estimated to hold vast reserves of fossil fuels, with the unexplored Ameriasian Basin north of the Canadian mainland is estimated to hold close to 10 billion barrels of oil and 56 trillion m^3 of gas (USGS, 2008). There are no currently active projects in the area, but the vast number of reserves makes future extraction activities likely if the oil price rises to previously high levels.

6.2.2 Opportunities for the Danish Maritime Sector:

The greatest opportunities in the Arctic for the maritime industry, and its sub suppliers, are found in the offshoring sector with the transport of oil and gas. This section presents the opportunities for the maritime industry in the Kingdom of Denmark as reported by NIRAS (2014). Danish companies in the offshoring and tanker sector already maintain a sizable fleet and have obtained knowledge through offshoring operations in both the Danish and Norwegian parts of the North Sea. Test drillings have also been carried out in the waters of Greenland. The opportunities for companies to provide transport the oil or gas away from the platform are greatest. However, several other types of vessels and equipment are needed to operate a drilling platform, which changes depending on the operational phase of the project.

In the investigation phase there is a need for maritime assets to collect seismic data, oil resource sampling and perform observations of the environmental state of the ocean. This employs several different vessel types, such as drill ships and support vessels. The production phase presents the greatest opportunity for the Danish industry, as they already maintains a fleet of transport of oil and gas as mentioned above. During the production phase there is an additional need for specialized vessels to assist both the drilling platform and the transport vessels. The operational phase further presents opportunities for suppliers of specialized equipment and materials to keep the platform operational in the harsh Arctic climate. Lastly, in the shutdown phase the platform is terminated and the well is sealed. This creates the need for materials and equipment to be transported away. In the sensitive Arctic environment, there may be need for continuous surveying vessels to perform environmental investigations, to monitor the environmental impact of the platform.

In addition to the above mentioned maritime activities, the extraction and transport of oil and gas creates opportunities for sub suppliers not directly involved with drilling. This includes the need for emergency response equipment in case of both human injuries and environmental accidents, such as minor oil spills where "stand-by" vessels specialized allow for quick response in the case of accidents. The offshore industry also creates opportunities for suppliers of general equipment for the cleaning of oil spills such as booms and pumps. Ship yards in Denmark have the capacities to produce such "stand-by vessels" as well as retrofit existing vessels with ice reinforcement and general anti-winterization measures.

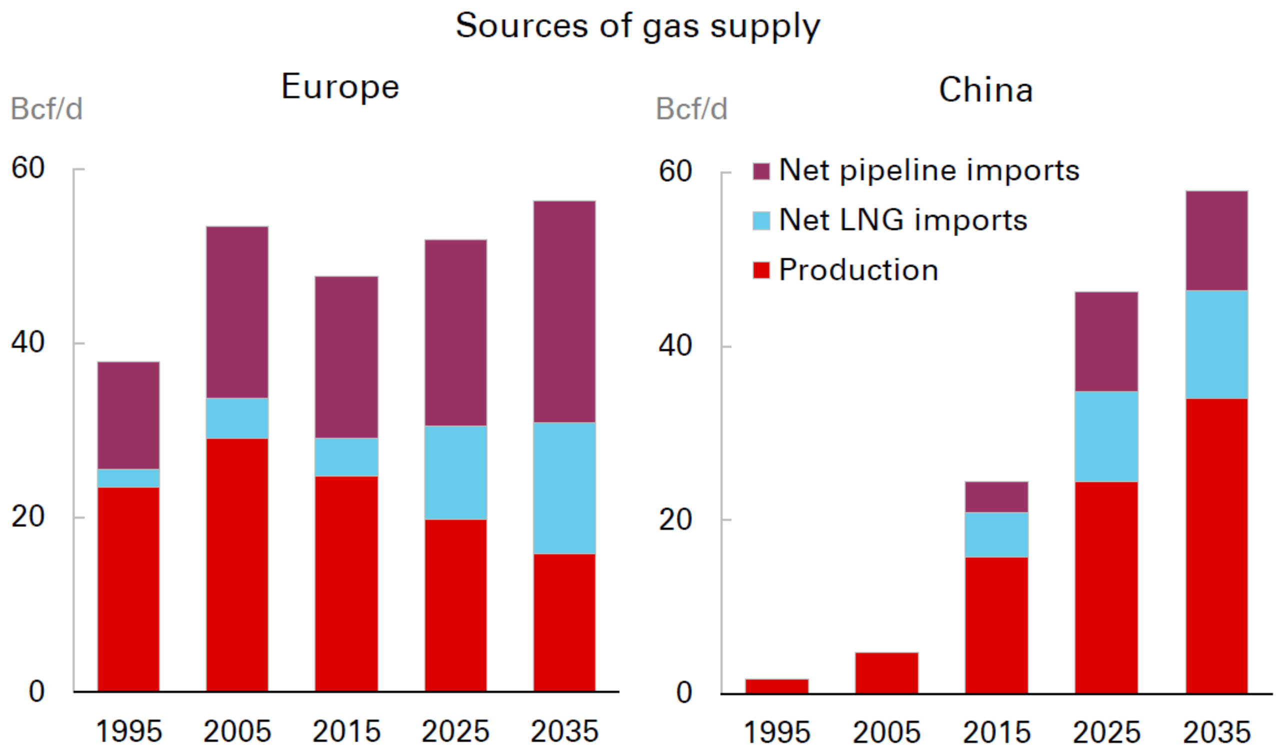

Figure 6.1: Projected sources of gas supply by region in 2035
Source: BP (2015)

Larger vessels are mostly produced in Asia; however several Danish companies are offering designs for ice strengthened transport vessels and are providing parts for these specialized vessels. Additionally, there are opportunities for the Danish sub-suppliers for servicing vessels that will be operating around the platform. Finally, the risk of drifting ice damaging the drilling platform creates a market for support activities such as ice surveillance, ice management and icebreaking. Experiences from the waters of Greenland has caused the Danish suppliers are well equipped to support such operations.

The majority of the off-shoring and tanker potential for the Danish maritime industry lies in Norway, Russia and Canada. Especially Norway, as several Danish companies are already supplying and working closely with the Norwegian offshore industry. In both Canada and Russia, however, the Danish industry is struggling to get on the supply lists of companies planning to extract petrochemicals in the Arctic. This is especially apparent with the Russian offshore companies where transparency is limited and subject to both technical and national barriers.

6.2.3 Long term potential

The major expansion in oil and gas extraction facilities in the Arctic has primarily been fueled by the major spike in oil prices observed during the last decade. The long term development of the Arctic oil and gas fields is therefore highly dependent on oil price levels reaching such high levels in order to be feasible[15]. The recent reductions in the oil price has caused the industry to postpone several of the planned projects, as a breakeven oil barrel price of close to a hundred USD is required for these projects to operate at a profit. Although such a fall in the price of fossil fuels severely challenges the development of oil and gas reserves due to high production costs, industry officials and policy makers expect the oil prices to return to at least reach 80 USD per barrel in the decade to come. This is due to the rising demand for energy being forecasted to continue to increase in the decades to come (Telegraph, 2015); (Oil Price, 2015); (WSJ, 2015). A rebound of the gas price faces more uncertainty, as the introduction of the fracking technology has sparked an energy revolution in America. A proliferation of the technology or increased

[15] Being substitutable goods, the European prices of oil and gas are generally correlated and a reduction in the oil price therefore also negatively affects that of price. See (Erdös, 2012)

export may easily lead to lower prices outside of North America.

Regardless of the short term price fluctuations, the increased economic activity of the world's large emerging economies has created an ever increasing demand for energy. Long term projections by British Petroleum expect such a demand to increase by as much as 41 percent between 2012 and 2035 with especially gas taking up a large amount of the total energy consumption in 2035. Figure 6.1 shows the projected sources of gas supply measured in billion cubic feet per day, to, Europe and China until year 2035. While a majority of gas supplies will continue to come from conventional gas sources and net pipeline import, a significant increase in projected net LNG imports provide opportunities for LNG transport and perhaps Arctic shipping as well. By 2035, both Europe and China is projected to supply close to 25 percent of their gas sources from net LNG import. However, not only China, but the East Asia-Pacific markets in general are projected experience a large increase in demand for LNG in the next two decades. Figure 6.2 illustrates the projected global and regional demand for LNG in 2035, clearly illustrating a large increase in especially Asian demand. With several unstable regimes and areas with armed

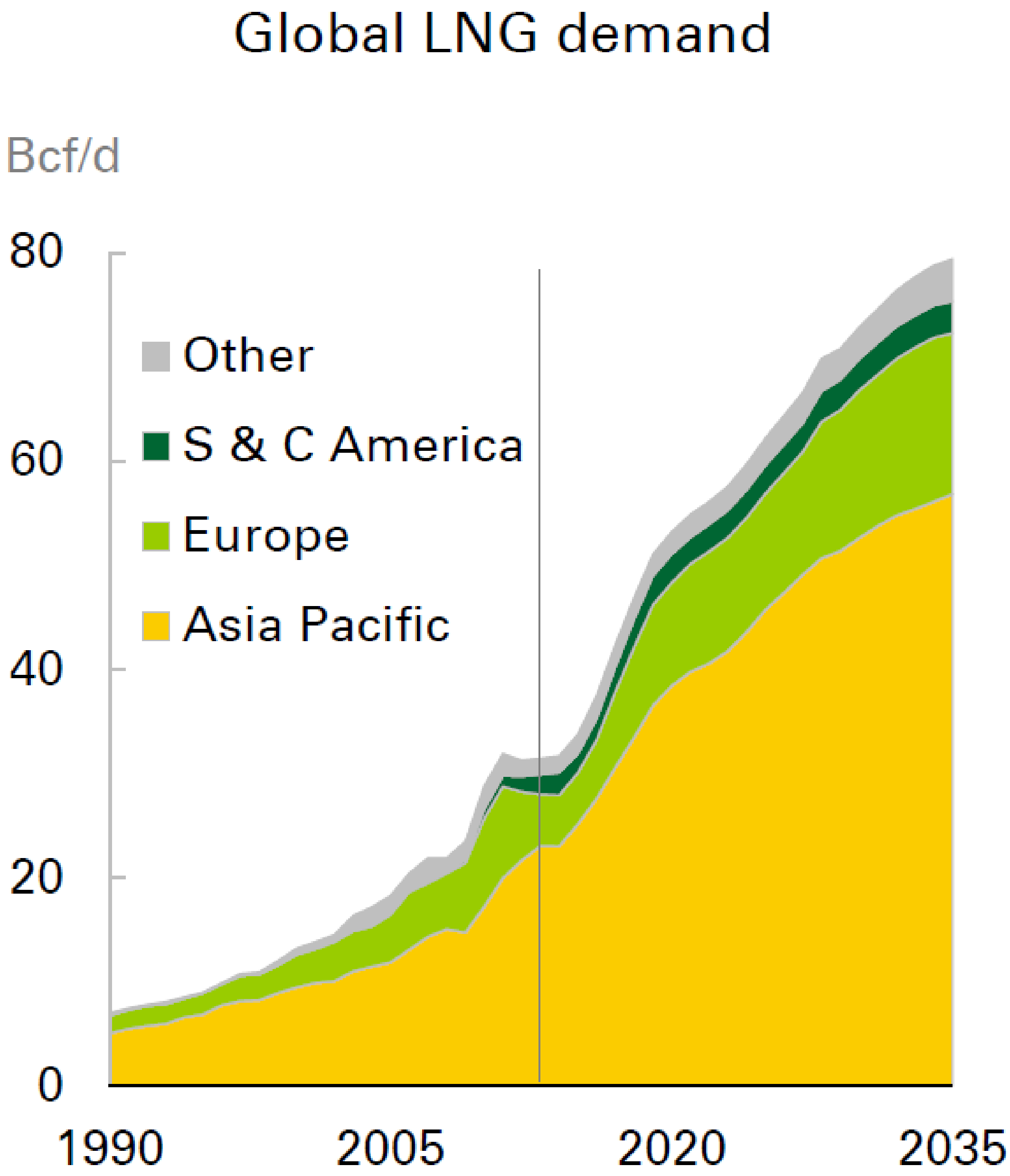

Figure 6.2: Projected global LNG demand by region
Source: BP (2015)

conflict in the Middle East, potentially causing disruptions in the energy supply lines, the Arctic has the potential to serve as an important source of oil. This could perhaps be of significance to the Arctic liquid bulk industry. Especially the Russian Arctic is expected to become a major source of oil in the future with the Asian countries being well placed to exploit these major gas reserves (WSJ, 2014b).

6.3 MINING OPERATIONS AND DRY BULK

Dry bulk has been operating in the Russian part of the Arctic for several decades, and the recent increase in the accessibility of the Arctic Ocean has expanded the areas where bulk vessels operate. In contrast to the majority of the petrochemicals produced in the Arctic being transported using an extensive network of pipeline systems, the heavy and voluminous minerals mined in the Arctic Circle requires transport using either ships or railway. Although such mining activities in the Arctic are limited, several major mines extracting iron, nickel, zinc and copper are present in the vicinity of the either the Arctic Ocean or the surrounding seas and rivers. Some of these mines are the largest in the world, extracting vast amount of ore to be shipped to the global markets. Additionally, such mining operations require supplies to accommodate the work force and machinery, which is often provided using maritime general cargo vessels.

While most of the Arctic Bulk traffic has been limited to transport from mining operations in the Arctic to larger ports located in ice free waters such as Murmansk, several successful transits over the NSR has been reported in recent years. Similar to the bulk sector, close to all of the Arctic bulk shipping activities are located north of Russia.

They are also primarily executed by Russian shipping companies like Sovcomflot, the Murmansk Shipping Company and Norilsk Nickel. One of the non-Russian companies having completed several bulk transits using is the pioneering Danish company Nordic Bulk Carriers. They specialize in transporting of dry bulk cargo in the Arctic, operating an expanding fleet of ice classed bulk carriers. They have successfully completed several voyages along the NSR, and were the first company in history to successfully transit the NWP for commercial means in 2012. From 2012 to 2013 Nordic Bulk completed 12 transits along the NSR, transporting iron ore from Murmansk to the Chinese cities of Qingdao and Huangua. They have also transported coal between Vancouver and Hamburg, while also backhauling through the Arctic (NSRA, 2015). Further the Nordic Bulk ore carrier “Nordic Oshima” measuring 76,180 DWT was the single largest vessel to transit the NSR during the 2014 navigation season (ibid.).

6.3.1 Present and future Arctic mining operations

While companies such as Nordic Bulk have mostly been transferring cargo through the Arctic, several large scale mining projects are currently in operation or in the planning phase creating commercial opportunities for the maritime sector. This part introduces some of the present and future mining operations, with opportunities for Arctic bulk shipping.

Russia: Mining operations have been active in the Russian part of the Arctic for decades, with the vast area in northern Russia holding an abundance of mineral resources. At present approximately 25 mines are in operation in the Russian part of the Arctic. Several of these mines are extracting precious mineral mines, thus requiring none or very few shipments (Emmerson & Lahn, 2012). The two major clusters of mining operations in the Russian Arctic are located on the Kola Peninsula and the central Siberian Plain near the Yenisei River. Murmansk serves as the regional hub for the maritime shipments of Bulk cargos from both these clusters. Most of the cargo leaving the port of Murmansk is shipped west through the ice free waters of the Barents Sea, but several shipments have also been transported to East Asia along the NSR. The Norilsk Nickel Company operates several mining facilities on the remote Central Siberian Plain and the Taimyr Peninsula both located near the Yenisei River. This river provides access to the NSR, as it runs into the Kara Sea allowing direct transit. The yearly nickel and copper output from the Central Siberian mines, is close to 500 thousand tons. The material extracted is shipped directly from the port of Dudinka at the Yenisei River to the port of Rotterdam, Hamburg and Shanghai during the NSR navigation season. When the navigation season is closed, a fleet owned by the Norilsk Nickel Company transfers material between Dudinka and Murmansk. These vessels are classified as ice reinforced Artic Class 7, with a potential to break through ice up to 1.5 meters thickness. This allows the vessels to operate even when the navigation season is closed, without requiring icebreaker assistance (Telegraph, 2012).

Scandinavia: Further west, in Arctic Scandinavia, several large scale iron ore mines relevant for bulk shipping are currently in operation. Reopened in 2009, the Sydvaranger mine in the extreme northeast of Norway is connected to the port at Kirkenes, allowing iron ore to be shipped to the worlds markets via the Barents Sea. Two of the largest iron ore mines in the world are located in Northern Sweden, Malmbjerget and Kiruna. They are connected to the sea by rail to the Norwegian port of Narvik, which has the capacity to export close to 20 million tons of ore annually to the European and Asian markets (LKAB, 2015). Although a large quantity of ore is being shipped from Scandinavia each year, the waters around these ports are primarily ice free throughout the year. Therefore opportunities for Arctic shipping are mainly conceived with shipments traversing the NSR.

Greenland: There are currently no active mining operations in Greenland, but large mineral deposits have been discovered recently. The government has thus actively been promoting mining operations, resulting in several planned mining projects. Several of these mineral deposits are projected to hold large reserves of the highly value rare earth minerals, which are currently produced under a Chinese monopoly. The Kvanefjeld project in the southern part of Greenland is estimated to host an abundance of rare earth minerals and uranium deposits. Greenland Minerals and Mining LTD expect to start construction of the mine as soon as the last permits have been granted. Being situated relatively south in Greenland, ice conditions are generally mild and the company plans to use the deep fjords around the area to ship the minerals directly to processing plants during the entire year (GMEE, 2014). The same favorable transport conditions apply to the TANBREEZ rare earth mineral mine, currently in the planning phase, situated near the port of Qaqortoq in southern Greenland. TANBREEZ, the company behind the project, is currently engaging in negotiations with the Greenlandic government and projects to mine 500 thousand tons of ore per annum initially, increasing to 1.5 million tons later (TANBREEZ, 2015). Further, the Chinese company General Nice has recently bought the rights the extract iron ore from the Isua field, which is expected to hold 1.1 billion tons of iron ore. The mine will be located just north of the Greenlandic capital of Nuuk and 110 km away from a proposed deep water harbor, from where the ore will be exported to foreign customers. Other projects where feasibility studies are currently being performed include the large scale mining projects in Northern Greenland by the company Iron Bark Zinc Ltd. These project proposals include mines at Citronen Fjord and Washington Land, both locations rich in reserves of zinc and lead. They are located in the northern remote part of Greenland, in the vicinity of the Arctic Ocean (Ironbark, 2013). The near permanent ice conditions in the waters of northern Greenland poses large challenges for further development of these mines and a reduction in the ice cover is therefore required for the projects to become economically feasible.

Canada and the US: Underneath the North American Arctic projections show an abundance of various mineral resources, with both Canada and the US already being amongst the largest mining nations in the world. Canada hosts approximately 800 active mining operations, although few of these mines are located in the Arctic. Several of these mining activities are related to the extraction of gold, diamonds and uranium. These resources require a limited need for shipping activities due to their attributes, and most of the resources extracted in the North American Artic generally serve domestic needs (Østreng, et al., 2013). The largest mine currently operating in the American Arctic is the Red Dog mine located in Northwestern Alaska near the Chukchi Sea. This mine is amongst the world's largest zinc mines, and due to its remote location, requires ships to transport the ore away from the mine. The mine hosts its own port facilities, where the zinc is stored during the winter while ice conditions are severe (NANA, 2009). After the closure of several mines in Nunavut and the Northwest territories, there are no active mining activities in the Canadian Arctic involving shipping. Only the Raglan Nickel mine in the low Arctic part of Quebec has a modest seaborne transportation need. The ore is shipped south to Quebec City, via Deception bay, using in only 4-5 trips per season (CASA, 2007). Future development in the North American Arctic include the massive Mary River iron ore project on Baffin Island, currently under development and expected to be operational by 2020. Baffinland, the company behind the project, expects the annual production to be 3.5 million tons increasing to 21.5 million tons annually by 2020. They are currently developing port facilities at Milne Inlet north of the mine (Baffinland, 2015). From the Milne Port, Baffinland plans to use bulk carriers to transport between 70 and 90 thousand tons of ore per transit, expecting to use more than 50 ships during the summer navigation season. This will drastically increase the traffic in the waters of the NWP (CBC, 2014).

The company MMG minerals, a subsidiary of the Chinese Minmetals Resources Ltd., have proposed a major mining project in the IZOK corridor in northern part of Nunavut Canada. The project will consist of several mines being connected by road to a planned port on the southern coast of Coronation bay, located along the NWP (MMG, 2015). An estimated 650,000 dry metric tons of mineral concentrates will be shipped out each year through the port. Minerals will be shipped Europe through the Behring Strait using the NWP, and conditions will allow passage to East Asia during the summer navigation season. MMG estimates that the amount of bulk carriers needed to service the mine at peak production must fulfill 16 round trips during the 100 – 120 days window of navigation (MMG, 2012). As of 2015, MMG is seeking partnerships to share the costs of developing port and road infrastructure, but it is doubtful if the project will be further developed given the current glut in global commodity prices.

6.3.2 Opportunities for the Danish Maritime sector

While destination voyages have the biggest potential for mining operations, there is a significant potential for the shipping industry in the establishment and termination phase of the mine through the transport of equipment and supplies to the mining site. The need for transport is largest in the operational phase, but specialized transport is also required in the phase of establishment and termination that can easily be transported over water. This section presents the opportunities for the maritime industry in the Kingdom of Denmark based on the findings by NIRAS (2014). By having a strong presence in the transport of bulk destination cargo, several Danish companies have established themselves as first movers in the Arctic bulk sector. They therefore have an advantage in the form of knowledge and equipment, including ice reinforced vessels. Especially decades of maritime experiences in Greenland navigating ice filled waters, as well as an insight into the political processes of the Greenlandic mining sector and understanding local challenges. In addition to the maritime activities related to the transport of bulk cargo and supplies, Arctic mining operations also creates possibilities for suppliers to service and repair maritime related equipment. Generally, Danish companies have a strong position in the areas of ice management, yielding opportunities for the mining and bulk industry in the Arctic. Ice management include icebreakers and ice surveillance, in order to secure ice free passages and escorting of transiting vessels. Further there is a need for specialized vessels for towing away icebergs, and an overall need for experienced ice pilots to man the ships operating in Arctic waters. The new-building or retrofitting of the ice reinforced bulk fleet may also present opportunities for the Danish industry. Specialized vessels may be needed to service the mine, and although built in Asia, the designing, classifying and certifying of large vessels create opportunities for the maritime sector in Denmark in their development phase and equipment. Both technical barriers and protectionism are seen as major challenges for the best utilization of Danish industry competencies in the Arctic. The technical barriers consist of local design and industrial standards, with several of the Arctic states having implemented some form of protectionism to support local suppliers. In Canada for example, equipment aboard vessels operating in the Arctic must have been produced domestically, providing a technical hindrance for Danish sub-suppliers. The American Jones Act states that all cargo between American ports must be transported by US owned vessels, with American employees, making it difficult for Danish bulk ships to operate in Alaska. Due to the ongoing presence in Greenland, Danish companies may leverage benefit from the Greenland commodity law. It states that companies must be located in Greenland and use Greenlandic employees, unless no Greenlandic competitive companies exists or no qualified work force is available to hire. In similarity with the offshore sector, several companies report difficulties in getting on to the list of suppliers, at international offerings of international companies. Becoming a part of international companies supply list is essential for getting a larger presence in the sector. This is further exacerbated for mining projects in the Russian Arctic, where the industry is worrying that all transport will be made by domestic companies, as observed in the Russian oil and gas industry. Challenges such as these hinder the possibilities for the Danish maritime sector and its sub-suppliers. This challenge is especially apparent for the smaller companies, which are heavily reliant on a fair level of competition.

6.3.3 Long term opportunities

In the area of Arctic mining operations and dry bulk, the long term opportunity is largely dependent on the accessibility of mineral deposits and the price of these commodities. This is similar to the offshore and liquid bulk sector. With the low commodity prices observed during the last few years, the development of new mines in the Arctic rests on the assumption of an increase in demand, and consequently an increase in price. The continued melting of the Arctic ice cover may, however, increase the number of trans-Arctic dry bulk transports using the NSR. This will possibly provide an alternative to the contemporary southern routes. The recently established Mary River iron ore mine will result in a dramatic increase of maritime activity along the waters of the NWP, which may also contribute to increased Danish involvement in the long term.

7 THE ARCTIC CRUISE INDUSTRY – OPPORTUNITIES AND CHALLENGES

LARGE PASSENGER SHIPS ARE INCREASINGLY NAVIGATING THE COASTAL AREAS OF THE ARCTIC OCEAN CREATING POSSIBILITIES FOR THE MARTIME CRUISE SECTOR. ICE CONDITIONS AND POOR CHARTING POSES A SERIOUS THREAT TO TRANSITING VESSELS AND THE REMOTENESS OF THE AREA PREVENTS LARGE SCALE RESCUE OPERATIONS IN CASE OF ACCIDENTS. THE FOLLOWING CHAPTER AIMS TO DESCRIPE THE POSSIBILITIES AND CHALLENGES FOR THE MARITIME CRUISE INDUSTRY IN THE ARCTIC.

While global warming's effect on polar ice caps has sparked a huge interest in the prospect of using the Arctic shipping lanes as international transport corridors, little focus has been placed on the Arctic cruise industry. As the Arctic ice cover has been receding during the last few decades, a significant increase in the number of passengers aboard Arctic cruise ships has occurred. This was especially apparent between 2003 and 2007, where the annual number of passengers traveling to the Arctic aboard cruise ships more than doubled (AMSA, 2009), although the number of passengers has stabilized during recent years (see figures 7.1 to 7.3). The Arctic cruise ships are generally small in comparison to the super large luxury liners operating on the lower latitudes, carrying between 50 and 400 passengers on each cruise (ibid.). A majority of the Arctic cruises ships navigate the less remote and generally ice free waters of Svalbard, the Northern Coast of Norway and the west coast of Greenland. However some smaller cruise ships have sailed as far as the North Pole and the North West Passage (Østreng, et al., 2013). Further, most cruise ships do not follow direct routes, but often seek more remote locations for wildlife and nature viewing purposes, regularly taking them through uncharted waters, (Johnston, et al., 2014).

7.1.1 Past cruise shipping activities by area

The ice free waters of Svalbard and Greenland are the primary destination for a majority of the cruise ships. Cruise shipping tourist numbers to Svalbard has seen a steady increase the last 20 years and peaked in 2012, reaching over 40 thousand persons, after a slight decrease the previous few years (see figure 7.1). While the number of passengers has increased, the total numbers of cruise visits have been falling from above 50 tours in 2007 to 38 tours in 2013. This indicates an increase in the size of the visiting cruise ships, with 11 visits of vessels with over one thousand passengers in 2012 alone.

The amount of cruise shipping tourists visiting Greenland increased dramatically during the last decade; reaching a

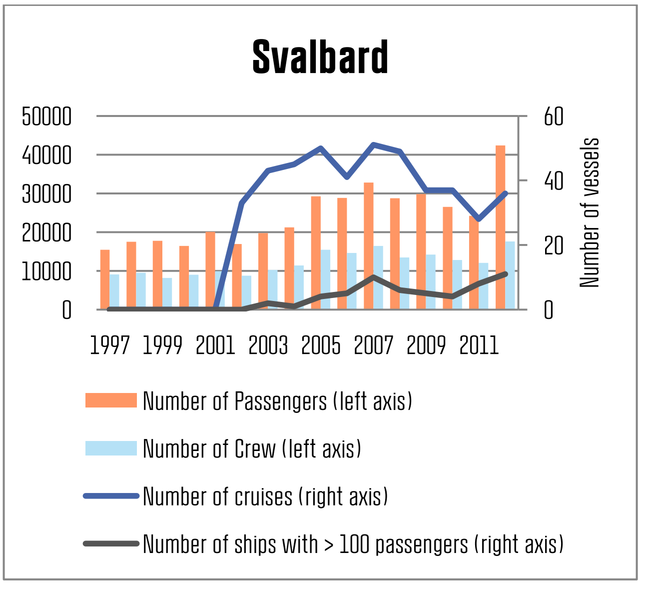

Figure 7.1: Number of passengers, crew and visits by cruise ships in Svalbard (1997 – 2012)
Source: Sysselmannen.no

peak of over 30 thousand persons in 2010 (see figure 7.2). Especially the west coast of Greenland has seen a surge in cruise ship activities. Between 2006 and 2008, the number of cruise ship port calls in western Greenland more than doubles increasing from 157 to 375 (AMSA, 2009). During the three consecutive years however, a reduction in

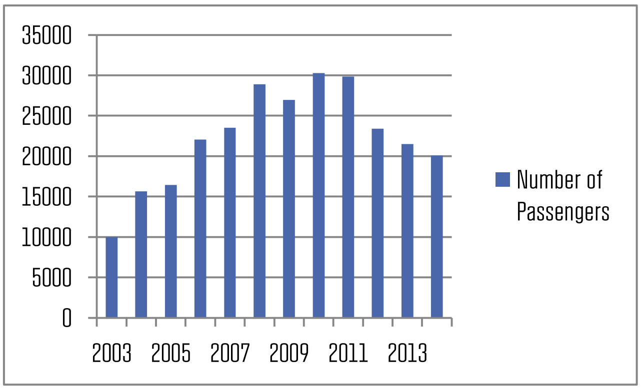

Figure 7.2: Cruise shipping passengers visiting Greenland (2003 – 2013)
Source: Statistics Greenland

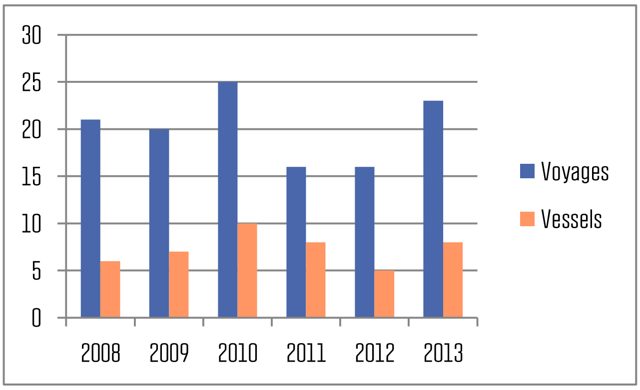

Figure 7.3: Annual number of voyages and vessels operating in the Canadian Arctic
Source: Association of Arctic Cruise Shipping Operators

the number of passenger was observed, dropping to approximately 21 thousand in 2013. This indicates a dampening in the demand for cruise tourism seen in the previous years. Since 1990, regularly cruise expeditions to the Franz Josef Islands and the North Pole were offered with the aid of the nuclear icebreaker "*50 let Pobedy*" and a number of voyages have been made to the Novaya Zemlya Islands in the west and Wrangel Island in the East (Pashkevich & Stjernström, 2014). Recently, however, the Russian provider of icebreaker service, Rosatomflot, announced that the "*50 Let Pobedy*" would be redirected to the Northern Sea Route to aid the increasing number of transiting merchant vessels after 2015, although this was later reversed when the icebreaker "*Sovetskiy Soyuz*" returned from repairs earlier than expected and therefore continuing the North Pole cruises until 2018 (BO, 2014a). The continuation of the icebreaker escort service to the North Pole after 2016 remains unclear but the redirection of the icebreaker to the Northern Sea Route will effectively ending the prospect of Arctic cruise shipping to the ice filled waters of the North Pole.

Cargo shipping along the North West Passage has been limited to community resupply with a few transits; however the cruise shipping industry has maintained significant presence in the Area. 23 commercial cruise ships have navigated the waters of the Canadian Arctic between 1984 and 2004 (AMSA, 2009) At the start of the millennia, the number of voyages in the Canadian Arctic saw a drastic increase, with 22 planned voyages in 2006 alone. From 2006 the yearly number of voyages stabilized between 23 and 26 annual voyages (Johnston, et al., 2014) before falling to 16 voyages in 2011 and 2012 (see figure 7.3).

7.1.2 Arctic cruise shipping challenges

Although the Arctic cruise-shipping sector has seen an increase in recent years, the sector faces a multitude of challenges – especially regarding the safety of passengers. The Arctic seas and coasts form a hazardous environment, and the increase in vessels operating in the Arctic has consequently increased the risk of major incidents. The nature of these potential incidents faced by cruise ships is similar to those of normal cargo vessels, including the risk of sinking, groundings pollutions, disabling by collision, fire and loss of propulsion (AMSA, 2009). With the amount of passengers aboard a cruise ship, however, the potential for human casualties from such an incident are much greater compared to ordinary merchant vessels. Additionally, cruise ships often navigate close to the coast and ice edges in order to provide the passengers with wildlife viewing opportunities, thereby further increasing the risk of groundings and collisions with the ice. So far, the Arctic cruise shipping industry has avoided major incidents and kept a good human safety profile.

However several incidents have been reported in recent years. In 1996 the cruise ship "Hanseatic" ran aground in the Simpson Strait in the Canadian Arctic, severely damaging the vessels fuel reservoirs, which lead to all 153 passengers being evacuated by emergency helicopter. In 2007, the Canadian cruise ship "MS Explorer" sank approximately 20 hours after striking an underwater ice formation near the South Shetland Islands in Antarctica. All of the 145 passengers and crew were evacuated into life boats, being rescued, after several hours in sub-zero temperatures, by the Norwegian Cruise ship "Nordnorge" also operating in the area (NBC, 2007). Recently, in 2010, the vessel Clipper Adventurer ran aground in the Coronation Gulf in the North West Passage with 118 passengers and 69 crew members aboard. It suffered serious hull damage, and was rescued by the Canadian Coast Guard icebreaker the "Amundsen" which by change was within 500 kilometers of the distressed vessel (Stewart & Dawson, 2011). In recent years the cruise ship vessels have been reported to travel increasingly further away from developed areas. This includes destinations like the city of Qaanaaq in northern Greenland and remote areas along the waters of the Canadian Arctic – both far away from sufficient emergency infrastructure (AMSA, 2009). For example, the Canadian Coast Guard estimates a response time of 11 hours for ocean going vessels in distress in the waters of the Canadian Arctic which may easily be too late to prevent human death tolls (Johnston, et al., 2014). Further, even if an incident should occur within range of such facilities, the sizable amount of passengers aboard cruise vessels would strain the already limited amount of SAR assets. In addition to the limitations in the current infrastructure, international regulations governing the Arctic cruise industry are lacking, yet improving. In 2014, the IMO agreed to adopt the Polar Code, which creates specific requirements in terms of construction & design, operations and manning, and equipment, for vessels operating in the two Polar areas. Set to enter force in 2017, the Polar Code will be mandatory under the SOLAS and MARPOL conventions.

Cruise shipping in the Arctic share many of the challenges also faced by bulk and tanker shipping, however important differences do exist, resulting in the need for a focused and more appropriate management regime in the future (Johnston, et al., 2014). The significant gaps in the regulation of the Arctic cruise industry has resulted in several of the cruise ships lacking sufficient ice classification, making them even more vulnerable to collisions with floating ice. Of the 88 cruise ships introduced on the world market between 2000 and 2008, only a small fraction is constructed to operate in Arctic conditions. With further growth of the industry, some of these vessels may be relocated to Arctic waters (AMSA, 2009). As a result of the limited international regulation of the sector, several cruise shipping operators have sought to reduce the risk of human casualties, in case of incidents through networks of industry self – regulations and official guidelines such as the IMO's "Guidance for passenger ships operating in areas remote from SAR facilities" (OECD, 2008). An example of an industry self-governing initiatives is the Association of Arctic Expeditions Cruise Shipping Operators (AECO) for cruise operators navigating the waters of Svalbard, Jan Mayen and Greenland. They aim to provide guidelines "*to ensure that cruise tourism in the Arctic is carried out with the utmost consideration of natural environment, local cultures, as well as challenging safety hazards at sea and on land*" (AECO, 2014). Additionally some cruise operators incorporate a policy of sailing in pairs when venturing deep into remote Arctic territories. It was a result of this "twinning" policy that the vessel "Nordnorge" was able to safely rescue the crew and passengers from the MS explorer in a remote Antarctic region (Johnston, et al., 2014). Although such official guidelines and self-regulatory measures have been established, the guidelines are not compulsory and opportunistic cruise ship operators are still able to provide voyages, with an unnecessary high degree of risk.

7.1.3 Possibilities for the Danish maritime industry

While a further expansion in Arctic cruise shipping will create opportunities for the maritime sector in general, the Kingdom of Denmark has no cruise shipping industry and the main beneficiaries are therefore likely to be the countries with such an industry (NIRAS, 2014). An increase in the number of Arctic cruise tourists may, however, create opportunities for the Danish industry not directly related to cruise shipping – especially around Greenland. These include the development of a service and experience industry for passengers aboard the numerous cruise ships arriving at Greenland, such as whale safari, sea fishing and trips to smaller fjords. Further, the large number of passengers aboard cruise vessels results in a high potential for producers of safety equipment as well as specialized stand-by ships in case of emergency (ibid.).

The current infrastructure to support cruise tourism is insufficient and the ports are generally too small to support the large vessels. Therefore significant investments are required for the Arctic cruise shipping industry to compete with contemporary destinations. Due to the inadequate experience of the industry to support cruise tourism within the Kingdom of Denmark, developing such experience and infrastructure capabilities may not prove feasible for the industry, given the limited size of the Arctic cruise shipping sector (ibid.).

7.1.4 Arctic cruise tourism: Overrated?

A further expansion of the number of companies offering cruises to the Arctic primarily depends on the demand for this form of adventure, as well as the future of development of the Arctic sea ice. The future level of regulations concerning Arctic shipping and passenger ships in particular, however, also play a role for the development of the industry. With the limited set of regulations currently active, cruise ship owners are able to easily divert open water vessels to arctic routes, allowing the industry easily to expand the number of voyages during the navigation season. However, a tightening of these regulations may easily result in some of the cruise ships being ineligible to operate in ice filled waters. The Arctic cruise industry has seen an increase in the number of passengers during the last decade, but has recently stagnated. A significant drop in the number of passengers

Source: Scanpix / Iris

visiting Greenland has especially been observed. During the dramatic increase in the amount of Arctic cruises in the middle of the last decade, the industry was optimistic and projected further expansions in both the number of passengers and vessels visiting the Arctic. According to AMSA (2009) the cruise ship industry considers the Arctic voyages to be an important and profitable service. In 2008 the prices for an Arctic voyage was priced between 2,900 and up to 55,000 USD per ticket. The cruise shipping industry has indicated that it intends to expand its activities in the Arctic, by increasing the amount of destinations, passengers and the season of operation (AMSA, 2009). Additionally, Wergeland (2013) argues that the Arctic cruise shipping tourism has great potential, but notes that the market for Arctic cruises still is a niche market compared to the large tourist destinations such as the Caribbean and the Mediterranean. The same conclusion was reached at a recent conference held in Ottawa, Canada, linked to the Arctic Council, where it was established that the Arctic cruise industry did not have the same potential as the Caribbean and Mediterranean (Shipping Watch, 2014c).

Based on the statistics presented by AECO at the conference, it was further established that the growth presented by the medias and analysts was highly exaggerated compared to reality (ibid.). Although different scholars project both positive and negative future scenarios for the Arctic cruise industry, a further reduction in the Arctic ice cover will allow higher accessibility for the industry, potentially increasing the number of annual voyages and destinations possible. The activity seen in the past years indicate that the industry maintains an Arctic presence although passenger numbers are still insignificant compared to non-Arctic cruise shipping and it remains to be seen if the industry will expand beyond the level observed during the last decade.

8 THE POTENTIAL FOR SUPPLIERS AND SUB-INDUSTRIES

The increasing accessibility of the Arctic Ocean, and the corresponding increase in maritime activities, has created a market for several companies in the maritime sector within the Kingdom of Denmark. Several of these companies are in a good position to benefit from the increased development, as the Danish fleet has a significant global and arctic regional presence, some already operating around Greenland providing a unique base of experience. A majority of the maritime companies of the Kingdom of Denmark are not engaged in activities related to the Arctic at present. Companies engaged in the Arctic, only see a modest contribution to the total company production, around ten percent. For a few companies Arctic activities provide the bulk of the operations, especially in the waters around Greenland. This chapter will introduce the possibilities and challenges for the different sectors and subsectors of the Danish maritime industry, mainly reviewing the findings of NIRAS (2014). The subsectors are those of the sea transport, the area of alertness, towing, salvage, maritime service, communication, surveillance, emergency equipment and finally maritime design.

8.1.1 Sea Transport

Of the five different sectors formulated by NIRAS (2014), sea transport holds the greatest potential for the Danish maritime industry. The opportunities for sea transport are linked to the transit and destination voyages with oil, gas, minerals and even container logistics – if the Arctic sea ice continues to decline at the current rate. Additionally, opportunities are linked to supply activities to resource extraction sites. Shipping companies based in Denmark operate a large and world spanning fleet, with several of these being ice reinforced and active in the Arctic.

Sea transport companies located in the Kingdom of Denmark already operating in the Arctic are Norden A/S, Royal Arctic Line and Nordic Bulk.

- DS Norden is currently transporting coal from the Svea Nord mine located in Svalbard.
- Nordic Bulk uses a model of sailing through the Arctic shipping routes during summer while operating in other ice infested waters when the navigation season ends in the high Arctic.
- Royal Arctic Lines transport cargo between the settlements in Greenland but also has operation near Antarctica during the winter on the northern hemisphere.

Further, companies currently operating logistics and supply services in the Arctic include Royal Arctic Line, arctic Base Supply, Martek and Blue Water Shipping.

However, a majority of the companies in the sector of maritime traffic located in the Kingdom of Denmark are currently not actively engaged in Arctic activities. These include most of the major shipping firms such as Maersk, Torm, J. Lauritzen A/S and DFDS.

8.1.2 Alertness, towing and salvage

In the areas of alertness, towing and salvage, companies within the Kingdom of Denmark are experienced in all of these services. The area of ice-management provides a lot of possibilities around resource extraction sites, such as general ice surveillance, icebreaker assistance and towing away drifting icebergs. Viking supply ships are a significant actor within this industry, currently active in Russia, Canada and the Baltic Sea. Smaller companies are also able to leverage their experience, like Greenland Maritime Solutions, offering consulting in areas of ice-management.

Towing boat assistance, support vessels and ice-management activities have a large arctic potential as a consequence of an increase in mining, offshoring and an increase in seaborne traffic. Towing boats are currently operated by Svitzer and Viking Supply Ships. Esvagt is another example of a Danish company delivering support vessels and stand by vessels to offshore activities around Greenland.

The environmental challenges derived by the offshoring and mining sectors in the sensitive Arctic environment have increased the need for environmental alertness. Growth in the environmental focus has meant that emergency response assets have been relocated to the Arctic, especially Greenland. Greenland Oil Response is a company owned by the Greenlandic government, while Esvagt also offers oil spill response services.

8.1.3 Maritime Service

The growing maritime activities in the Arctic can cause an increase in demand for the maritime sector in the areas of vessel servicing, supervision and maintenance. On Greenland and on the Faroe Islands lies the Nuuk Værft and MEST shipyard are able to provide services. While in Denmark lays Karstensens shipyard, Vestergaard maritime service and Orskov Group - all yards capable of servicing and repairing vessels operating in the Arctic. Additionally maritime servicing includes the approval and classification of ships, arctic classification focusing on ice reinforcement, equipment, safety and crew. DNV GL is a major company performing classifications on ships and currently holds a large share of classifications for vessels operating in the Arctic.

8.1.4 Communication, surveillance and safety equipment

In order to ensure the safe operations in the Arctic, sufficient communication, surveillance and emergency equipment must be ensured for vessels and platforms operating in the arctic waters. This creates opportunities for suppliers to provide companies operating in the Arctic with specialized safety equipment adapted to the environment. Viking Lifesaving Equipment and Harding are presently amongst the largest companies in supplying maritime safety products, both offering special products for ice filled waters. Cobham Satcom and Lyngsø Marine are both Danish suppliers of navigation and communication equipment.

8.1.5 Maritime Design

Arctic conditions require specialized ships and platforms, able to withstand the sea ice and sub-zero temperatures. This creates significant possibilities for shipyards and engineer design companies within the Kingdom of Denmark. Although the building of ships have moved to Asia in the last decades, a niche for building, retrofitting and designing specialized vessels, is still present. This is noticeable with standby vessels to the offshore industry and smaller ice reinforced bulk and freight ships. Karstensens Shipyard is an example of a yard producing such specialized vessels. Both OSK-Shiptech and Odense Maritime Technology are two firms designing ice reinforcement retrofits and special purpose vessels with ice reinforcement, produced on a licence throughout the world.

Further there is a considerable potential for suppliers of equipment and knowledge to shipyards retrofitting and building new vessels capable of operating in the Arctic. Amongst these is Hempel, which produces specialized paint for operations in the icy waters. Odense Maritime Technology has developed and designed propellers for ships navigating the Arctic, where efficiency and strength are optimized for the conditions. Further, DESMI produces pump and cooling systems for the off-shore industry. These systems are as also relevant for environmental accidental equipment, such as containment booms for the management of oil-spills.

8.1.6 Challenges

Suppliers and companies in the Kingdom of Denmark also face numerous challenges in entering the Arctic Maritime industry – especially in relation to activities such as resource extraction operations. The suppliers and shipping companies in the maritime sector have a severe lack of competent experience in the Arctic environment. These competences range from navigation in ice filled waters, to how material and supplies are affected by Arctic weather conditions and how to properly adapt to the safety standards of the Polar Code. This lack of knowledge and expertise translates into difficulties in establishing a presence in the Arctic maritime sector. Companies may face difficulties defining what factors need to be taking into consideration, and where to obtain such information. Further, the costs derived from entering the Arctic market are often significant, due to vessels requiring ice reinforcement and specialized equipment such as anti-winterization measures, facilities for securing sufficient communication and lifesaving equipment. Lastly, entering non-European Union markets may provide a challenge for companies of a limited size. Such challenges can be a product of both national requirements of local production or employment or technical barriers. These barriers are especially apparent in the sectors of oil, mining and gas extraction, where Danish companies have difficulties being considered as sub suppliers by the major foreign resource extraction companies.

9 ARCTIC GOVERNANCE STRUCTURES

POLITICAL STRUCTURES ARE EMERGING ALONGSIDE THE INCREASING ECONOMIC INTEREST IN THE HIGH ARCTIC. TO NAVIGATE THE REGULATORY LANDSCAPE, STAKEHOLDERS ACTIVE IN THE ARCTIC MUST UNDERSTAND HOW THE DIFFERENT GOVERNANCE STRUCTURES CREATE THE LEGISLATIVE FRAMEWORK. THIS SECTION SEEKS TO PROVIDE AN OVERVIEW OF THE PROCESS LEADING TO INSTITUTIONS CREATION, CURRENT INTERNATIOANL GOVERNANCE STRUCTURES AND FUTURE TRAJECTORY OF THE NORTHERN FRONTIER.

Historically, the world seas have been difficult to regulate, with a basic tension between regulation and freedom presiding in all arguments of how to operationalize the sea. The first global maritime regimes were based on the notion of “Freedom of the seas” from the 17th century. Defined by the Dutch jurist and philosopher Hugo Grotius, it argues that the sea is international territory and should allow free seafaring trade without any restrictions. The counter argument, as presented by the Portuguese Serafim de Freitas, claimed that the sea should be controlled by states in 1625. This notion was a Portuguese claim to the sole rights for all trade with the East Indies (Vieira, 2003).

Understanding the basics of the international historic tensions in regulation is important to understand the relevant governance structures in the Arctic. Arctic governance is created by each of the Arctic regimes operating within their own sphere of legitimacy, due to the differences in scope and mandates (Stokke, 2013). The first ratified global maritime regulation was the United Nations Law of the Sea Convention (LOS Convention, also known as UNCLOS). This treaty defines the territorial boundaries of states and as a build in mechanism for settling territorial disputes. This function is highly important for resource extraction industries, as it defines the jurisdiction of the Arctic states. The other global mandated organization relevant for this case is the International Maritime Organization (IMO), which in 2014 ratified the Polar Code. This code prescribes minimum operational principles for vessels in the polar waters, given the challenges of drift ice and waters being mostly uncharted. On the regional basis, the Arctic Council maintains a privileged position as the coordinating forum for Arctic states. It advises on different regional issues with a vast range of stakeholders involved in the process. Work by the Arctic Council will be presented to illustrate the future trajectory of Arctic governance, considering the environmental impact and optimal utilization.

9.1 UNITED NATIONS LAW OF THE SEA

In 1702, territorial waters were defined as a three nautical mile belt around the states coastline. The range of cannons defined this limit, as states could protect their claimed territory (Vieira, 2003). Many maritime nations claimed that the three-mile belt was insufficient due to concerns of pollution, exhaustion of fish livestock and protection of other seabed resources. The first international challenge of “freedom of the seas” was presented in 1945 by the US, claiming jurisdiction over their continental shelf to protect their natural resources. Many nations made territorial claims following this, creating international tension between many neighboring countries (United Nations, 2012).

As a result of the rising tensions, UNCLOS was created in 1958 as a convention to clearly define states territorial boundaries. UNCLOS lead to four conventions concerning issues of territorial disputes: *Territorial Sea and the Contiguous Zone, the High Seas, Fishing and Conservation of the Living Resources of the High Seas*, and finally *the Continental Shelf*. However, this version of UNCLOS was not able to handle the swift technological advances in resource collection of the 20th century or the political tensions between Eastern and Western Superpowers. A re-negotiation of UNCLOS was done in 1960, which failed to achieve majority support (United Nations, 2012).

In 1967, Malta’s Ambassador to the United Nations again raised concerns of the tensions of super-powers rivalry, pollution and the instability created by seabed disputes. He called for "*an effective international regime over the seabed and the ocean floor beyond a clearly defined national jurisdiction. (…) It is the only alternative by which we can hope to avoid the escalating tension that will be inevitable if the present situation is allowed to continue*" (United Nations, 1967).

The issue of seabed regulation resulted in a re-negotiation of UNCLOS, creating a stable international process and a dispute settlement mechanism. The third UNCLOS convention was adopted in 1982 after nine years of negotiation, revision and consolidation of earlier conventions. Described by the then UN Secretary General as possibly the most significant legal instrument of the century, UNCLOS III came into force in 1994. The convention became the first real basis for creating stable governance of the sea, containing characteristics of maritime operations and definition of states boundaries (United Nations, 2012).

LOS is at this moment the only accepted international convention to define sovereign rights of coastal states, defined by Part II of LOS. It defines different zones off the coast, each with different rights for national states over the waters. Article 3 in the Convention defines the territorial sea to 12 nautical miles from the baseline of the countries coastline, which gives the state full utilization of all resources and the right to regulate any matters deemed necessary. Article 33 on contiguous zones, allows states to extend customs, fiscal, immigration or sanitary regulation to a reach of 24 nautical miles (UNCLOS, part II).

Due to major gas and oil reserves, the legal debate in the Arctic is concerned with the right to extract resources further than the 24 nm offshore. LOS convention provides provisions of to define the Exclusive Economic Zone. These zones allow costal states to claim the sovereign right to explore and exploit natural resources. The Exclusive Economic Zone can range up to 200 nautical miles from the baseline (UNCLOS, Article 57).

Coastal states around the Arctic can claim an extended sovereignty of the underwater continental shelfs that are seen as a natural prolongation of their territory. The claim beyond 200 nautical miles from the baseline is possible if the shelf can be defined as a natural prolongation of the land territory (UNCLOS, part VI).

9.1.1 Arctic Territorial Disputes

The Danish territorial claims are a potent topic in the arctic due to the wide scope of the claim. Denmark has claimed the territory around the Lomonosov ridge, as it is determined to be a natural prolongation of Greenland. The claim overlaps with large parts of the Russian claim, as Russia also considers the Lomonosov ridge as a prolongation originating from the Russian coast. The Danish claim also challenges some parts of the Canadian claim. Major overlaps are primarily observed between these three countries, leading to a lengthy process to assess sovereign rights (Durham University, 2015).

In 2008, the five Artic coastal states signed the Ilulissat Declaration of Arctic Commitment, agreeing to use the existing multilateral bodies in the Arctic. The declaration established that the states would follow the legal framework of UNCLOS to settle overlapping territorial claims (Ilulissat Declaration, 2008). The *Commission on the Limits of the Continental Shelf* (CLCS) will provide their recommendation on claims in the Arctic, as mandated in section 5 of UNCLOS. The verdict is to be used as foundation for future bilateral negotiations between the coastal states (Nyeng, 2015).

Jørgen Staun from the Danish Defense Academy asserts that Arctic states will continue to have a cooperative approach to the maritime disputes, due to overall long-term interest in the geopolitical arena. The Russian motivation for Arctic development is the economic fortune of resources in the Arctic, which they cannot extract without Western know-how. Staun points out that especially Foreign Minister Sergej Lavrov has been important for Russian Arctic policy, being a proponent of multilateralism and a supporter of the Arctic Council. This allows for a peaceful rhetoric to achieve results in the Arctic (Nyeng, 2015). The revenue related to Arctic activities have a large financial potential for all Arctic states, as territorial boundaries will determine countries rights for extraction of resources. For firms, the territorial dispute thus defines the legal framework the corporations act within.

9.2 GLOBAL VESSEL MANDATE: THE INTERNATIONAL MARITIME ORGANIZATION

The LOS convention defines borders of states in the sea, and in the creation of this it was acknowledged that sea borders should have a minimal discriminatory effect on ships. This is important due to strategic waterways, where some states alter the right of innocent passage. To provide uniform standards for shipping, the International Maritime Organization (IMO) is the only global institution with a mandate to create minimum standards for sea operations. With the declining ice coverage, new water ways are being opened up to allow vessels to transit the risky Arctic waters. The IMO is therefore an important institution in establishing how vessels should operate in these waters, using its ability of knowledge-building and norm-development around shipping (Stokke, 2013).

IMO was founded as the competent UN agency in 1948. Article 1 of the IMO gives the organization legitimacy to provide cooperation among governments, regarding the regulation and technical matters affecting international maritime activities. This covers safety issues, navigation, and the prevention of maritime pollution from vessels. On top of this, the organization is also a framework for legal and administrative matters relating to this (IMO, 2015). The three important global conventions being: The International Convention for the Safety of Life at Sea (SOLAS), the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW) and the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 2015).

Building on their global expertise and mandate, the IMO has developed the Polar code, codifying aspects of polar vessel operations to reduce crew and environmental risk. It provides specific requirements to vessels, such as design, construction, equipment, operations and crew training. The polar code has been amended into SOLAS in November 2014, and environmental amendments to MARPOL were adopted in May 2015 (IMO, 2015).

Equipment requirements include protective clothing for all persons on board, ice removal kits, and a list of devices adapted for the harsh climate. This spills over into the design and construction, classifying ships into three categories of ice class: medium fist-year ice, thin first-year ice and open-water conditions less severe. This sets requirements to the materials used, as they must be suitable for Arctic operations, and the overall design to efficiently navigate through ice. Lastly, the operations and manning section sets requirements in the navigational information ships must obtain and what crew training is required for operations. The date of entry for the Polar Code is expected to be 1 January 2017, where ships constructed before date of entry will be forced to comply at first investigation after 1 January 2018 (IMO, 2015).

The implication of the Polar Code for Arctic vessels is a wave of retrofitting and upgrading, necessary to comply with the new requirements. The cruise industry will be impacted by these rules, due to the extension of the clothing requirements for all persons on board. Ice class strengthening retrofitting will also rise, as there is now one regional code for all operators to follow. Indirectly it will therefore impact resource extraction operations, potentially increasing operational costs (IMO, 2015).

The current conditions for Arctic operations vary slightly with the Canadian and Russian icebreaker classifications. Article 234 in UNCLOS allows states to adopt non-discriminatory laws and regulation for vessel navigation in ice-covered areas. Thus, the question arises for Arctic shipping: Should the new waterways be considered to be under costal sovereignty (suggested by Canada and Russia) or as international navigation waterways? The Polar code provides a minimum standard, and the question remains how it will be implemented.

9.3 REGIONAL FORUM: ARCTIC COUNCIL

The first article in the founding declaration of the Arctic Council defines the role as supporting sustainable development of the Arctic by focusing on environmental impact, economic development and social well-being of native inhabitants (Artic Council , 1996). Established in 1996, the Arctic Council was the first multilateral forum for Arctic states established by Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States of America.

The Arctic Council was founded as a knowledge-building institution for publishing results and recommendations related to the multiple challenges of the region. A more elaborate commitment to the Arctic Council could not be agreed upon due to the differences observed between states in the area of military security. As Stokke observes, the Arctic Council was founded to rebuild trust between Cold-war enemies in the High Arctic. As a knowledge-building institution, the results produced are purely scientific, which provides the institution with a high degree of legitimacy and credibility. Over time the Arctic Council has become the dominant forum for Arctic recommendations (Stokke, 2013).

The primary stakeholders in the Arctic Council are Arctic countries, followed by the permanent participants and observers. States and participants are active stakeholders providing in the council, providing inputs when topics are within their domain. A series of specialized working groups support the process of the council, producing inputs between the state-level meetings.

The Arctic states have a permanent membership and every two years the chairmanship rotates between the seven states. The responsibility of the chairmanship is hosting high-level meetings between Senior Arctic officials, and determining the goal for their respective chairmanship. This allows the different Arctic countries to direct the

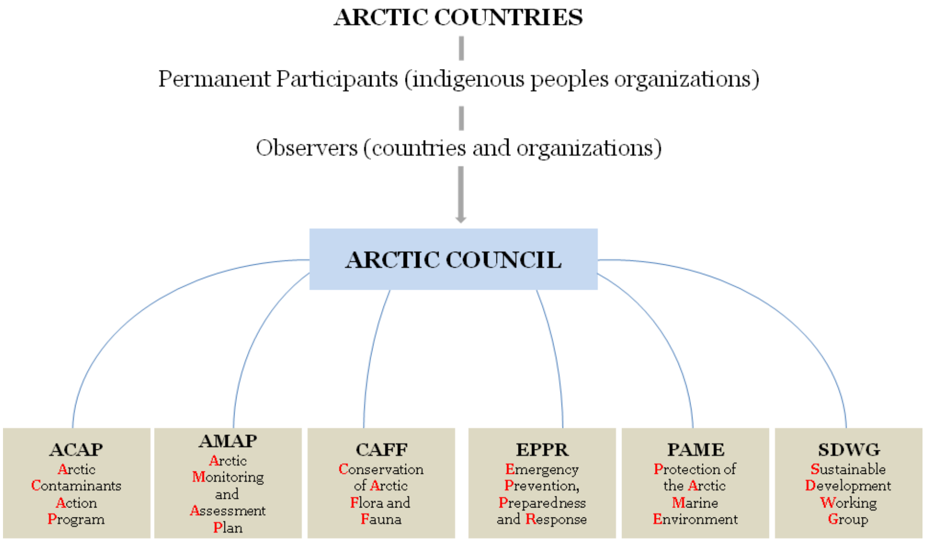

Figure 9.1: Structure of the Arctic Council
(Arctic Council , 2015)

focus of the Arctic Council over time, like the current US chairmanship being very explicit on reducing the impact of black carbon particles (Rosen, 2015). To include all stakeholders, the Arctic indigenous groups have a privileged position as a permanent participant, allowing for consultation with these representatives in matters that are relevant (Artic Council , 1996).

Article Three in the declaration provides the right for external parties to contribute to the Arctic Councils work, given their expertise and knowledge relevant for the council's work. This includes non-Arctic states, inter-governmental or non-governmental organizations (Artic Council , 1996). Currently the twelve non-Arctic states with observer status are diverse, but can be classified into an Asian and European cluster. Intergovernmental organizations include: United Nation programs, environmental focus commissions, and other ministerial institutions. Notably the European Union is applying to obtain observer status, however they have not been approved by all permanent members yet. The last grouping of NGO observers consists of three segments: scientific, environmental and social focus areas (Arctic council, 2011).

9.3.1 Structure and Agreements of the Arctic Council

The Arctic states meet in regular intervals to provide inputs to the topics worked with, allocating responsibilities to six working groups. The permanent participants and observers are also presented in this process, allowed to monitor the process. Each of the working groups has a specific operational mandate, each with their own chairman and management board. They include a multitude of stakeholders, but primarily representatives from relevant government agencies of Arctic Council member states and permanent participants. If deemed an asset observer, states and organizations are also allowed to attend, and working groups might invite external experts. The mandates of the respective working groups can be found in the ministerial declaration, a product of the ministerial meetings. The six working groups are: Arctic Contaminants Action Program (ACAP), Arctic Monitoring and Assessment Program (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Emergency Prevention, Preparedness and Response (EPPR), Protection of the Arctic Marine Environment (PAME) and Sustainable Development Working Group (SDWG) (Arctic Council , 2015).

The Arctic Council working groups have produced several papers and recommendations since its establishment, like the AMSA shipping report. Currently, the Arctic Council's working groups have developed two binding treaties, ratified by the Arctic states. The first agreement was the Aeronautical and Maritime Search and Rescue agreement, which clearly defines SAR responsibilities for the Arctic states. This provides more stability for stakeholder operations within the Arctic, as these responsibilities have been allocated to the different states. It was created in 2009, by a task force under "Emergency Prevention, Preparedness and Response" (EPPR), as a result of the ministerial meeting declaration in Tromsø (Farré, et al., 2014).

The second agreement was signed in 2011, dealing with Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic. Like the SAR agreement, this agreement mandates areas for Arctic states related to solving potential oil pollution incidents. It clearly mandates monitoring of waters, notification of oil spills and the financial implications of oil spill cleanups. Due to the very delicate environment of the Arctic, this convention is crucial for the future protection of Arctic wildlife (Arctic Council, 2015).

9.4 FUTURE ARTIC COOPERATION

Multiple considerations have to be made when evaluating how Arctic states will cooperate in the future. In 2007, PAME was tasked with identifying future uncertainties in the Arctic future operations. Using scenario planning, they produced a report covering *Scenarios on the Future of Arctic Marine Navigation in 2050*. Inherent to scenario planning, a multitude of stakeholders were included to create the report, to capture the complexity of the Arctic environment (PAME, 2007).

The projected resulted in four narratives of the future, around a binary combination of the two uncertainties. These uncertainties are hard to predict and have a high impact on the future for Arctic operations. These uncertainties are then combined with what the literature defines as predetermineds, i.e. elements that are

Figure 9.2: Arctic Marine Shipping Assessment
(Arctic Council, 2009)

predictable, common to all narratives, and with a high impact on the future. Scenario planning is useful due to the articulation of four plausible scenarios, brainstorming and defining aspects that might not be obvious to the participants in the start (Hitt, et al., 1998).

The first uncertainty defined was governance stability in the Arctic (PAME, 2007). This aspect covers the aspect of how governance is created in the Arctic, either as an unstable or stable structure. For the unstable rules, all Arctic countries will provide limited coherence between their respective national legislations. In a future scenario of stable rule-based governance, countries will cooperate in development of rules, creating a level playing field for stakeholders in the north. The other uncertainty chosen was Resources and Trade, a representation for the demand for Arctic resources in the global market place (PAME, 2007). Linked to the resource extraction industry, the focus is on how the developing trends in the world economy, focusing on the demand for oil and other rare earth minerals. If there is a high demand then firms will start a “race-to-the-bottom”, given the governance framework created by the Arctic Countries.

The report concludes that multilateral stable rules-based governance is important for best Arctic preservation and utilization. Governing trans-nationally allows for the best preservation of the ecosystem as the legitimacy of the boundaries are established by a wider group of stakeholders. Likewise by using multilateral governance, countries are able to provide stable unified operating terms for private companies in the Arctic. This allows for higher mobility of assets and equal standards. The first move towards this can be seen in the adaptation of the Polar Code by Arctic countries. Having homogenous benchmarks preserves the environment, which is independent of the demand for Arctic resources (PAME, 2007).

9.5 SUM-UP FOR STAKEHOLDERS

This mapping of political actors should provide readers an understanding of the global and regional governance structures active in the Arctic. UNCLOS influences states by allocating maritime rights and defining territorial boundaries within the Arctic. The IMO has a legitimate mandate to regulate vessel operations, allowing them to create the Polar code. Exceptions to this best practice might still be present due to Article 234 in UNCLOS. However, Arctic operators can hope for a better harmonization of standards as a result of the Polar Code. The Arctic Council has a regional focus and knowledge building approach, providing recommendation for its members in seeking to secure corporative governance between states. The AMSA scenario planning analysis exposes the multiple potential futures, where stable governance in the region is optimal for all parties involved. The biggest issues challenging stability are the territorial disputes and how resources should be extracted safely in the very sensitive environment of the Arctic frontier.

For the different business stakeholders, the future framework will define the rules they operate within. Given the current development of operational standards, business should get involved in the process of developing standards that are feasible and protective of the environment. Stability and commitment to the governance regimes by industry and states will allow a uniform framework for stakeholders to operate under and for the Arctic to flourish. This section does not seek to provide answers on how to operationalize in the Arctic, but for stakeholders to understand that political structures will affect them in the long run. Our mapping of stakeholders does not seek to understand the interplay between the Arctic governance structures, and future research should therefore target this.

10 APPENDIX A: RESULTS FROM LINER SHIPPING CASE STUDY

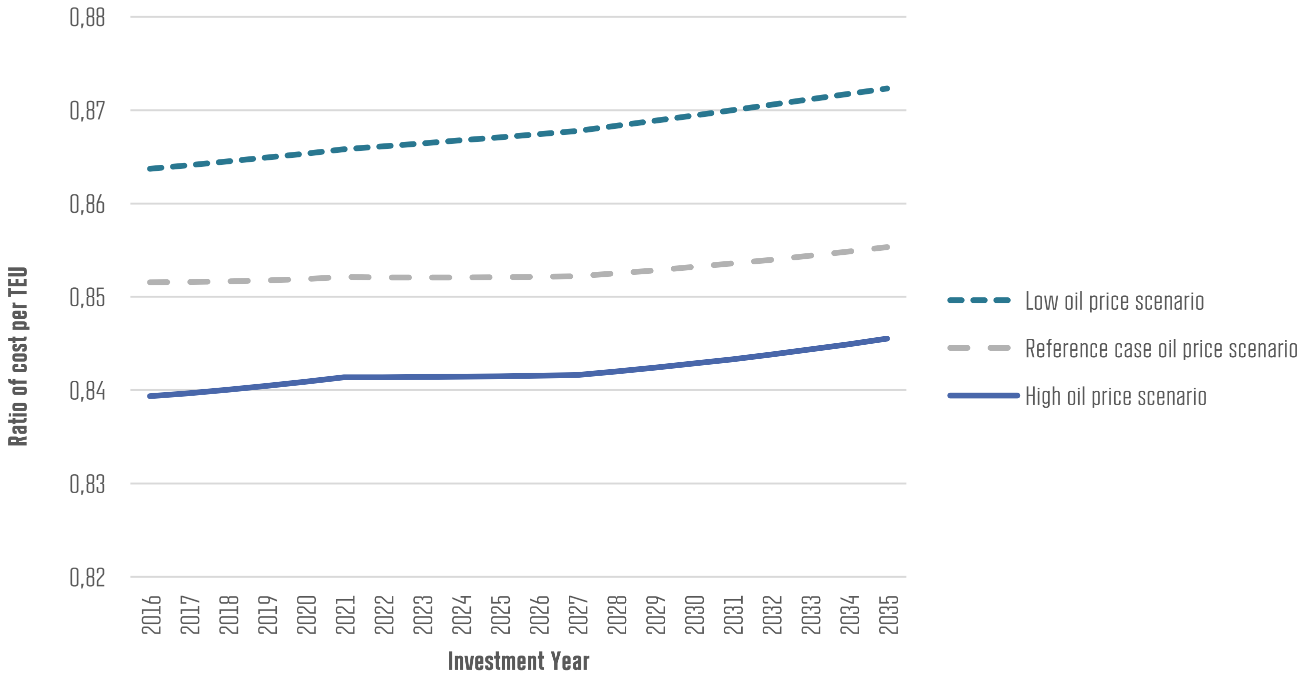

Figure 10.1: Cost per TEU ratio for the 10000 TEU vessel in the low warming scenario
The total cost per TEU ratio of the investment of a 10000 TEU open water vessel to an 8000 TEU ice strengthened vessel, as a function of the investment year. The ratio is calculated in the low Arctic warming scenario with a discount factor of 7 percent. A ratio above one indicates that the investment in the ice reinforced vessel is favorable.
Source: Own Calculations

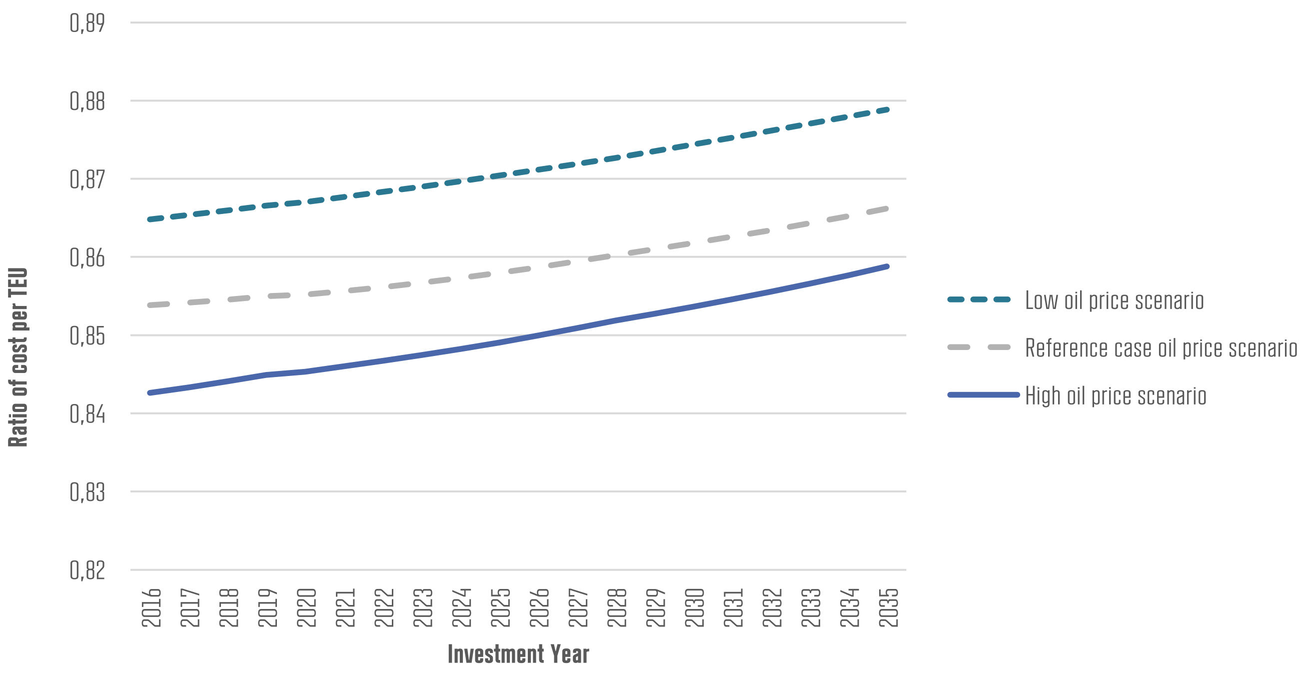

Figure 10.2: Cost per TEU ratio for the 10000 TEU vessel ratio in the high warming scenario
The total cost per TEU ratio of the investment of a 10000 TEU open water vessel to an 8000 TEU ice strengthened vessel, as a function of the investment year. The ratio is calculated in the high Arctic warming scenario with a discount factor of 7 percent. A ratio above one indicates that the investment in the ice reinforced vessel is favorable.
Source: Own Calculations

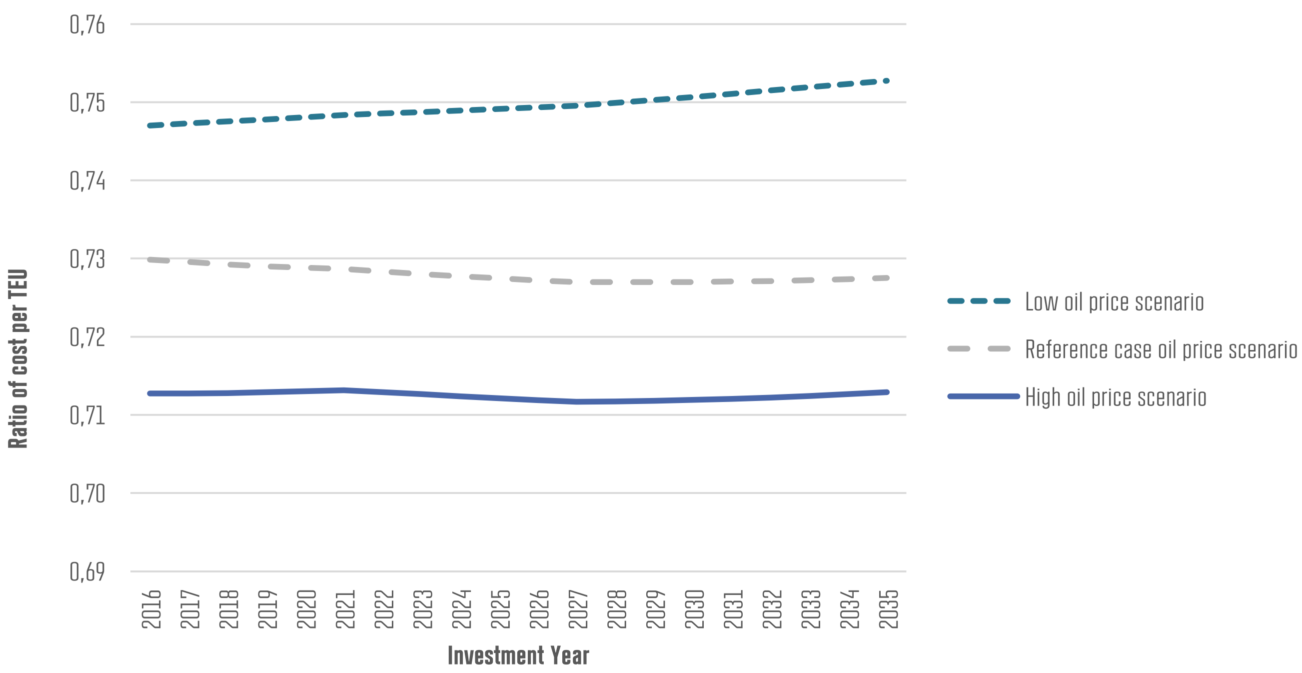

Figure 10.3: Cost per TEU ratio for the 15000 TEU vessel in the low warming scenario
The total cost per TEU ratio of the investment of a 10000 TEU open water vessel to an 8000 TEU ice strengthened vessel, as a function of the investment year. The ratio is calculated in the low Arctic warming scenario with a discount factor of 7 percent. A ratio above one indicates that the investment in the ice reinforced vessel is favorable.
Source: Own Calculations

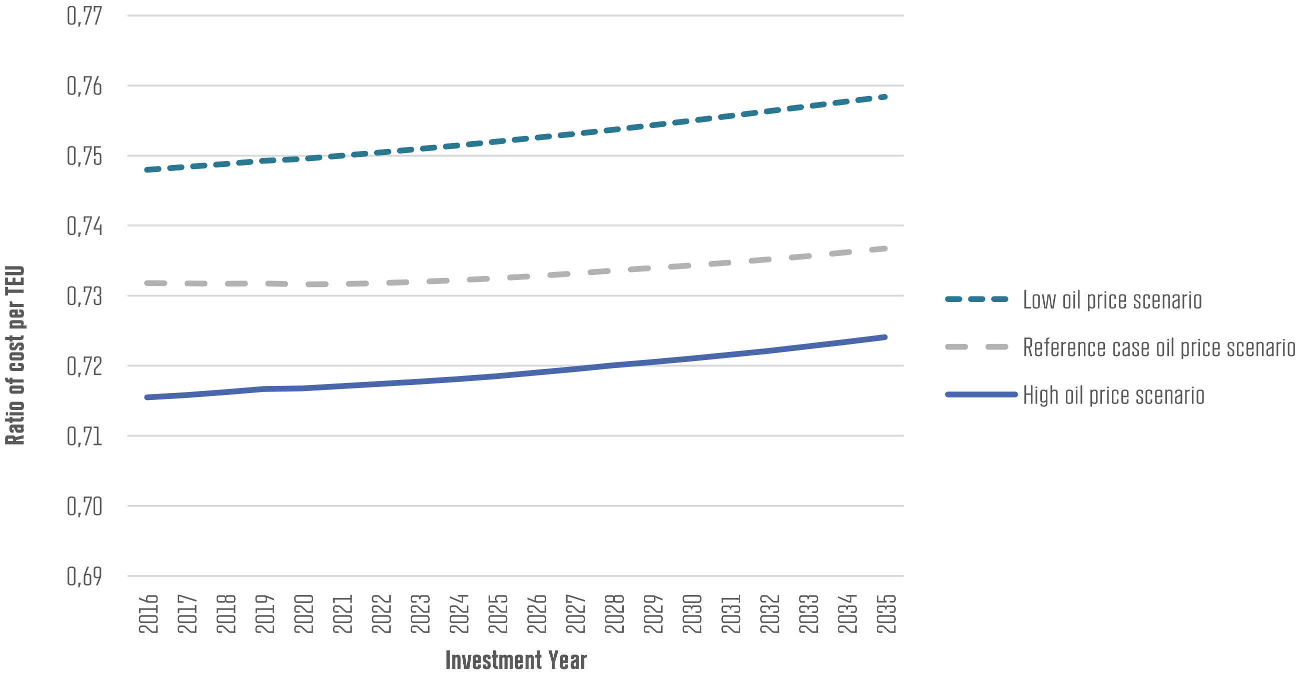

Figure 10.4: Cost per TEU ratio for the 15000 TEU vessel in the high warming scenario
The total cost per TEU ratio of the investment of a 15000 TEU open water vessel to an 8000 TEU ice strengthened vessel, as a function of the investment year. The ratio is calculated in the high Arctic warming scenario with a discount factor of 7 percent. A ratio above one indicates that the investment in the ice reinforced vessel is favorable.
Source: Own Calculations

11 APPENDIX B: GUIDE TO ONLINE CALCULATION TOOL

The calculations presented in the liner shipping case study of chapter 4, are based on a calculation tool specifically designed to support the conclusions of the case study. This calculation tool allows researchers and industry professionals to insert the specifications of a given vessel, along with environmental and economic parameters in order to obtain information on the feasibility of transporting containerized cargo along the NSR. Specifically, the model allows the user to determine the year when the investment in an ice reinforced containership operating along the NSR during the navigation (and the SCR at other times), will become favorable compared to an ordinary container ship solely operating on the SCR. This is done by calculating the total and annual costs per TEU of each vessel. These values are compared resulting in a ratio, which allows for the estimation of the critical point at which the costs per TEU of the ice reinforced vessel becomes advantageous compared to the open water vessel that solely operates on the SCR. Based on this, the creation of detailed scenarios can help to understand how different factors influence the feasibility of transport using the NSR. Integrated into the calculation tool is the ship calculation tool made by Hans Otto Kristensen which allows for the determination of vessel fuel consumption given user determined values of speed, vessel engine size, engine type, capacity utilization and hull specifications. This gives the calculation tool a high degree of prediction power while still maintaining significant customization options. The calculation tool is available for download free of charge on the CBS Maritime homepage (http://www.cbs.dk/viden-samfundet/business-in-society/cbs-maritime/downloads).

The following is a guide on how to successfully utilize the program. It includes a detailed explanation of the results, layout and cells in which data can be entered. The user interface is divided into three sheets with the first being the front page, the second page containing the major input as well as illustrating the results, and the third allowing for the alterations of specific cost and time variables.

11.1 FRONT PAGE

The front page serves as a brief introduction to the calculation tool and lists the economic and environmental assumptions creating the framework of the calculations behind the model, along with a short description of the incorporated fuel price projections.

The user initiates the calculation by clicking on the picture located in the left side columns.

The program will automatically redirect the user to the input and result section after clicking on the picture.

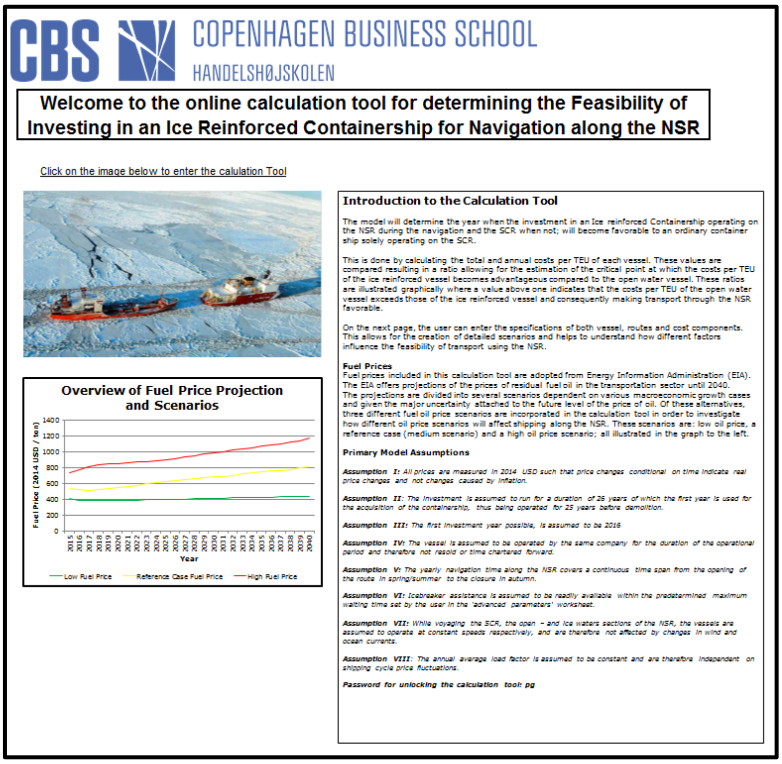

Figure 11.1: Calculation tool front page

11.2 RESULTS PAGE

The "*Results*" page allows the user to insert the primary variables and presents the results of the calculations. The left side column labelled "*Input*" contains the input cells where the user can specify the primary inputs of the vessels and routes, as well as financial valuations.

The results in the middle columns are divided into two sections. The top section of the middle columns are the "*Total cost per TEU*", listing the first year where the investment in the ice reinforced containership will become advantageous to that of an ordinary open water vessel, measured in total costs per TEU. The lower section labelled "*Annual costs per TEU*" lists the first year where the annual operation costs per TEU of the ordinary containership exceeds those of the ice reinforced vessel. The third section labelled "*Illustration*" on the right side columns graphically depicts the results achieved from the middle section by listing both the ratios of the total and annual costs per TEU depending on the year, of the two containerships examined.

Finally, this page features two buttons; the orange button takes the user back to the Front-page, allowing for the selection of a ship in another segment. The green button titled "*Advanced Parameters*" redirects the user to the advanced settings page where the user can change the values of different cost components for each of the vessels examined.

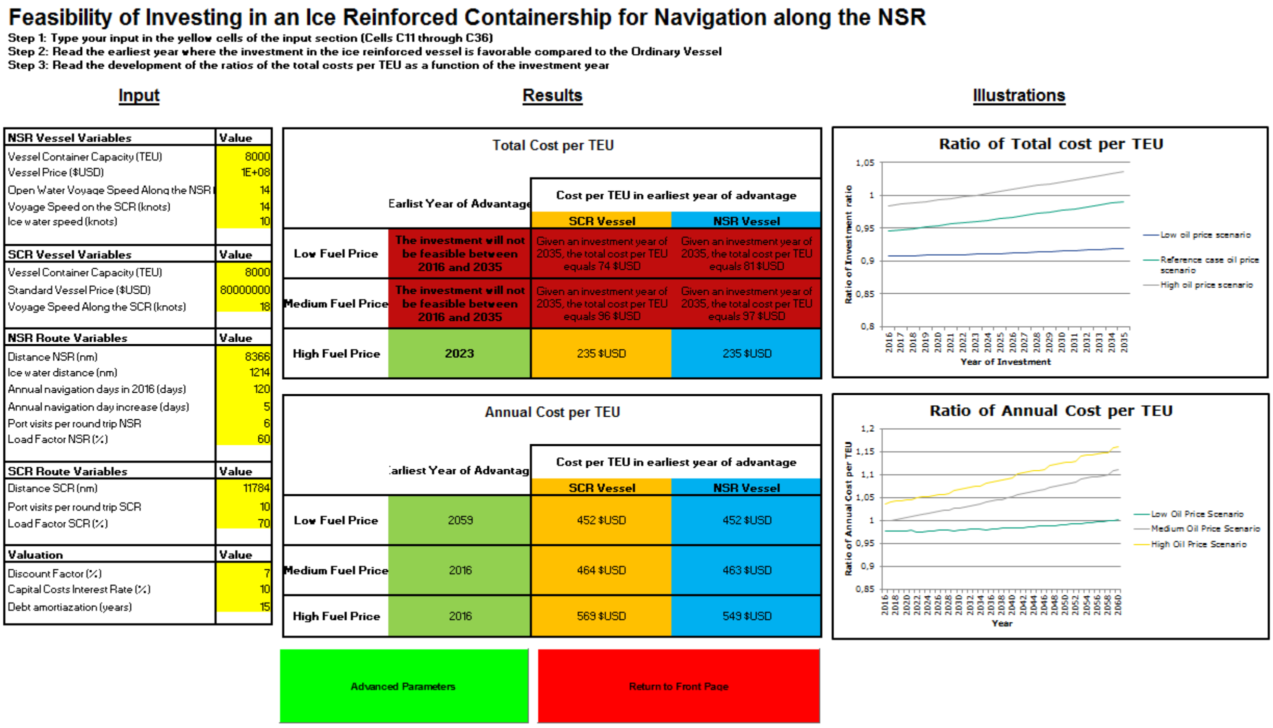

Figure 11.2: Calculation tool results page

11.2.1 Input section

The input section lists the values of the most vital primary and secondary variables required to calculate the optimal fuel strategies. The cells in which the user is encouraged to enter specific values are marked by the colour yellow.

The input cells require the following input:

NSR vessel variables:

- **C10:** Enter the maximum TEU capacity of the ice reinforced vessel, measured in number of TEU.
- **C11:** Enter the new building price of the ice reinforced vessel, measured in $USD.
- **C12:** Enter the average sailing speed in the open water sections of the NSR measured in knots.
- **C13:** Enter the average sailing speed of the ice reinforced vessel when voyaging the SCR, measured in knots.
- **C14:** Enter the average sailing speed in the ice water section of the NSR, measured in knots.

SCR vessel variables:

- **C17:** Enter the maximum TEU capacity of the ordinary (i.e. non-ice reinforced) vessel, measured in TEU.
- **C18:** Enter the new building price of the ordinary vessel, measured in $USD.
- **C19:** Enter the average sailing speed of the ordinary vessel, measured in knots.

NSR Route Variables:

- **C22:** Enter the average distance of the NSR, measured in nautical miles per voyage.
- **C23:** Enter the average distance of ice covered waters[16] along the NSR, measured in nautical miles per voyage.
- **C24**: Enter the amount of navigation days along the NSR in year 2016, measured in days.
- **C25:** Enter the annual increase in navigation days along the NSR after year 2016, measured in days (example: entering the value “3” will result in an annual increase in navigation days of 3).
- **C26:** Enter the amount of port visits of a round trip when navigating the NSR.
- **C27:** Enter the average capacity utilization of the ice reinforced vessel when navigating the NSR, indicated by a number from 0 to 100, where 100 indicates full utilization.

SCR Route variables:

- **C30:** Enter the average distance of the SCR, measured in nautical miles per voyage.
- **C31:** Enter the amount of port visits of a round trip when navigating the SCR regardless of the vessel type.
- **C32:** Enter the average capacity utilization when navigating the SCR regardless of the vessel type (see C27).

Valuation:

- **C35:** Enter the annual discount factor used for the calculations of the total cost per TEU as a function of investment year, measured in percentages (example: for 8 percent insert the value “8”).
- **C36:** Enter the annual interest rate used for determining the annual debt payments of the investment in each of the two vessels, measured in percentages (example: for 10 percent insert the value “10”).
- **C37:** Enter the number of years over which the vessel investment costs are amortized, measured in years.

[16] Ice covered waters means, in this case, parts of the NSR where the vessels has reduced speed due to ice, whether it is fast ice, pack ice, or small floes.

11.2.2 Results Section: Total Cost per TEU

The upper middle section in the range E9:H22 calculates the point in time when the total costs per TEU of the investment in the ice strengthened vessel is favorable to the total costs per TEU of the investment in an open water vessel that solely navigates the SCR. The earliest year where such an investment is advantageous is presented in column F, given the three different fuel price scenarios, while the corresponding total costs per TEU for the ordinary and ice reinforced vessels are listed in columns G and H, respectively. If the investment does not become feasible prior to year 2036, the calculation tool will report so and list the total costs per TEU for each vessel given an investment year of 2035; the latest investment year possible given the timespan of this study.

A colour code is attached to each strategy in order to easily recognize how different input variables may change the strategy rankings. The colour codes are as follows:

- Investment is favourable before 2036 (green).
- Investment will not be favourable prior to 2036 (red).
- Total investment costs per TEU for the open water vessel (orange).
- Total investment costs per TEU for the ice reinforced vessel (blue).

11.2.3 Results Section: Annual Cost per TEU

The lower middle section in the range E25:H39 calculates when the annual costs per TEU of the ice strengthened vessel will become favorable to those of the open water vessel that solely navigates the SCR. The earliest year where the annual costs per TEU if the ordinary vessel exceeds those of the ice reinforced vessel is presented in column F, given the three different fuel price scenarios, while the corresponding annual costs per TEU for the two vessels are presented in the columns G and H, respectively. If the annual costs per TEU of the ice reinforced vessel will not be lower than those of the ordinary vessel prior to year 2060, the calculation tool will report so and list the total costs per TEU for each vessel in the year of 2060; the latest operational year given the timespan of this study.

A colour code is attached to each of the cells in the middle columns, in order to easily recognize how different input variables may change the feasibility of operating the ice reinforced vessel. These colour codes are as follows:

- Annual cost per TEU is favourable before 2060 (green).
- Annual cost per TEU will not be favourable before 2060 (red).
- Annual cost per TEU for the open water vessel (orange).
- Annual costs per TEU for the ice reinforced vessel (blue).

11.2.4 Graphical Illustrations

The results presented in the middle section are derived from the two graphs on the right side columns which illustrates the total and annual costs per TEU of the ice reinforced vessel relative to the open water vessel. More specifically, the upper and lower graphs illustrate the ratios of the cost per TEU comparisons (vertical axis) as a function of vessel investment year and annual operational costs, respectively (horizontal axis), given the three different oil price scenarios incorporated into the analysis. These ratios are calculated by dividing the costs per TEU of the ordinary open water vessel with the costs per TEU of the ice reinforced vessel. A ratio above one therefore indicates that the costs per TEU of the ice reinforced vessel are lower than those of the ordinary vessel and vice versa. Consequently, the point where the value of the curves exceeds values of one determines the first year where the investment or operation of the ice reinforced vessel results in a lower cost per TEU.

11.3 ADVANCED SETTINGS

The "*Advanced Settings*" page allows for the customization of the values of different fixed and variable cost components of the two vessels examined. Additionally, the advanced settings allow for the alteration of values determining the average wait time when transiting the Suez Canal and the NSR. The input cells are all marked with yellow and located in the left side column which is divided into three subsections labelled "*Speed Variables*", "*Ordinary Vessel Costs*" and "*Ice reinforced Vessel Costs*".

Finally, this page features two buttons; the green button labelled "*Return to results*" takes the user back to the results page and will include the user defined alterations to the variables. The orange button labelled "*Reset to Defaults*" resets all the variables on the sheet to their default values and formulas (this may be useful if the results show inconsistent results).
Several of the input cells include standard formulas for the calculation of the cost components that automatically approximate realistic values based on the vessel sizes. The user is encouraged to overwrite these formulas by entering predetermined values of the different cost components.

11.3.1 Speed Variables:

This section contains variables influencing the transit speed of the two routes examined by allowing the user to approximate the average waiting times encountered by the vessels when transiting the Suez Canal and the ice covered waters of the NSR. The changeable input cells require the following input:

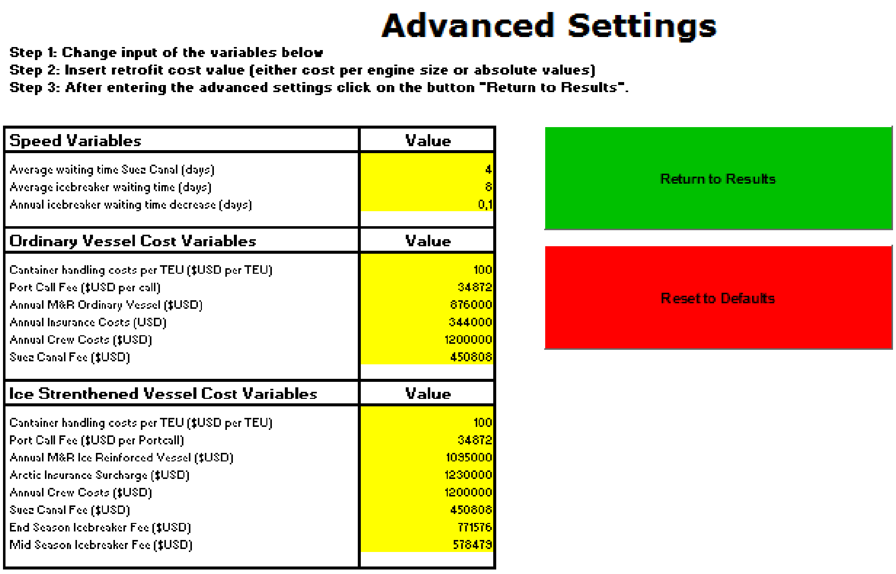

Figure 11.3: Calculation tool advanced settings page

- **C9:** Enter the average waiting time encountered when transiting the Suez Canal, measured in days.
- **C10:** Enter the average waiting time encountered when waiting for icebreaker assistance on the ice-covered part of the NSR, measured in days.
- **C11:** Enter the annual decrease in the average waiting time encountered when waiting for icebreaker assistance on the ice-covered part of the NSR, measured in days.

11.3.2 Ordinary Vessel Cost Components:

This section contains the default values of the variable and fixed cost components of the ordinary open water vessel, allowing the user to change these into predetermined cost estimations. The changeable input cells require the following input:

- **C14:** The total cost of handling one TEU (loading and discharging), measured in $USD.
- **C15:** Enter the costs incurred when calling at a port (berthing and towage), measured in USD per port call.
- **C16:** Enter the annual maintenance and repair costs, measured in USD.
- **C17:** Enter the annual insurance costs, measured in USD.
- **C18:** Enter the annual crew costs, measured in USD.
- **C19:** Enter the Suez Canal toll of the ordinary vessel, measured in USD.

11.3.3 Ice Reinforced Vessel Cost Components:

This section contains the default values of the variable and fixed cost components of the ice reinforced vessel, allowing the user to change these into predetermined cost estimations. The changeable input cells require the following input:

- **C22:** Enter the cost of handling one TEU (loading and discharging), measured in USD.
- **C23:** Enter the costs incurred when calling at a port (berthing and towage), measured in USD per port call.
- **C24:** Enter the annual maintenance and repair costs of the ice reinforced vessel, measured in USD.
- **C25:** Enter the annual insurance costs for the ice reinforced vessel, measured in USD.
- **C26:** Enter the annual crew costs of the ice reinforced vessel, measured in USD.
- **C27:** Enter the Suez Canal toll of the ice reinforced vessel, measured in USD.
- **C28:** Enter the icebreaker assistance fee during the first and last NSR transit, where additional icebreaker service is needed, measured in USD.
- **C29:** Enter the icebreaker assistance fee during normal transits, where the vessel only required two zones of icebreaker escort, measured in USD per gross tonnage.

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CBS MARITIME

KILEVEJ 14A, 3RD FLOOR, 2000 FREDERIKSBERG, DENMARK
CBSMARITIME@CBS.DK · MAIN: +45 3815 3815
WWW.CBS.DK/MARITIME

CBS COPENHAGEN BUSINESS SCHOOL
HANDELSHØJSKOLEN