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Master Thesis:

## **The Commercial Viability of the Arctic Shipping Routes**

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The school takes no responsibility for the methods used, results found and conclusions drawn.*

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## Abstract

*(Keyword: Global warming, sea ice, Arctic Shipping routes, Cost comparison, Time Comparison, Commercial viability.)*

It is commonly held that the Arctic Ocean and Arctic routes, presents an alternative to the traditional shipping routes through the Suez- and Panama- Channel, which is less time and cost consuming. This thesis strives to uncover whether or not this is the case by assessing the environmental developments, the distance and time characteristics of each defined route, as well as the individual costs associated with each route. The results from the alternative Arctic routes are then compared with the traditional routes. The results show that, though the distance between most of the ports of departure and arrival are in most cases shorter or considerably shorter, in extent presenting a decrease in the voyage time. Current sea ice conditions on the other hand only allow for the commercial shipping operations along the Northern Sea Route (NSR). The cost comparison proves that the NSR only become profitable with the implementation of the know industry practise of slow speed. The result is important as it has the prospective possibility to alter the commercial shipping traffic around the world, connecting major parts of the world with a less costly and faster way of trade.

### *In Portuguese*

*(Palavra-chave: Aquecimento global, gelo marinho, rotas de navegação do Ártico, comparação de custos, comparação de tempos, viabilidade comercial)*

*É geralmente aceite que o Oceano Ártico e as rotas do Ártico, constituem uma alternativa às rotas de navegação tradicionais, através dos canais do Suez e do Panamá, por serem menos dispendiosas em termos de tempo e custos. Esta tese procura aferir da veracidade dessa suposição através da avaliação dos progressos ambientais, da distância e do tempo de cada uma das rotas definidas, assim como dos custos individuais associados com cada rota.*

*Os resultados das rotas alternativas do Ártico são depois comparados com os custos das rotas tradicionais mostrando que no primeiro caso a distância entre os portos de partida e chegada é na maioria dos casos inferior ou consideravelmente inferior, resultando numa diminuição no tempo de viagem. Por outro lado, as condições actuais do gelo marítimo permitem apenas as operações ao longo da rota do Mar do Norte (NSR).*

*A comparação de custos mostra que a NSR apenas se tornará lucrativa com a implementação da conhecida prática de navegação em slow speed. Os resultados são importantes uma vez que ilustram o potencial que estas rotas tem de alterar o tráfego comercial marítimo mundial, ligando a maior parte dos portos de forma mais barata e rápida.*

## **Acronyms**

TSR: Transpolar Sea Route

NSR: Northern Sea Route

NWP: North West Passage

NEP: North East Passage

H&M: Hull and Machinery

P&I: Protection and indemnity

DWT: Dead Weight Tonnage

SCNT: Suez Channel Net Tonnage

NRT: Net Registered Tonnage

TUE: Twenty-foot equivalent Unit

MYI: Multi Year Ice

## Table of Contents

Acknowledgment .....	ii
Abstract.....	iii
Acronyms .....	iv
Table of Tables .....	vii
Table of Figures.....	viii
Introduction .....	1
Research Question .....	2
Literature Review.....	3
The Arctic Geography.....	3
Global Warming .....	5
Sea Ice .....	5
Sea Ice projections .....	7
Shipping routes .....	8
The Historical and traditional shipping routes.....	9
The Northwest Passage.....	9
The Northern Sea Route .....	10
The Northeast Passage.....	10
The Transpolar Sea Route .....	10
Prospective Shipping Activity along the Arctic Shipping Routes .....	11
World shipping activity and projected demand .....	12
Slow speed .....	13
Arctic Restrictions and Vessel Requirement .....	14
Regional Issues.....	15
Data collection .....	16
Distance.....	16
Vessel data .....	18
Voyage time .....	21
Fuel and Lubrication costs .....	23
Insurance.....	23
Crew cost.....	24

Maintenance.....	25
Depreciation.....	26
Transit cost.....	26
Calculation .....	29
Results.....	30
Cost Analysis without additional cost and risk of an arctic transit.....	30
Cost Analysis with additional cost and risk of an arctic transit.....	32
Slow speed .....	33
Analysis and Discussion.....	37
Prospective.....	39
Research Limitations.....	41
Future research.....	41
Conclusion.....	42
Bibliography .....	44
Annex – Excel .....	48
Appendix 1 - Expected Oil & Gas Reserves .....	53
Appendix 2 – Google Earth plotting.....	54
Appendix 3 – Sea Ice Cover & Arctic September shipping Routes.....	58

## Table of Tables

Table 1.....	17
Table 2.....	20
Table 3.....	22
Table 4.....	25
Table 5.....	27
Table 6.....	28
Table 7.....	30
Table 8.....	31
Table 9.....	32
Tabel 10.....	33
Table 11.....	34
Table 12.....	34
Table 13.....	35
Table 14.....	36
Table 15.....	38

## Table of Figures

<i>Figure 1: Earth Rotation Axis</i> .....	3
<i>Figure 2: The Arctic Ocean</i> .....	4
<i>Figure 3: Sea Ice extent (a) September (b) March</i> .....	6
Figure 4: Season Max/Min ice cover: .....	6
Figure 4: Season Max/Min ice cover: .....	7
<i>Figure 5: Arctic Routes:</i> .....	8
<i>Figure 6: World Shipping Activity</i> .....	9
<i>Figure 7: GCM Simulation.</i> .....	11
<i>Figure 8: Shipping flow</i> .....	13
Showing the international shipping flow and trade values. ....	13
<i>Figure 9: Displaying the Rotterdam: Tokyo routes.</i> .....	18
<i>Figure 10: Suez Channel fee calculator</i> .....	26

## **Introduction**

Global warming has been a hot topic within international politics, press and research the last few decades, where one of the issues receiving much attention has been the Arctic and Antarctic regions, which as of a consequence of the global warming is experiencing major changes to. The surveying and data collection of the Arctic and northern areas started in 1979. Where a clear and consistent data is confirming that snow and ice during summer and winter in the northern hemisphere is disappearing with an exponential rate.

Nations and explorers have for decades been drawn towards the inhospitable regions of the north, as it was to start with though that the north could connect the continents of the earth in trade, where the first exploration set out to explore the Arctic region in 325 B.C. With technology and building techniques that came with the industrial revolution and late advances in the 1800's, the northern areas were rigorously explored until the beginning of the 1900's. The Soviet Union was the first one to commercially use the Arctic Ocean as a method of transporting goods and supplies, though only possible during the summer months.

With time, the arctic has become a more attractive area, and the prospects of opening the Arctic Ocean for commercial shipping have never been more present. The question remains is whether it is profitable in comparison to the traditional routes.

## **Research Question**

**Are the climate changes in the Arctic Ocean presenting alternative commercially viable shipping routes in comparison to the historically traditional shipping routes?**

## Literature Review

### The Arctic Geography

The Arctic is the region surrounding the North Pole, geographically regarded as the region above the Arctic Circle at 66°(degrees)33”(minuets) North, though definitions such as treeline and permafrost may also be used. Throughout this paper the Arctic will be defined as the area within the Arctic Circle.

This region is exposed to harsh climate conditions. Because of the rotational tilt and gravitational pull of the sun, the region has months at end with continues sun light exposure during the summer, as well as months with complete darkness during the winter. This only occurs above Arctic Circle or below the Antarctic Circle, therefor making the geographical definition of 66°33” an important one (National snow and ice data center), indicated in Figure 1 by the first, upper red circle.

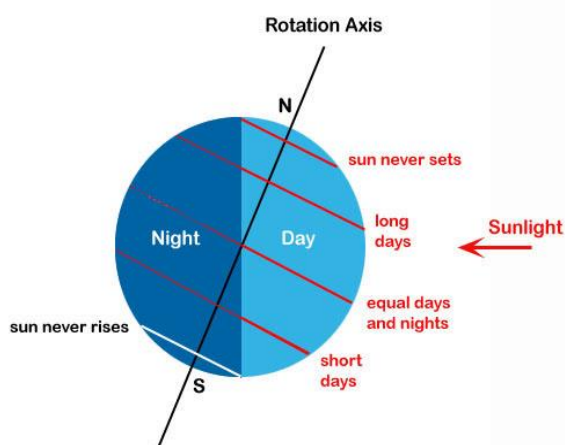


Figure 1: Earth Rotation Axis

Illustration of the vertical tilt of the earth in relation to sun exposure.  
<http://www2.astro.psu.edu/~mce/A010/lectures/lect04.html>

The Arctic is a vast geographical region, dominated by the Arctic Ocean, surrounded by continental landmasses in the outskirts. Even though the area is dominated by the Arctic Ocean, most of the ocean's surface is solidified in ice, and the extent of the ice cover varies in accordance with the season. In addition the earth's horizontal tilt and rotation leaving the region less exposed to the amount of sunlight/sunrays present along the equator (Figure 1). Because of the tilt the energy from the sun needs to pass through a larger mass of atmosphere, where it becomes relatively thicker, than along the equator. This effect of all these factors leaves the Arctic colder than most other places on Earth (Arctic Uoguelph, 2013). These lower temperatures allows for the creation snow and ice (Arctic Monitoring and Assessment Programme (AMAP), 2011).

The Arctic Ocean has four geographical points of entry via the sea. First is the entrance through the Norwegian Sea between Norway and Iceland, in close proximity to the second entrance through the

Greenland Sea between Greenland and Iceland. Third is the David Strait between Canada and Greenland, and forth is the Baring Strait between USA (Alaska) and Russia, the only entrance from the pacific into the Arctic Ocean (Figure 2).

The Arctic region is one of the few areas on earth that is not dominated by humans. Still the area is subject to major climate alterations due to human activity. Never the less, the region is off massive political interest, where the main stakeholders are USA, Canada, Russia, Sweden, Finland, Iceland, Norway and Denmark as the governing stat of Greenland (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 80). The interest is largely founded in the oil and gas reserves expected to be found in the area (Appendix 1). All these stakeholders are represented in the Arctic Council, which is an intergovernmental forum facilitating communications between the members, aligned efforts such as research, legislation and regulation of activity of the area (Arctic Council, 1996).



*Figure 2: The Arctic Ocean*  
This is a map over the Arctic region, containing regional name definitions.

(<http://portal.inter-map.com/#mapID=49&groupID=304&z=1.2&up=864687.1&left=688741.7>, 2013)

During the winter season, the lack of sunlight sets the stage for the formation of snow and ice, which occur at freezing point of 0 degree Celsius (Helmenstine) and -1.9 in salt water (noaa.gov, 2013), in combination with traditionally cold summers, the conditions have led to the development of multiyear ice (MYI).

The features of snow, ice and frozen surroundings in and around the North and South Pole have led to the development of the science field of Cryosphere. The understanding of these elements, are

crucial in the projections and preservation of the region (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 18).

Because of global warming “the extent and duration of snow (and ice) cover have decreased throughout the Arctic” (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 19). Areas that traditionally would have been frozen or covered with snow and ice are now diminishing, and the areas that once were covered have significantly decreased over the past 30 years, hitting a record in the summer of 2012. The record of 2012 is about 1/3 of the average measured between 1979 and 2000 (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 34).

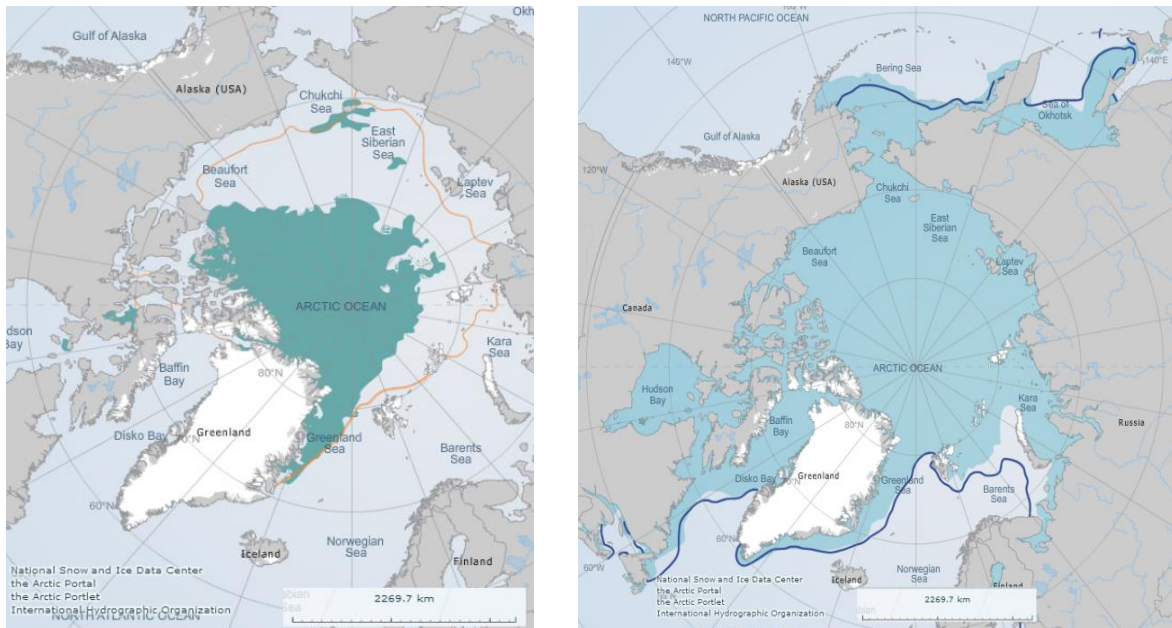
## **Global Warming**

With the Industrial revolution, the human impact on the earth and climate increased substantially, and it sparked the beginning of what would become known as climate changes and global warming (nasa.gov, 2013). The amount of carbon dioxide has increased with 38% and methane with 148% since the beginning of the industrial revolution (nasa.gov, 2013). The “average surface temperature rose 0.6 to 0.9 degrees Celsius between 1906 and 2005” (nasa.gov, 2013). The definition of global warming is widely agreed upon as “the recent and on-going global average increase in temperature near the earth’s surface” (United States Environmental Protection Agency, 2013), which in extent have led to the diminishing of ice and snow at poles (Arctic Monitoring and Assessment Programme (AMAP), 2011).

## **Sea Ice**

As the earth revolves around the sun, the tilt creates seasonal effects on the earth, resulting in a dynamic expansion and contraction of the sea ice (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 38). Large quantities of ice and snow appear white or with no colour at all, and because of this feature it absorb very little for the energy from the sun (National Snow & Ice Data Center, (c) 2013), the melting is attributed to external factors such as air, land and the sea itself (National Snow & Ice Data Center, (c) 2013). The summer temperatures in vast parts of the arctic are around the average temperature of 10 degrees Celsius, known as the isotherm (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 28).

The summer temperatures are a big factor to the diminishing of the frozen areas in the Arctic. The sea ice cover has seen dramatic changes during the last 30 years. The sea ice cover is today under continuous surveillance, where the March sets the peak and September sets the low of the sea ice cover. The results from March and September are then measured up against the data from 1979, and previous years to determine the latest developments.



*Figure 3: Sea Ice extent (a) September (b) March*

The left picture shows the sea ice extend during September 2012, compared to the average, orange line, from 1979-2000. The right picture shows the sea ice cover during March 2012, versus the average 1979-2000 blue line average <http://portal.inter-map.com/#mapID=49&groupID=304&z=1.0&up=1900409.8&left=2001105.4>

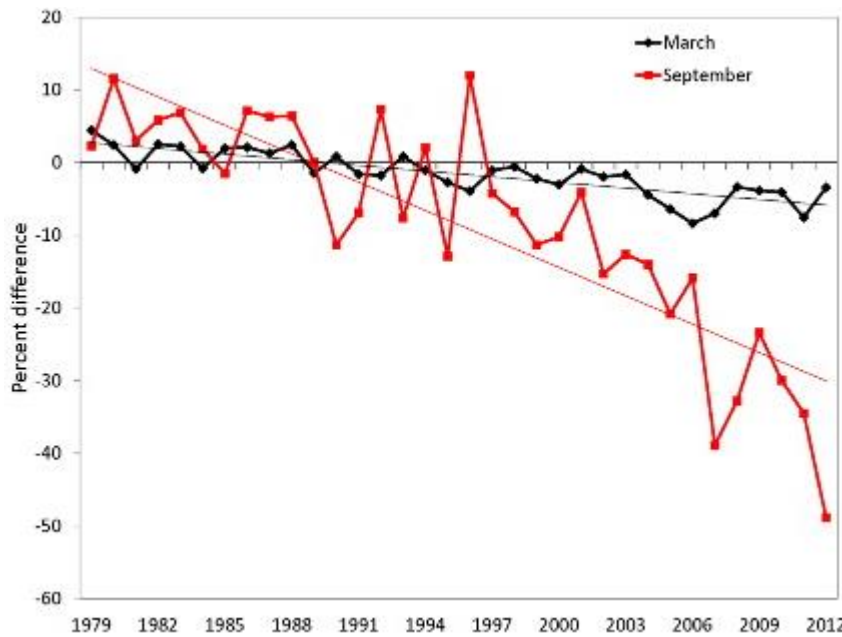
Source: [nsidc.org/data/seaice\\_index](http://nsidc.org/data/seaice_index)

From the data illustrations above, where we can observe that the sea ice cover in the arctic is diminishing. The largest changes can be observed during September. The melting of the sea ice itself accelerate the further melting of the sea ice, as cold water sinks, making space for warmer water that continues the melting process. This effect is a part of the ocean currents that is believed to have great importance in the world's environmental and ecosystem. The warmer water that replaces the melt-water from the sea ice arrives through ocean currents via currents from the Atlantic and Pacific (National Snow & Ice Data Center, (c) 2013). Though the sea ice is diminishing on an overall yearly average, the ice cover around the Baring straight and sea seems to be expanding, though this is only during the winter, Figure 3.

Data on the sea ice cover only dates back to 1979. From the data all but one trend is clear, and it is that the sea ice is diminishing both during the summer and winter (D.Perovich, 2012) (Heygster, 2011). The melting of the sea ice can be observed in figure 3 (a) (b), where most of the recent years of data have beaten the previous minimum records. The data extracted form figure 3(b) shows that the sea ice coverage in the Arctic is contracting on average 2.6% during the winters and 13% during the summers per decade (D.Perovich, 2012).

Sea ice is found in four forms, young ice witch is less than 30 cm in thickness, first year ice that can attain a thickness of 1 meter. Multiyear/old ice is two or several layers of seasonal ice, compacting and strengthening the ice. The fourth is icebergs that originate form glaciers, which are very dense

and strong (Arctic Marine Shipping Assessment 2009 Report, 2009, p. 26). The deterioration of the sea ice also diminishes the creation of new multi-year ice (MYI), because it has to become sufficiently cold for the ice and snow to get a new foothold. The sea ice cover in September is the MYI for the upcoming winter season, where we can observe from figure 3(b), there is further more positive correlation between the amount of MYI and the sea ice cover during the winter (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 40).



Figurer 4: Season Max/Min ice cover:

Shows the maximum and minimum of March and September's sea ice cover within the Arctic Circle. The anomaly value for each year is the difference in %in ice extent relative to the mean value for the period 1979-2000. The un-dotted red and black line is the squared linear regression, indicating ice melting March -2.6% and September -13% per decade. Source: (D.Perovich, 2012)

### Sea Ice projections

Because of these statistical observations, multiple attempts have been made to simulate the future sea ice cover. The simulations are known as Global climate models (GCM), and there extent of the simulations vary, though the results of a diminishing sea ice cover as shown in Figure 4 is consistent.

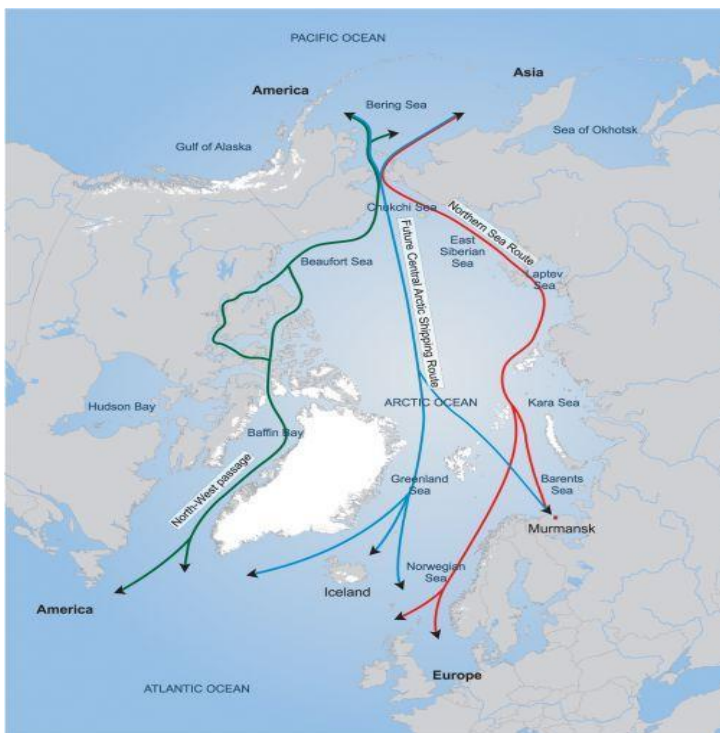
The models are based on collected data, which then are subjected to exogenous factors such as if there is an increase or decrease in the emission of greenhouse gasses. All the modulations reviewed for this thesis are all based on a semi positive, implying a reduction in the emission of greenhouse gases (Arctic Council, 2009) (Arctic Monitoring and Assessment Programme (AMAP), 2011) (Smith & Stephenson, 2012). The GCM's are conducted in a semi positive future scenario, as a radical change is unlikely to occur, which is the only scenario in which a positive outcome would be possible. Secondly an increase in greenhouse gases would only increase the melting of the sea ice cover (Arctic Council, 2009) (Arctic Monitoring and Assessment Programme (AMAP), 2011).

One of these is the GCM conducted by the researchers attached to the Arctic Council in the release of The Arctic Climate Impact Assessment, which "simulate a continuous decline in sea ice coverage

through the 21<sup>st</sup> century” (Climate Change 2007). Furthermore, one of these simulations from the Arctic Climate Impact Assessment indicated an ice-free during some summers during the 21<sup>st</sup> century. There are however no GCM that having been able to produce a reasonable projection of ice free winters in the arctic (Arctic Marine Shipping Assessment 2009 Report, 2009, p. 29) (Smith & Stephenson, 2012) (Shipping across the Arctic Ocean, 2010).

## Shipping routes

Global warming and in extension the diminishing of the arctic sea ice cover sett the possibility for arctic shipping. Arctic shipping is the term used for shipping from to or through Arctic areas. As of 2009, most of the activity within the arctic is to and from locations, moving resources out of the area (Arctic Marine Shipping Assessment 2009 Report, 2009, p. 76), where very few voyages went through the arctic in 2009. Never the less, the activity and prospect of shipping through the Arctic becomes more and more attractive for shipping companies as the sea ice cover continues to diminish (Smith & Stephenson, 2012).



*Figure 5: Arctic Routes:*

This figure shows North eastern Route / Northern sea route indicated in red off the coast of Russia, and the North western route indicated in green off the coast of Canada and USA (Alaska). The figure also indicated the prospectus sea way directly over the north pole, indicated in blue.

<http://www.nato-pa.int/Default.asp?SHORTCUT=2082>

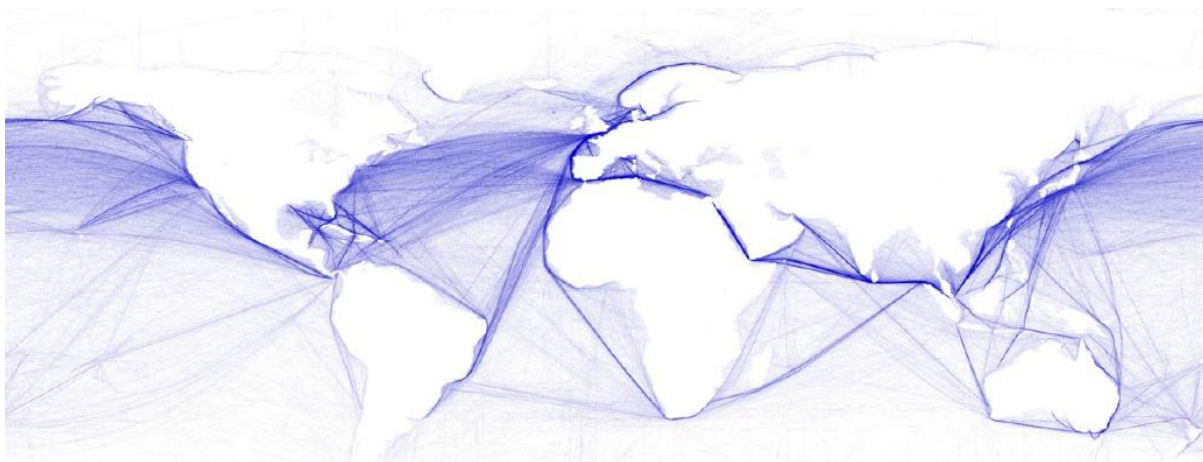
The first recorded expedition of the Arctic Ocean occurred in 325 B.C. As the understanding of the earth grew, it became apparent that the arctic could connect continents if the waters of the Arctic Ocean proved to be navigable. The NSR was the first route to be used, by Russian merchants during the 1700 century. The NWP was first successfully navigated in the 1900's by the explorer Roald Amundsen (Arctic Council, 2009, p. 46). In the 1900 trade between Europe and America with Asia

was well underway, and the Arctic proved to have the potential of becoming a short cut, decreasing the distance between Rotterdam and Tokyo by 1/3 (Eide, Eide, & Endresen, 2010) (Arctic Monitoring and Assessment Programme (AMAP), 2011).

Today, only the NSR is transited by commercial shipping vessels. The NWP is only partially sailed, where resources are moved out of the nearby region, while the TSR has not seen any commercial activity (Arctic Council, 2009).

### **The Historical and traditional shipping routes**

The formation of what today is referred to as traditional shipping routes, the Suez and Panama Channel routes were recent event and opened 1869 and 1914. (Grigentin & Verny, 2009). Because of the world's geography, the concentration of humans around the equator, most shipping activity can be located around the equator. With the diminishing of the sea cover of the Arctic Ocean, the traditional sea routes, illustrated below is under threat.



*Figure 6: World Shipping Activity*

Adapted by Hengl, T. (2010). *Shipping Routes*. Retrieved (04.30.12) from, Arctic yearbook: <http://www.arcticyearbook.com/book/> p.307 Based on Harper, B.S., Walbridge, S., Selkoe, K. A., Kappel, C.V., Michelo, F., D'Agrosa, C, Watson, R. (2008), A global map of human impact on marine ecosystems. *Science*. (319)5865, 948-952. doi: 10.1126/science.1149345

### **The Northwest Passage**

The Northwest Passage (NWP) is the name of multiple routes going from the Atlantic Ocean to the Pacific via the Arctic Ocean along the Northern Coast line off North America. The route was first successfully navigated by Roald Amundsen in the 1900's. Successfully navigating the NWP was believed to open the sea way, and present an alternative route to moving goods within the USA and between the west coast of USA and Asia, bypassing the Panama Channel (Arctic Monitoring and Assessment Programme (AMAP), 2011, p. 24).

The NWP showed itself to be extremely difficult to navigate because of this approximately 36 000 islands. Only two of the routes the multiple routes defined as the NWP are classified as deep waters, allowing for certain sizable ships (max 15 m) to navigate the region. Because of the islands, the average temperature is lower than at sea, increasing the formation of ice, making the route extremely difficult to navigate, and it is expected to be the last arctic route to be ice free (Heygster, 2011) (Smith & Stephenson, 2012) (Arctic Council, 2009, p. 112).

### **The Northern Sea Route**

The Northern Sea Route (NSR) is defined in “Russian Federation Law as a set of marine routes from Kara Gate in the west until the Bering Strait in the east” (Arctic Council, 2009, p. 27). This passage also includes multiple routes in between islands, but fare less than what is found along the NWP. The NSR just as the NWP have areas with shallow waters, putting some restrictions on which routes commercial ships can take. The NSR is the passage that is the most explored and mapped, due to Russia and the Soviet Union’s extensive usage of the sea route during the Second World War and the Cold War (Ragne, 2008, p. 3).

### **The Northeast Passage**

The Northeast Passage (NEP) is a route that starts off the coast of Norway, and goes to the Bering strait. This route has a high degree of correlation with the NSR. The major difference between the two routes is that the NEP covers the howl voyage through the Arctic Ocean, while the NSR only covers the voyage within the Russian territorial waters (Arctic Marine Shipping Assessment 2009 Report, 2009, p. 38). At some regards the NEP and NSR is regarded as the same routes especially after the opening of commercial shipping of the NSR in 1991 (Humpert, 2011).

### **The Transpolar Sea Route**

With the continuing and future diminishing of the sea ice in the Arctic, the prospectus of opening the a shipping route in close proximity of the North Pole, or even over the North Pole is present during the late summer months (Smith & Stephenson, 2012) (Eide, Eide, & Endresen, 2010, p. 14). This sea route is referred to as the Transpolar Sea route (TSR). This route will be defined as the Pole Route (PR) throughout the paper. This route has deep waters allowing for adjustments of shipping routes in relations to the sea ice coverage (Arctic Marine Shipping Assessment 2009 Report, 2009). This route has only been partially sailed, by a Russian Icebreaker that after reaching the North Pole returned along the same route I arrived along.

## Prospective Shipping Activity along the Arctic Shipping Routes

One of the most comprehensive research papers on the development of the Arctic Shipping routes was conducted by Laurence C. Smith and Scott R. Stephenson (2013) in their paper on “New Trans-Arctic shipping routes navigable by mid-century”. This paper incorporated 7 GCM’s in a simulation of two vessel types, and the possibility of them sailing through the Arctic Ocean during the month of September. The two vessel types are classified as 1: A traditional Open-Water ships (OW) and 2: A moderately ice-strengthened ships (PCS).

In order to verify the results from the simulations, they first conducted a simulations based the data projection from 1979 to 2005 and 2006 to 2015. The results from these simulations projected the usage of the NSR as the primary sea way for OW’s and PCS’s to sail through the arctic at the current state climate environment, in line with the actual shipping activity of the Arctic, setting a historical base line, where the primary difference between the 1979 to 2005 and 2006 to 2015 projections was that several trips a year would have the opportunity of sailing further north. They then ran the projected data for 2040 to 2059, yielding results that showed significant changes in the traffic patterns. The results opened for traffic of OW and PCS vessels along NEP, NWP and TSR, secondly PCS would be able to transit the PR. The results showed that traffic now would take place along all three sea routes during the summer month of September. It is important to underline that these simulations only look at projected CGM data and traveling distance optimisation, and not cost savings.

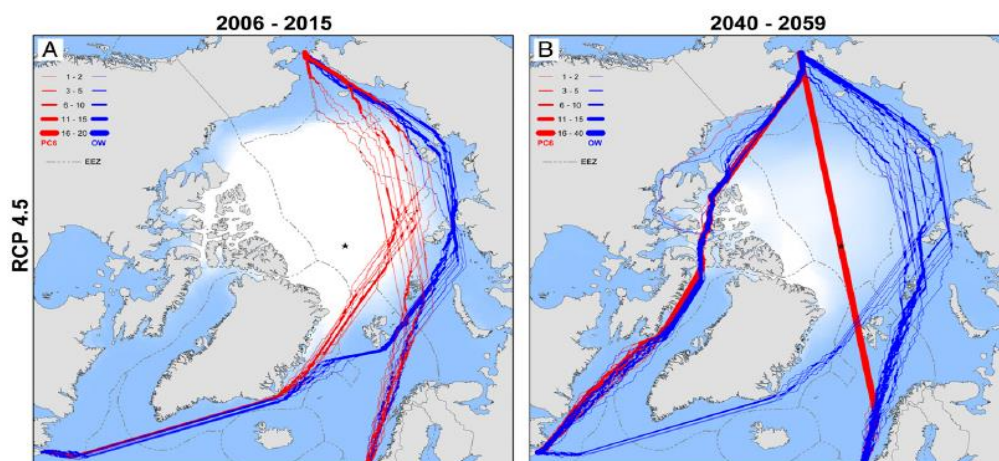


Figure 7: GCM Simulation.

This is the illustrated simulations of the shipping activity along the sea routes corresponding to the CGM’s, in this particular case the CGM RCP 4.5. (Smith & Stephenson, 2012)

Other studies did however reviled the NSR is currently navigable at 15 knots from June to December (Niini, 2008), and 11 knot from January to May (Jensen, 2006). In relation to the continuous deterioration of the sea ice over, it has also been found that the average speed through the Arctic

will increase gradually (Bertoia, 2003) (Stroeve, 2007). A position paper by Det Norsk Veritas (DNV), a respected risk assessment company, determined that within 2030 the NSR would be open 100 days a year, and 120 days within 2050 (Eide, Eide, & Endresen, 2010)(Appendix 3).

## **World shipping activity and projected demand**

The interest of the arctic passages have been present with mariners for hundreds of years, and for hundreds of years been viewed as a short-cut connecting the East-Coast of the United States and Europe with a connection to Asia (Arctic Council, 2009, pp. 41,42,46,47).

Shipping is a result of global trade, with the need of transporting products and goods from distant locations. One of the most famous notions about modern globalisation was noted by Lord John Maynard Keynes: “The inhabitant of London could order by telephone, sipping his morning tea in bed the various products of the whole earth, in such quantity as he might see fit, and reasonably expect them early delivery upon his doorstep” (1914). That was a hundred years ago, when commercial flights was just about to take off, implying that just about all global trade was transported by boats. Over a hundred years much have not changed, as it is assumed that about 90% of all global trade is carried by sea (Interntional Maritime Organization, 2012, p. 7).

The worlds shipping fleet have more than doubled since 1980, even with the contraction that took place during 2009 as a result of the financial crises August 2008 (Interntional Maritime Organization, 2012, p. 9). The world trade fleet is in a very close correlation with the amount of global trade (UN International Merchandise Trade Statistics, 2011). Global trade is vulnerable to economic downturns, following the finance crises, and is quite noticeable in the trade statistics of the UN international Merchandise Trade Statistics. Likewise the global demand for Oil is increasing just about doubled since 1970 (U.S. Energy Information Administration (EIA), 2009). The demand for raw materials, such as iron ore, is following the same statistical trends as merchandise and oil (Eurostat, 2012).

The demand for shipping is almost in a perfect correlation of the demand for goods and oil & gas, as we often find natural-, capital- and labour resources located at different locations of its demand, effectively creating a flow of trade (Ronald). The following image is an illustration of the world’s shipping routes based upon shipping data collected by the international maritime organisation a United Nations Agency, Figure 8. The image also contains prospective rotes where the NEP and NWP/NSR is represented, indicating an increase in the Arctic shipping activity also in the view of the International Maritime Organisation. Thirdly the image shows the development in world imports.

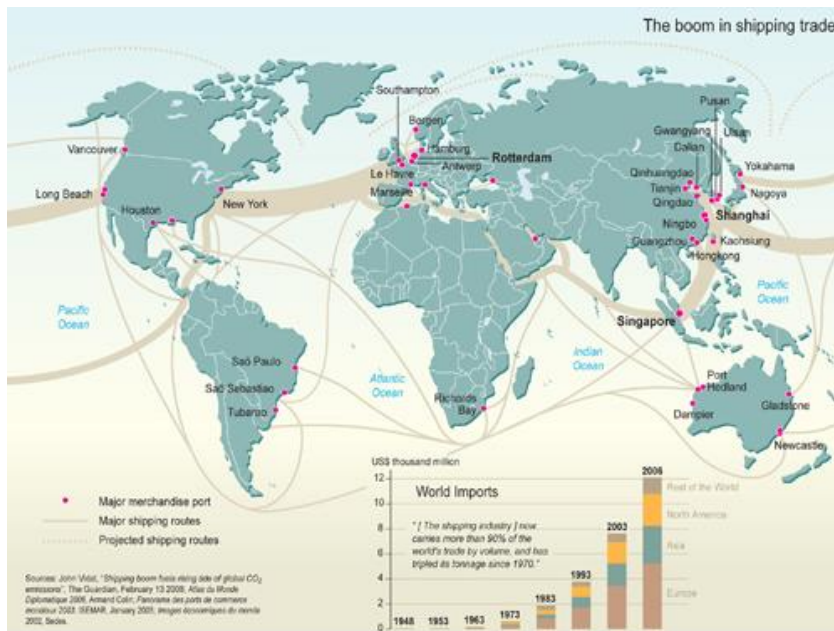


Figure 8: Shipping flow

Showing the international shipping flow and trade values.

<http://www.imo.org/KnowledgeCentre/ShipsAndShippingFactsAndFigures/TheRoleandImportanceofInternationalShipping/PublishingImages/shipping-trade%20routes%20UNEP-Arendal.jpg>

Not only will the shipping activity increase as a result of the opening of the arctic routes, but the known oil and gas reserves in represents 12% of the world's know resources (Arctic Portal) ( Appendix 1). As with Arctic shipping, oil and gas extraction in ice covered waters are is as difficult if not even more challenging, due to all year activity that is needed, if the operations are not of subsea extraction. The current oil and gas activity are only found in the arctic periphery, indicating that the challenges posed by the sea ice are restricting the activities, but as the sea ice is diminishing the distance to the North Pole will only decrease. Just as with the access to oil & gas, the defrosting of the Arctic also increases the accessibility to the minerals within the earth, which have been unreachable for humans for thousands of years (Arctic Monitoring and Assessment Programme (AMAP), 2011) (Arctic Council, 2009).

## Slow speed

In the aftermath of the financial crises of 2008, the shipping sector was heavily impacted, at some shipping companies experienced that they were sailing with losses. As a result some companies implemented "slow speed"<sup>1</sup>. Slow speed involves the vessels sailing slower than the traditional cruising speed. The world's largest shipping company, Maersk, implemented slow speed, reducing the cruising speed with 20%. The result of lowering the speed by 20%, was that the fuel consumption reduced by approximately 40%<sup>1</sup>.

<sup>1</sup> (<http://www.guardian.co.uk/environment/2010/jul/25/slow-ships-cut-greenhouse-emissions>, 2010)

## Arctic Restrictions and Vessel Requirement

Even though there are potential for commercial activities in and through the Arctic Ocean, there are still restrictions put in place by the governing states to ensure the safety of the vessels, crew and environment. The Arctic and its ecosystem are highly vulnerable, and a sinking or a ship run a shore would have major implications. This is one of the reasons why Canada and Russia, the two largest stakeholders in the arctic, have agreed upon common requirements for commercial shipping within the arctic under the UNCLOS Article 234, as well enforced by national legislation (Arctic Marine Shipping Assessment 2009 Report, 2009, p. 70).

The legislation says that vessels operating in the Arctic Ocean needs to hold an arctic classification, either Arc4 or 1-A, where there is little that sets the Arc4 and 1-A apart (Arctic Logistics Information Office, 2012). The vessel class states what level of ice resistant/braking capabilities the vessels have, in the sense of their ability to sail in ice waters. Additionally there are also requirements to the propeller, crew, supplies and communications equipment (Center for high north logistics, 2012, p. 19) (International Association of Classification Societies LTD., 2011).

In addition Canada and Russia have implemented specific regulations regarding shipping operations in their domestic waters. The Canadian government has a zero pollution law, restricting most vessels to date from operating in the waters (Transport Canada, 2013). Russia on their side has a requirement stating that any vessel that operates in the national arctic waters, have to file a request to an administrative office. The request establishes a line of communications between the vessel and the FSUE Atomflot, the operating unite of the NSR. Secondly the request also reveals the vessels arctic abilities, i.e. if it covered the requirements for sailing along any part of the NSR. From the request the FSUE Atomflot can determine the level of support the vessel will need on its voyage, and in extent the fee it needs to pay<sup>2</sup>, as it is in direct correlation with the level of support the vessel will need (Arctic logistic information office, 2011) (Arctic Marine Shipping Assessment 2009 Report, 2009, p. 71) (Federal Rate Service, 2011). The Fees are given in maximum terms per ton of cargo, stating the maximum fee which the FSUE Atomflot is able to claim while assisting vessels along the NSR. The request of sailing through the NSR needs to be field between 15 days and 4 months before the planned voyage (Arctic Logistics Information Office, 2012).

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<sup>2</sup> ([http://www.arctic-lio.com/nsr\\_tariffsystem](http://www.arctic-lio.com/nsr_tariffsystem), 2011)

The accessibility of the Arctic has historically been restricted in comparison to the traditional routes through the Panama- and Suez- Channel. In extent this means that to facilitate for future shipping activity the infrastructure such as radio, GPS, mapping and emergency services needs to be established and strengthened (Arctic Marine Shipping Assessment 2009 Report, 2009).

## **Regional Issues**

The Arctic region as well as the Arctic Ocean has a range of state stakeholders, due to their sovereignty and historical presents in the region there are few disputes, none of which are likely to destabilise the region. The most present dispute is regarding Canada's sovereignty of the Arctic waters north of Canada including the NEP, a route that also is of major interest to the United States of America. The sovereignty gives Canada the regulatory mandate over the waters, something that the United States would like to have a say in. It is however most unlikely that this disagreement will restrict vessels under the American flag to sail in the area (Hayward & Canadian Press, 2010).

## Data collection

In order to create a basis for the comparison of data of potential time and cost saving, we need to obtain the relevant data from several sources. We need data regarding the distance between the ports, as well as vessel data, which in extent will determine the time which a vessel uses on a voyage, its fuel consumption as well as to determine the vessels transit cost through the arctic routes, Panama- and Suez Channel.

Furthermore, the following individual cost factors will be collected for this comparison basis:

- Fuel cost
- Lubrication oil
- Hull and Machinery (H&M) and Protection and Indemnity (P&I) Insurance
- Crew cost
- Maintenance
- Depreciation
- Transit cost

In order to obtain the different cost, a common factor in all of them is the distance and time usage along each route, which also needs to be found.

## Distance

One of the most apparent factors that need to be obtained is the distance between the ports. The data regarding the distance will help determine the time per voyage and the cost of each factor per voyage. Because of the close proximity of the NSR and NEP, the routes will be combined in the terms of this thesis, and referred to as NSR.

Distance data for the respective routes was collected using Google Earth, where the routes was plotted using the software's plotting tool, which in the end measured the distances of the plotted route. The results were reported in kilometres (Km) and Nautical Miles (Nm) (Appendix 2).

In order to have a comparable set of data, Rotterdam was selected as the port representing Europe, while the New York was selected to represent the East Coast of the United States of America. The Asian ports, situated from the South East until the East coast was selected because of their economic significance, and size<sup>3</sup>.

- Singapore
- Hong Kong
- Shanghai
- Tokyo

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<sup>3</sup> (<http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports>, 2012)

From:	To:	Km:	Nm:
Rotterdam	Singapore	15536	8389
Rotterdam	Hong Kong	18160	9806
Rotterdam	Shanghai	19484	10521
Rotterdam	Tokyo	20908	11289

NWP				Diff.:
Rotterdam	Singapore	19259	10399	124%
Rotterdam	Hong Kong	16886	9118	93%
Rotterdam	Shanghai	15515	8378	80%
Rotterdam	Tokyo	14120	7624	68%

NSR				
Rotterdam	Singapore	18697	10095	120%
Rotterdam	Hong Kong	16324	8814	90%
Rotterdam	Shanghai	14953	8074	77%
Rotterdam	Tokyo	13558	7320	65%

TSR				
Rotterdam	Singapore	17056	9209	110%
Rotterdam	Hong Kong	14683	7928	90%
Rotterdam	Shanghai	13312	7188	89%
Rotterdam	Tokyo	11917	6434	88%

From:	To:	Km:	Nm:
New York	Singapore	23285	12572
New York	Hong Kong	18205	9829
New York	Shanghai	19806	10688
New York	Tokyo	21042	11361

NWP				Diff.:
New York	Singapore	18467	9971	79%
New York	Hong Kong	16094	8690	88%
New York	Shanghai	14723	7950	74%
New York	Tokyo	13328	7196	63%

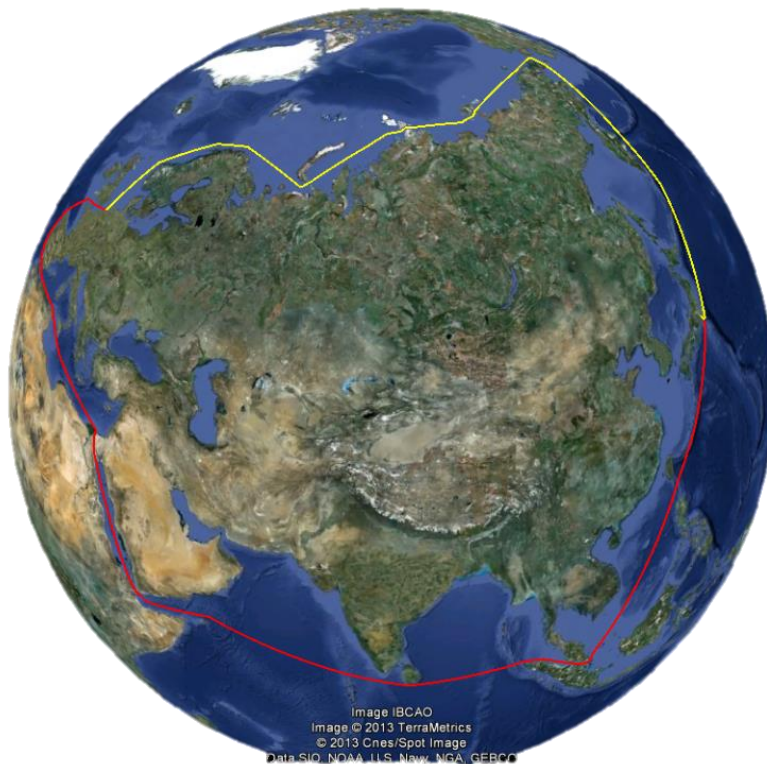
NSR				
New York	Singapore	22735	12276	98%
New York	Hong Kong	20362	10995	112%
New York	Shanghai	18991	10255	96%
New York	Tokyo	17596	9501	84%

TSR				
New York	Singapore	20223	10919	87%
New York	Hong Kong	17850	9638	98%
New York	Shanghai	16479	8898	83%
New York	Tokyo	15084	8144	72%

Table 1

The distance from departing Port to arrival port along the different routes. The difference along the Arctic routes and the traditional routes, are identified by the percentage comparison titled Diff.:

Table 1 shows the length on any route, given in kilometres and nautical miles. An initial comparison is made between the traditional and new alternative arctic route, given in the following percentage (diff.) after the route i.e. the NSR Rotterdam – Tokyo is only 65% ~ (2/3) of the distance in comparison to Rotterdam – Tokyo via the Suez Channel.



*Figure 9: Displaying the Rotterdam: Tokyo routes.*

The traditional route via the Suez Channel is displayed in red, while the NSR route is displayed in yellow. Red route: 20908 Km / 11289 Nm Yellow route 13558 Km / 7320 Nm.

Source: Google Earth

Distance: Excel 'Distance'

Complete image plotting: Appendix 2

## Vessel data

Data regarding the vessels are important in determining the voyage time, costs, such as fuel and lubrication oil consumption, insurance, crew cost, maintenance, depreciation and the cost of transit through areas where such fees are imposed. Obtaining complete data regarding the vessels proved difficult to gather. It has therefore been necessary to make assumptions based on data from one or two of the other vessels.

As we know from the literature review, any ship traveling through the arctic needs to hold an arctic classification, deeming the vessel fit for traveling through ice covered water. With the purpose of revealing whether or not there is a cost savings potential, three vessels has been chosen for this study:

- **OOCL Montreal** <sup>4,5</sup>
  - *Cargo / Container vessel*
- **Marinor** <sup>6,7</sup>
  - *Tanker / Liquid natural gas*
- **Nordic Odyssey** <sup>8,9</sup>
  - *Dry bulk*

Collecting data about the vessels are important for several reasons. First of all we obtain data about the vessels dimensions, which are important in the aspect of calculating the cost of the vessel through areas where there are a fee attached to the channel transits. The dimension of the vessel also tells us how much it is capable of carrying in cargo. This information is then used to calculate the value of which the vessel is carrying and therefor needs to be insured. We also obtain the value of the ship used to estimate the cost of insuring the vessels itself. Finally it is also needed to obtain data concerning the vessels capabilities, such as it sailing speed, its range and fuel consumption in order to look at the cost of sailing different routes.

Some data proved itself difficult to obtain, resulting on the theses needing to relay on some assumptions supported by other backup data. First of thesis data was the displacement weight of the Nordic Odyssey. The displacement weight is the weight of the water which is displaced when a vessel is loaded. Because of similar vessel dimensions between the Nordic Odyssey and Marinor, the displacement weight of the Marinor was applied as also being the displacement weight of Nordic Odyssey.

Data such as oil capacity, fuel consumption, range and required crew members were also difficult to obtain. Marinor, being similar to Nordic odyssey became a valid asset as a source of value assumption for this thesis. Partial data from the individual vessels have therefor been used as a baseline, from which the equivalent values for the two other vessels have been based upon.

One of these important pieces of information is the fuel consumption of the vessels. The vessels run on a particular fuel, produced for ship engines, in order to calculate the fuel cost of the vessels we to establish how much they use. Fuel consumption was however only available about Marinor, which

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<sup>4</sup> (<http://www.oocl.com/eng/ourservices/vessels/iceclass4402/Pages/ooclmontreal.aspx>) - 22.04.2013

<sup>5</sup> (<http://www.marinetraffic.com/ais/shipdetails.aspx?mmsi=477321000>) - 22.04.2013

<sup>6</sup> (<http://www.marinvest.se/ship.asp/id/300510/lid/33139>) - 22.04.2013

<sup>7</sup> (<http://www.brodosplit.hr/Portals/44/Tankers4.pdf>) - 23.04.2013

<sup>8</sup> (<http://www.nordicbulkcarriers.com/services/ice-bulk-carriers>) - 24.04.2013

<sup>9</sup> (<http://www.marinetraffic.com/ais/shipdetails.aspx?mmsi=373428000>) - 23.04.2013

uses 49.2 tons of fuel a day<sup>10</sup>. Because of Marinor and Nordic Odyssey's similar dimensions, it is fair to assume that this vessel have the same fuel consumption.

With regards to OOCL Montreal, the vessel is longer than the two other vessels, however the dead weight tonnage (DWT), the maximum overall weight of the vessel is less than the two others. It is assumed that this allows for the vessel to have a smaller engine than an equally sized tanker. OOCL Montreal is therefore having the same fuel consumption of 49.2 tons of fuel each day. Since it is assumed that all the vessels have the same fuel consumption, and in extent the same engine, it is also assumed that the engines have the same need and capacity for oil lubrication.

The same issue appears when trying to attain the cruising range of the vessels, where the data was only available for Marinor, and adapted to the two other vessels, being 15000 Nm, well within the distances needed to sail (Table 1). The three vessels average speed is within the expected average speed of vessels sailing in the arctic (Eide, Eide, & Endresen, 2010) (Smith & Stephenson, 2012).

Fourth is the collection of the crew data, something that varies accordingly to the complexity of the vessels and the legislated security requirements. Yet again the numbers are only available for one of the vessels, OOCL Montreal, reporting 20 crew members, with additional rooms for Panama crew members. For the purpose of this thesis it will be assumed that all vessels carry a crew of 20 sailors. The channel crew is not accounted for as they are compensated through the transit fee.

Data vessel name	OOCL Montreal	Marinor	Nordic Odyssey
Vessels of research	Container / Cargo	LNG / Tanker	Dry Bulk
DWT	47,828	74,999	74,000
SCNT	23,914	37,500	37,000
NRT	22,426	37,500	40,000
Registered Transit Load	N.A.	60,992	66,000
Average speed ( knots)	12	12	13
Length M	294	227	225
Length F 1M=3.2808 f	965	745	738
Beam (M)	30	31	32
Beam (f)	98	102	105
Draft (M)	10	14	13
Draft (F)	31	44	43
Oil Capacity	2,294	2,294	2,294
Summer load Displacment	69,065	61,280	61,280
TUE's/ M^3 /ton	4,402	85,950	40,000
Daily fuel consumption t/day	49	49	49
Cruising range (NM)	15,000	15,000	15,000
Crew	20	20	20

Table 2

The Vessel Data

<sup>10</sup> (<http://www.brodosplit.hr/Portals/44/Tankers4.pdf>) - 23.04.2013

## **Voyage time**

In order to calculate the voyage time of the vessels, we divide the nautical miles (Nm) of the route on the average knots of the vessels, which has a 1 to 1 ratio (1 knot/h = 1 Nm). The result of this action leaves us with the amount of hours that is needed for the voyage, by yet again dividing the amount of hours by 24 we obtain the days needed per route. Because of the mirror image value of knots and nautical miles, the correlation between the distance (Table 1) and voyage (Table 3) time is perfect. Furthermore, it is presumed that an alternative route needs to be less time consuming.

The Commercial Viability Of The Arctic Sea Routes

Days:						Days:					
From:	To:	Nm:	OOCL Monteral:	Marinor:	Nordic Odyssey:	From:	To:	Nm:	OOCL Monteral:	Marinor:	Nordic Odyssey:
Rotterdam	Singapor	15536	52.63	53.06	51.38	New York	Singapore	23285	78.88	79.53	77.00
Rotterdam	Hong Kong	18160	61.52	62.02	60.05	New York	Hong Kong	18205	61.67	62.18	60.20
Rotterdam	Shanghai	19484	66.00	66.54	64.43	New York	Shanghai	19806	67.09	67.64	65.50
Rotterdam	Tokyo	20908	70.83	71.41	69.14	New York	Tokyo	21042	71.28	71.86	69.58

NWP		Dif.%		Dif.%		Dif.%	
Rotterdam	Singapore	19259	65.24	12.6	65.78	12.7	63.69
Rotterdam	Hong Kong	16886	57.20	-4.3	57.67	-4.4	55.84
Rotterdam	Shanghai	15515	52.56	-13.4	52.99	-13.6	51.31
Rotterdam	Tokyo	14120	47.83	-23.0	48.22	-23.2	46.69

NSR		Dif.%		Dif.%		Dif.%	
Rotterdam	Singapore	18697	63.34	10.7	63.86	10.8	61.83
Rotterdam	Hong Kong	16324	55.30	-6.2	55.75	-6.3	53.98
Rotterdam	Shanghai	14953	50.65	-15.3	51.07	-15.5	49.45
Rotterdam	Tokyo	13558	45.93	-24.9	46.30	-25.1	44.83

TSR		Dif.%		Dif.%		Dif.%	
Rotterdam	Singapore	17056	57.78	5.1	58.25	5.2	56.40
Rotterdam	Hong Kong	14683	49.74	-11.8	50.15	-11.9	48.55
Rotterdam	Shanghai	13312	45.09	-20.9	45.46	-21.1	44.02
Rotterdam	Tokyo	11917	40.37	-30.5	40.70	-30.7	39.41

NWP		Dif.%		Dif.%		Dif.%	
New York	Singapore	18467	62.56	-16.3	63.07	-16.5	61.07
New York	Hong Kong	16094	54.52	-7.2	54.97	-7.2	53.22
New York	Shanghai	14723	49.87	-17.2	50.28	-17.4	48.69
New York	Tokyo	13328	45.15	-26.1	45.52	-26.3	44.07

NSR		Dif.%		Dif.%		Dif.%	
New York	Singapore	22735	77.02	-1.9	77.65	-1.9	75.18
New York	Hong Kong	20362	68.98	7.3	69.54	7.4	67.33
New York	Shanghai	18991	64.33	-2.8	64.86	-2.8	62.80
New York	Tokyo	17596	59.61	-11.7	60.10	-11.8	58.19

TSR		Dif.%		Dif.%		Dif.%	
New York	Singapore	20223	68.51	-10.4	69.07	-10.5	66.88
New York	Hong Kong	17850	60.47	-1.2	60.96	-1.2	59.03
New York	Shanghai	16479	55.82	-11.3	56.28	-11.4	54.49
New York	Tokyo	15084	51.10	-20.2	51.52	-20.3	49.88

Table 3. The table indicated the voyage time from departing to the arriving port in days. Values indicated in red are routes that take longer time, while green values indicates les time. Following the voyage time in days, the time is indicated in percentage.

## Fuel and Lubrication costs

To develop the fuel and oil lubrication costs associated with the voyages we multiply their fuel consumption with the travel time. We know from the data collected about the vessels that, they uses 49.2 tons a day, as well as the voyage time as also been calculating. By multiplying the two factors we yield the exact amount of fuel the vessel consumes on one trip. What remains is to multiply the consumption with the cost of the fuel. Fuel for marine vessels is specially produced for its engines, and is sold as a specific type of fuel with its individual quot. The fuel cost was attained from Bloomberg<sup>11</sup>. The fuel price data is historical five year data, with monthly closing prices, creating a sufficient data set to develop an average price, 541.16 USD per ton.

To derive the fuel costs it was just necessary to multiply the consumption per day 49.2 ton with the amount of days attributed to each route, and then multiplies it with the average price of fuel. Consult the excel calculation concerning fuel cost for specific data on fuel cost with regard to the vessel and route (Annex Excel).

In order to minimise the wear of the engines the engine oil needs to be changed periodically, and is therefore a cost that needs to be taken into consideration. The cost of the oil was extracted from Chevron's price list<sup>12</sup>, at an approximated average price of 7 USD per litre. The price depending upon speed of engine and temperatures, but in order to create a compatible foundation of a cost comparison, this value at 7 USD per litre, and set to be changed after completed voyage. To attain the cost, the oil capacity of the machinery is there for multiplied with the price, 7 USD. And as its assumed that all vessels have the same engine and i.e. oil capacity, the cost of oil / lubrication is 17 474 USD per trip.

## Insurance

There are two types of insurance that needs to be calculated, the Hull & Machinery- (H&M) and Protection and indemnity- (P&I) insurance<sup>13</sup>. Calculation of any insurance is based on the fair value of the object itself, and the risk associated in transportation of the object. In extent to calculate the insurance cost of the H&M and P&I insurance, it is necessary to obtain the value of the H&M and P&I. For this thesis it is assumed that that any insurance cost is estimated as a percentage of the fair value.

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<sup>11</sup> (<http://www.bloomberg.com/quote/BUNKS138:IND>) – 16.04.2013

<sup>12</sup> ([http://www.ctgl.net/Chevron\\_PriceScheduleUpdate15Jan2008\\_PRINT\[2\].pdf](http://www.ctgl.net/Chevron_PriceScheduleUpdate15Jan2008_PRINT[2].pdf), 2008) – 19.04.2013

<sup>13</sup>

(<http://www.skuld.com/upload/News%20and%20Publications/Publications/Introduction%20to%20PandI/Introduction%20to%20PandI.pdf>, 2009) - 15.05.2013

To calculate the H&M insurance we need the value of the vessel. However the value of the three vessels has not been available for the public, as two of the three vessels are owned by private companies. From the literature review we know that an arctic vessel needs to answer to specifications, and is presumably more expensive to build. In order to value the vessels, the value of "Golden Future<sup>14</sup>" sold in 2010 for 72 million USD, was set as a valuation base. Because of the additional specification of an arctic classified vessel, the value of the vessels in this thesis is assumed to be almost 65% higher, valued at 110 million USD. The insurance is set to 0.5% - 550 000 USD a year. For the reason of achieving the insurance cost of every trip, the value is divided on the time required on one voyage.

Valuing the P&I, is a bit more difficult than the H&M value estimation. The P&I insurance cover the shipping company's third party liabilities. Valuation of P&I is difficult to assess, as it is any third party of the ship owner that can claim this. For example an oil tanker can go ashore, and intoxicate an entire coastline. The chance of this happening is low, but real. For this reason it will be assumed that the P&I insurance will be set in accordance with the value of the cargo. OOCL Montreal is a container ship, and we assume that its cargo is worth 100 million USD. Marinor the tanker is able to ship 85950 cubic of oil, and Nordic Odysy can carry 40 000 tons of iron ore. We value the cargo based on Bloomberg quotas. The quota of oil is given in barrels where one barrel holds 0.15988 cubic meters. Secondly it is assumed that the oil price is 100 USD, a target price of the (OPEC, 2013)<sup>15</sup>. From this Marinor is carrying 53 759 069 USD worth of oil. Nordic Odysy is able to carry 40 000 tons of iron ore. The price quota of the iron ore is based on a one year monthly ending price from Bloomberg, averaging at 124.1 USD per ton. Nordic Odysy is carrying 4 965 000 worth of cargo. For the calculation of the P&I insurance it is assumed that the yearly cost is 5% of the cargo carried.

### **Crew cost**

The crew cost may in reality fluctuate according to which flag it sails with. For the purpose of this thesis an assumed price level will be set as equal of all vessels. The price is passed upon the info attained from the shipping company Odfjell, a Norwegian company<sup>16</sup>. Their average monthly pay check ranges from 1000 USD until 5000 USD for an experienced crew member. As a registered cost for the shipping company this is a higher cost regarding elements such as pension, health and injury insurance and training. This paper will therefor assume that the average yearly cost of 50 000. With

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<sup>14</sup>

([http://www.goldenocean.no/?view=hugin\\_feed&menu=21&feed=http://cws.huginonline.com/G/135378/PR/201009/1447173.xml](http://www.goldenocean.no/?view=hugin_feed&menu=21&feed=http://cws.huginonline.com/G/135378/PR/201009/1447173.xml), 2010) 11:30 15.05.2013

<sup>15</sup> (<http://www.reuters.com/article/2012/06/14/us-markets-oil-idUSBRE83H17O20120614>, 2012) 27.04.2013

<sup>16</sup> ([http://www.bt.no/nyheter/lokalt/God-lonn\\_-men-toffe-forhold-for-filippinske-sjofolk-2444197.html#\\_UX1webWQVv8](http://www.bt.no/nyheter/lokalt/God-lonn_-men-toffe-forhold-for-filippinske-sjofolk-2444197.html#_UX1webWQVv8), 2004) 28.04.2013

a crew of 20, this amounts to 1 million a year. In order to find the crew cost per trip, we then multiply 1 million USD with the amount of days used on one particular trip divided on 365 days. Thought the data is from 2006, it is not adjust it for inflation, as the ratio would remain the same in both cases.

## Maintenance

The ships need new paint to protect the vessels from corrosion as well as repairs, overhauls and upgrades. Along the traditional channel routes, this maintenance cost is presumably lower than the once found along the Arctic routes due to the harsh climate conditions documented in the literature review. There is however difficulties of assessing how much a vessel need in maintenance, as it is a cost that will vary.

For this reason it is assumed that the maintenance cost is 2.5% of the vessels value, i.e. 2 750 000 a year per vessel, and only taking into account the difference between arctic and conventional routes, and not each route specifically. This is divided on the voyage time of one year, to find the cost of one trip. Furthermore, because of the high uncertainty of the maintenance costs as well as realizing the potential harm of sea ice, two calculations have been conducted. First the maintenance cost for the traditional routes and new potential arctic routes without additional costs attributed was calculated. Secondly the maintenance cost of the arctic routes was adjusted for more potential wear by a 30% increase costs.

### Maintanance cost

#### Rotterdam - Asia

		No Assosiated Risk	
Vessels	Annual cost	Suez avrage	Arctic
<b>Total</b>	\$ 2,750,000	\$ 253,929	\$ 212,810

#### Risk assosiated \*30%

Arctic
\$ 276,653

#### New York - Asia

		No Assosiated Risk	
Vessels	Annual cost	Panama average	Arctic
<b>All vessels</b>	\$ 2,750,000	\$ 282,143	\$ 242,118

#### Risk assosiated \*30%

Arctic
\$ 314,754

Table 4

Estimated maintenance cost along the different sea ways

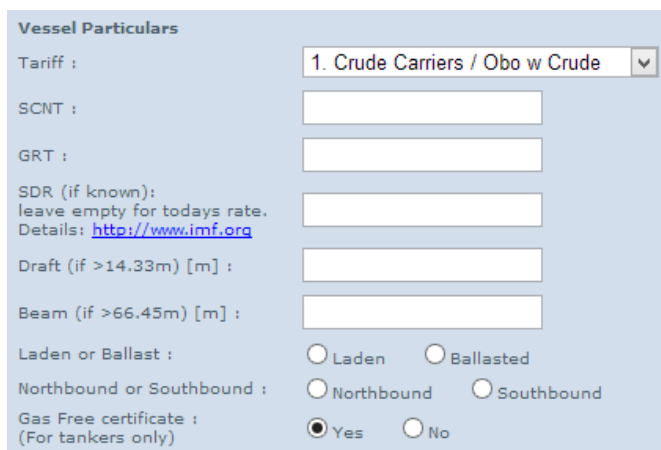
## Depreciation

Depreciation of the vessels is also a cost that needs to be registered by the vessel owners. The life span of a shipping container vessel is expected to be about 26 years<sup>17</sup>. This depreciation principle is attributed to the other type of vessels as well. However it is not that common for a vessel to be in the same ownership through its life span. Because of this the value of the ship is depreciated over 10 years, with no recorded residual value. We have already stated that the value of the vessels are set at 110 million USD, and in a straight lined depreciation scenario the ship owner sustains a 1.1 million loss every year, which then can be divided on the prospected time needed for on trip to get the specific depreciation cost.

## Transit cost

The transit cost, in relation to the sea routes is an important factor in calculating the potential cost savings of a transit through the arctic. The transit costs available to the public through information websites attached to the operating companies or authorities.

The transit cost attained from the Suez channel, was attained through a transit agency, providing an input calculator.



The image shows a web form titled "Vessel Particulars" for calculating Suez Channel fees. The form includes the following fields and options:

- Tariff : 1. Crude Carriers / Obo w Crude (dropdown menu)
- SCNT : (text input field)
- GRT : (text input field)
- SDR (if known): leave empty for todays rate. Details: <http://www.imf.org> (text input field)
- Draft (if >14.33m) [m] : (text input field)
- Beam (if >66.45m) [m] : (text input field)
- Laden or Ballast :  Laden  Ballasted
- Northbound or Southbound :  Northbound  Southbound
- Gas Free certificate : (For tankers only)  Yes  No

Figure 10: Suez Channel fee calculator

The type of vessel is selected in the first section, which determines the price class of the vessel. The SCNT stands for Suez Chanel Net Tonnage, and is attained every time the vessel transits the channel. The GRT is the gross tonnage of the vessel, which stands for the vessel total registered volume. For the entire vessel the both the draft and beam was les the respective 14.33 m and 66.45 m, and therefore not put in. For the purpose of attaining the transit cost through the Suez channel it is

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<sup>17</sup> (<http://www.worldshipping.org/about-the-industry/liner-ships/container-ship-design>) 29.04.2013

assumed that the vessel uses ballast as is heading southbound, even though the cost becomes the cost indifferent of which way the vessel sails.

- OOCL Montreal 209 506.71
- Marinor 149 770.03
- Nordic Odyssey 157 297.28

The cost of transiting through the panama channel is issued through a pricing table<sup>18</sup>. The table distinguishes between the type of vessels, and then ascribing a different cost depending upon the tonnage it is carrying from the first 10 000 tones second 10 000 tones and then for the rest.

Attaining the transit fee of the panama channel as not as easy as just putting data about the vessels into a calculator. The authorities of the Panama Canal uses a price table of any vessel, stating the price of its load by attributing one cost for the 1<sup>st</sup> 10 000 tone, a second cost for the 2<sup>nd</sup> 10 000, and finally a third cost the for the remaining tons of cargo. In addition the vessel also needs to compensate for the vessels displacement, which is the weight of water which the vessel displaces.

Tolls per PC/UMS Ton	1st: 10K	2nd: 10 K	Rest	Fee displacment ton		1st	2nd	rest	Total
General Cargo	5.10	4.99	4.91	3.49		51,000	49,900	11,912	353,849
Dry bulk	5.06	4.00	3.93	3.49		50,600	40,000	78,600	383,067
Tankers	4.92	4.84	4.75	3.49		49,200	48,400	83,123	311,596

*Table 5*

The table presents the cost of transiting through the Panama Channel for each vessel.

On the alternative arctic routes, the TSR and NWP have no administrative fee associated with transiting through the waters. In contrast, the NSR has a transit fee, based on the weight of cargo of which the vessel carries. There are some features with the NSR transit fee that sets it apart from the once present along the Suez- and Panama Channel. First there is no fee associated with the displacement of the vessel. Secondly the fee goes to the efforts done by the Atomflot in assuring a safe voyage along the route.

The commercial traffic along the NSR is managed by the Atomflot, which in extent is operated by the Russian federation. The Atomflot have been given a directive which determined the maximum fee it is able to attain from transiting vessels. The fee is established based on the cargo the vessel carries, and the overall weight of the goods.

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<sup>18</sup> (<http://www.pancanal.com/eng/op/tolls.html> , 2012)- 29.04.2013

<b>Nomenclature of cargo</b>	<b>Unity</b>	<b>Rate</b>	<b>UDS</b>	<b>Transit cost</b>
Cargo, transported in standard containers	Roubles per ton of nominal gross mass of container	1048	33.059	741,399.81
Bulk cargo	Roubles per ton	707	22.302	892,110.75
Bulk liquid cargo	Roubles per ton	530	16.719	626,961.27

*Table 6.* Presents the transit cost per ton of cargo through the NSR at maximum fee. The actual fee is equal or lower to the total cost in relation to the level of support the vessel needs on its voyage.

The rates are given in Rubbles, and at an exchange rate RUB/USD 31,70<sup>19</sup>, we attain the USD rate. The rate is the maximum fee which is allowed to be taken by the Atomflot (Federal Rate Service, 2011), and all calculations will be based on maximum fee in order to see the worst case scenario. Secondly there is no obtainable data off the transit fees of previous voyages, which could have been used as a benchmark for an average fee<sup>20</sup>.

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<sup>19</sup> (<http://www.bloomberg.com/quote/USDRUB:CUR/chart>) - 20.04.2013

<sup>20</sup> ([http://www.arctic-lio.com/nsr\\_tariffsystem](http://www.arctic-lio.com/nsr_tariffsystem), 2011) - 20.05.2013

## Calculation

The cost calculation consists of adding the individual costs together, and comparing the total costs of the alternative arctic routes with the traditional Suez- and Panama- channels routes to the designated Asian ports. In order to do this comparison in a clear and understandable way, the first cost comparison is made without any additional cost risk or associated costs of arctic transits. This will allowed for a more rigours cost analysis in the discussion and analysis.

Secondly, these values will be changed to include the additional cost and cost risk of sailing in the arctic. From this we will obtain a more realistic view of the potential cost savings along the Arctic routes. Third these calculations will be subjected to know cost saving practises within the shipping industry.

The total cost is put together by the following factors:

- Fuel cost
- Lubrication oil cost
- Insurance cost
- Crew cost
- Maintenance cost
- Depreciation

## Results

### Cost Analysis without additional cost and risk of an arctic transit

In the first cost comparison, we look at the costs along the traditional Suez Channel connection Rotterdam and Asian ports versus the Arctic shipping routes, but with no additional costs or cost of associated risk of sailing in ice covered waters.

The first section of the calculations (Table 7) show the total cost the three vessels sailing the traditional route from Rotterdam – Asian ports through the Suez Channel. This cost, establishes the base line of which the alternative routes will be compared, eventually determining whether or not it will be less cost intensive.

The following three sections are the costs of sailing, present the total cost of any vessel along the distinguished routes. The costs of the alternative routes are measured against the traditional route, where a higher cost level is indicated with red, and lower costs are indicated in green.

Total				
From:	To:	OOCL Montera:	Marinor:	Nordic Odyssey:
Rotterdam	Singapore	2,363,279	2,313,295	2,294,179
Rotterdam	Hong Kong	2,504,236	2,455,407	2,431,780
Rotterdam	Shanghai	2,575,361	2,527,116	2,501,212
Rotterdam	Tokyo	2,651,759	2,604,139	2,575,790

Table 7

NWP				
Rotterdam	Singapore	2,301,671	2,310,859	2,274,981
Rotterdam	Hong Kong	2,174,243	2,182,386	2,150,587
Rotterdam	Shanghai	2,100,630	2,108,171	2,078,727
Rotterdam	Tokyo	2,025,626	2,032,551	2,005,508

The voyage between Rotterdam – Asian ports with no additional cost or additional associated cost of risk of sailing through the Arctic. As we can see from the calculations the NWP and TSR yields a cost saving result.

NSR				
Rotterdam	Singapore	3,009,868	2,901,669	3,131,549
Rotterdam	Hong Kong	2,882,439	2,773,196	3,007,154
Rotterdam	Shanghai	2,808,827	2,698,981	2,935,295
Rotterdam	Tokyo	2,733,822	2,623,361	2,862,076

TSR				
Rotterdam	Singapore	2,171,698	2,179,821	2,148,103
Rotterdam	Hong Kong	2,044,270	2,051,348	2,023,708
Rotterdam	Shanghai	1,970,658	1,977,133	1,951,849
Rotterdam	Tokyo	1,895,653	1,901,513	1,878,630

The second comparison is from New York to Asian ports, where the traditional route through the Panama Channel is used as the baseline of comparison versus the transit through the Arctic. The total costs are presented in the same way as Table 8, red indicating a higher cost level, while green indicated a total cost saving. The first section presents the cost of sailing along the traditional Panama route from New York to the Asian ports. The following parts present the total cost from sailing each of the arctic routes.

		Total		
From:	To:	OOCL Montera:	Marinor:	Nordic Odyssey:
New York	Singapore	2956948	2931657	2959635
New York	Hong Kong	2684085	2656559	2693270
New York	Shanghai	2769535	2742709	2776685
New York	Tokyo	2836482	2810205	2842038

		NWP		
New York	Singapore	2276457	2291070	2256750
New York	Hong Kong	2149028	2162597	2132356
New York	Shanghai	2075416	2088381	2060496
New York	Tokyo	2000411	2012762	1987277

		NEP		
New York	Singapore	3271563	3173817	3396526
New York	Hong Kong	3144134	3045344	3272132
New York	Shanghai	3070522	2971128	3200272
New York	Tokyo	2995517	2895509	3127053

		TSR		
New York	Singapore	2381950	2397428	2359732
New York	Hong Kong	2254522	2268955	2235337
New York	Shanghai	2180909	2194739	2163478
New York	Tokyo	2105905	2119120	2090259

Table 8

The voyage between New York – Asian ports with no additional cost or additional associated cost of risk of sailing through the Arctic. As we can see from the results, only the NWP and the TSR presents a cost saving in comparison to the traditional Panama route.

Calculating the total cost in both the traditional routes from Rotterdam and New York through the Suez and Panama Channel, versus the alternative Arctic routes, we are also able to measure the respective ratio cost of the individual costs in relation to the total cost.

From this ratio calculation we are able to distinguish the largest individual costs. Two cost factors emerges as the most significant, the fuel and depreciation costs. The fuel cost represents between 23%- 57% of the total costs, fluctuating in relation to the voyage distance. The cost of depreciation ranges from 29% - 47%, also fluctuating according to the length of the voyage, as the straight line depreciation is divided on the calculated voyage time.

The individual costs ratios of the depreciation and fuel are the highest along the routes where there are no transit costs, being the NWP and TSR. Along the Suez-, Panama – Channel and NSR there are transit cost present, which is paid to the respective administrator authorities. This cost varies

according to the fee system. Along the Suez channel, the cost represents between 5,7% - 8,8% of the total cost. Along the Panama Channel the cost is between 11% - 14%, while along the NSR, the maximum cost of transiting ranges between 19% - 31 % of the total cost. The three major costs are the fuel cost, depreciation and transit costs, where the rest of the costs are small in relation to one of these cost.

### Cost Analysis with additional cost and risk of an arctic transit

The second set of calculations incorporated the additional cost risk and associated cost of sailing through the arctic yielding a more realistic end result. The additional cost of risk and associated costs are distinguished in the data collection. The individual cost factors that are a subject to an increase are the:

- Insurance
- Crew cost
- Maintenance

The first section of calculations, presented below, is the total costs of the voyages between Rotterdam – Asian ports. The first part is the baseline calculations of the traditional route through the Suez Channel. The following parts are the alternative three routes through the Arctic.

		Total		
From:	To:	OOCL Monteral:	Marinor:	Nordic Odyssey:
Rotterdam	Singapore	2363279	2313295	2294179
Rotterdam	Hong Kong	2504236	2455407	2431780
Rotterdam	Shanghai	2575361	2527116	2501212
Rotterdam	Tokyo	2651759	2604139	2575790

Table 9

Presents the total cost along the respective traditional and arctic routes with the additional cost and cost of risk added on the voyage between Rotterdam and the selected Asian ports.

		NWP		
Rotterdam	Singapore	2418605	2424753	2386577
Rotterdam	Hong Kong	2287607	2292667	2258687
Rotterdam	Shanghai	2211923	2216364	2184841
Rotterdam	Tokyo	2134834	2138647	2109549

		NSR		
Rotterdam	Singapore	3135499	3033229	3265707
Rotterdam	Hong Kong	3004502	2901142	3137853
Rotterdam	Shanghai	2928818	2824876	3063972
Rotterdam	Tokyo	2851728	2747122	2988715

		TSR		
Rotterdam	Singapore	2290856	2299412	2265918
Rotterdam	Hong Kong	2159859	2167361	2138064
Rotterdam	Shanghai	2084175	2091059	2064183
Rotterdam	Tokyo	2007086	2013306	1988927

As we can see from the table above, the NWP loses some of its attractiveness, where the utilisation of the NWP in a transit between Rotterdam and Singapore, costs more. The NWP retains its cost saving potential on all the other routes, though it decreases. The NSR continues to be unprofitable to sail in comparison to the traditional route. While the shortest route using the TSR, retains all its cost saving potential.

The following calculation is the total cost of the New York – Asian ports. As we can observe, the NWP and TSR still holds the cost saving attribute in comparison to the traditional route, while the NSR still remains unprofitable.

		<b>Total</b>		
<b>From:</b>	<b>To:</b>	<b>OOCL Monteral:</b>	<b>Marinor:</b>	<b>Nordic Odyssey:</b>
<b>New York</b>	<b>Singapore</b>	2956948	2931657	2959635
<b>New York</b>	<b>Hong Kong</b>	2684085	2656559	2693270
<b>New York</b>	<b>Shanghai</b>	2769535	2742709	2776685
<b>New York</b>	<b>Tokyo</b>	2836482	2810205	2842038

		<b>NWP</b>		
<b>New York</b>	<b>Singapore</b>	2400987	2416002	2380025
<b>New York</b>	<b>Hong Kong</b>	2269990	2283950	2252170
<b>New York</b>	<b>Shanghai</b>	2194306	2207648	2178289
<b>New York</b>	<b>Tokyo</b>	2117217	2129930	2103033

		<b>NSR</b>		
<b>New York</b>	<b>Singapore</b>	3409841	3312631	3533243
<b>New York</b>	<b>Hong Kong</b>	3278844	3180544	3405353
<b>New York</b>	<b>Shanghai</b>	3203160	3104242	3331472
<b>New York</b>	<b>Tokyo</b>	3126035	3026524	3256216

		<b>TSR</b>		
<b>New York</b>	<b>Singapore</b>	2512473	2528414	2488878
<b>New York</b>	<b>Hong Kong</b>	2381475	2396362	2360988
<b>New York</b>	<b>Shanghai</b>	2305791	2320060	2287107
<b>New York</b>	<b>Tokyo</b>	2228702	2242307	2211851

*Tabel 10*

Presents the total cost along the respective traditional and arctic routes with the additional cost and cost of risk added on the voyage between New York and the selected Asian ports.

## Slow speed

We know from the data collection that there is some significant time saving along most of the alternative arctic routes. This time saving allows us to implement the practice of slow speed, presented in the literature review, where the vessels speed is reduce by 20%. We add 20% to the calculated voyage time and observe the following transit times. From the results we can observe that we lose much of the time savings along the arctic routes.

Rotterdam – Asian ports

**Days:**

From:	To:	Nm:	OOCL Monteral:	Marinor:	Nordic Odyssey:
Rotterdam	Singapor	8389	28.4	28.7	27.74
Rotterdam	Hong Kong	9806	33.2	33.5	32.43
Rotterdam	Shanghai	10521	35.6	35.9	34.79
Rotterdam	Tokyo	11289	38.2	38.6	37.33

**NWP**

			Dif.%		Dif.%		Dif.%	
Rotterdam	Singapore	10399	42.3	13.9	42.6	14.0	41.3	13.5
Rotterdam	Hong Kong	9118	37.1	3.8	37.4	3.9	36.2	3.8
Rotterdam	Shanghai	8378	34.1	-1.6	34.3	-1.6	33.2	-1.5
Rotterdam	Tokyo	7624	31.0	-7.3	31.2	-7.3	30.3	-7.1

**NSR**

Rotterdam	Singapore	10095	41.0	12.6	41.4	12.7	40.1	12.3
Rotterdam	Hong Kong	8814	35.8	2.6	36.1	2.6	35.0	2.5
Rotterdam	Shanghai	8074	32.8	-2.8	33.1	-2.8	32.0	-2.8
Rotterdam	Tokyo	7320	29.8	-8.5	30.0	-8.6	29.0	-8.3

**TSR**

Rotterdam	Singapore	9209	37.4	9.0	37.7	9.1	36.5	8.8
Rotterdam	Hong Kong	7928	32.2	-1.0	32.5	-1.0	31.5	-1.0
Rotterdam	Shanghai	7188	29.2	-6.4	29.5	-6.5	28.5	-6.3
Rotterdam	Tokyo	6434	26.2	-12.1	26.4	-12.2	25.5	-11.8

New York – Asian ports

**Days:**

From:	To:	Nm:	OOCL Monteral:	Marinor:	Nordic Odyssey:
New York	Singapore	12572	42.59	42.94	41.57
New York	Hong Kong	9829	33.30	33.57	32.50
New York	Shanghai	10688	36.21	36.50	35.34
New York	Tokyo	11361	38.49	38.80	37.57

**NWP**

			Dif.%		Dif.%		Dif.%	
New York	Singapore	9971	40.5	-2.1	40.9	-2.1	39.6	-2.0
New York	Hong Kong	8690	35.3	2.0	35.6	2.0	34.5	2.0
New York	Shanghai	7950	32.3	-3.9	32.6	-3.9	31.5	-3.8
New York	Tokyo	7196	29.3	-9.2	29.5	-9.3	28.6	-9.0

**NSR**

New York	Singapore	12276	49.9	7.3	50.3	7.4	48.7	7.1
New York	Hong Kong	10995	44.7	11.4	45.1	11.5	43.6	11.1
New York	Shanghai	10255	41.7	5.5	42.0	5.5	40.7	5.4
New York	Tokyo	9501	38.6	0.1	38.9	0.1	37.7	0.1

**TSR**

New York	Singapore	10919	44.4	1.8	44.8	1.8	43.3	1.8
New York	Hong Kong	9638	39.2	5.9	39.5	5.9	38.2	5.7
New York	Shanghai	8898	36.2	-0.04	36.5	-0.04	35.3	-0.03
New York	Tokyo	8144	33.1	-5.4	33.4	-5.4	32.3	-5.3

Table 11

The voyage time along Rotterdam – Asia, the Arctic routes are adjusted for Slow Speed.

Table 12

The voyage time along the New York – Asia, Arctic, routes are adjusted for Slow Speed.

A reducing in the speed by 20% yields a 40% reduction in fuel consumption of the vessels. We know from the ratio calculation, that the fuel cost is one of the most significant costs along most of the routes, fluctuating in accordance with the distance needed to sail.

Slow speed on the other hand increases the time at sea; reducing the length one vessel is able to sail in comparison to the previous examples where the vessels are sailing in accordance with its average speed. The increase in the time needed for one trip, also increases the crew cost, in comparison to the previous examples.

The following calculation presents the total cost of sailing between the departing port of Rotterdam and the arriving Asian ports. The traditional route through the Suez Channel is calculated by using the average speed of the vessels.

Total				
From:	To:	OOCL Monteral:	Marinor:	Nordic Odyssey:
Rotterdam	Singapor	2363279	2313295	2294179
Rotterdam	Hong Kong	2504236	2455407	2431780
Rotterdam	Shanghai	2575361	2527116	2501212
Rotterdam	Tokyo	2651759	2604139	2575790

Table 13

The individual costs are adjusted for Slow Speed along the Arctic routes, Rotterdam – Asia.

NWP				
Rotterdam	Singapore	2027944	2036758	2009058
Rotterdam	Hong Kong	1944353	1952482	1927458
Rotterdam	Shanghai	1896065	1903798	1880320
Rotterdam	Tokyo	1846864	1854194	1832289

NSR				
Rotterdam	Singapore	2722418	2617212	2858149
Rotterdam	Hong Kong	2638827	2532936	2776548
Rotterdam	Shanghai	2590539	2484252	2729410
Rotterdam	Tokyo	2541338	2434647	2681380

TSR				
Rotterdam	Singapore	1914569	1925933	1904301
Rotterdam	Hong Kong	1830979	1841657	1822701
Rotterdam	Shanghai	1782691	1792973	1775563
Rotterdam	Tokyo	1733489	1743369	1727533

Due to the 40% decrease in fuel cost on every nautical mile, the impact on the total cost calculation is profound. From the calculation above we can observe that the NWP achieves cost savings along all its routes, and the TSR increases its cost saving potential. More interestingly the NSR starts yielding cost savings in comparison to the traditional Suez Channel route.

In the New York – Asia ports, we also see significant changes in the total cost comparison. The NWP and TSR continue to be cost saving routes. The NSR starts having a cost saving potential, though under no circumstances for the vessel Nordic Odyssey.

Total				
From:	To:	OOCL Monteral:	Marinor:	Nordic Odyssey:
New York	Singapore	2905380	2879668	2909296
New York	Hong Kong	2632518	2604569	2642931
New York	Shanghai	2717968	2690719	2726346
New York	Tokyo	2784915	2758215	2791699

Table 14

The individual costs are adjusted for Slow Speed along the Arctic routes, New York – Asia.

NWP				
New York	Singapore	2031990	2044004	2019833
New York	Hong Kong	1948399	1959728	1938233
New York	Shanghai	1900111	1911044	1891095
New York	Tokyo	1850910	1861440	1843065

NSR				
New York	Singapore	2924091	2822902	3059058
New York	Hong Kong	2840501	2738626	2977457
New York	Shanghai	2792213	2689943	2930319
New York	Tokyo	2743011	2640338	2882289

TSR				
New York	Singapore	2080918	2093333	2067596
New York	Hong Kong	1997327	2009057	1985996
New York	Shanghai	1949039	1960374	1938858
New York	Tokyo	1899838	1910769	1890828

From the literature review it was determined that the NSR is only open for 80 days. Utilising a shorter route will allow the shipping vessels to cover a larger amount of nautical miles over one year. Along the NSR connecting Rotterdam and Tokyo, the vessels are close of being able to make one additional transit during the 80 days, in comparison to the traditional route (Table 11 & 12).

(Though the most values and results are presented in this thesis, because of the extensive size of the Excel calculation, all calculations and results have not been possible to present in this paper form. A CD with the excel calculations will follow this thesis, or will be made available upon request via: alexander.nilsen@gmail.com)

## Analysis and Discussion

The calculations have yielded very interesting results, which needs some further analysis and reflections, in order to make a rational and reflected conclusion of this thesis, and we start by analysing the results from the first set of calculations where there are no additional costs attached to the risk, nor other additional costs of sailing through the Arctic.

Looking at the first set of calculation, starting with the Rotterdam and New York traditional routes to the Asian ports versus the new Arctic routes, there are several issues and aspects that need to be analysed. First of all, it is only the NWP and TSR that present a cost saving potential for the Arctic transit alternative, while the NSR costs more in all accounts.

An interesting result for two reasons, first the NWP and TSR are not of subject to a transit cost such as the NSR, for good reasons, as presented in the literature review, the NWP and TSR is not open for commercial transits such as the NSR. The NWP is expected to be the last arctic seaway to be completely free of ice, and until this point in time, the passage will be of high-risk to drift ice, which will make the passage very difficult to navigate. It is known that some voyages are made through the NWP, but they are more of research and community supply efforts then for commercial operations. The TSR on its side will be free of ice sooner than the NWP, but as shown in the CGM's not to happen until around the mid-century. Currently the TSR has only been partially transited by an Ice Breaker on the peak of the summer 2004, only to return in the same pathway it created after reaching the North Pole.

The shipping activity along the NWP and TSR is so restrictive due to the climate conditions, that any commercial shipping operations along these routes would need ice breaker support, such as found along the NSR. Though the NWP and TSR currently has no transit cost which is fixed such as found along the traditional routes and NSR, this does not mean that the passages are viable for transit, which the NSR is. If and when the NWP and TSR opens for commercial shipping it is further difficult to argue that they will continue to remain free of transit costs, as they would need investments in navigation, surveillance and communication infrastructure which the NSR is currently investing in. In extent making any calculations on the NWP and TSR become irrelevant, until further data is available.

The second interesting aspect of the first set calculation comes from the ratio calculation, where the cost of depreciation and fuel cost are distinguished as the largest costs associated with an arctic transit. The fuel cost is the most interesting cost of the two, as it is the only one which is a subject to a large change due to a change in the voyage route.

In the second set of calculations, the additional cost of sailing through the arctic and risk is applied to the voyages through the Arctic, and we observe a further deterioration of the cost saving potential along all the routes. Where some routes starts yielding a higher cost level than the traditional. For clean presentation done in such a manor to highlight the effect in impose on the total cost. Secondly, by doing so we are able to obtain the cost of the additional Arctic cost of the risk, maintenance and crew cost (Table 14).

NSR		OOCL Monteral	Marinor	Nordic Odyssey
Rotterdam	Singapore	0.042	0.045	0.043
Rotterdam	Hong Kong	0.042	0.046	0.043
Rotterdam	Shanghai	0.043	0.047	0.044
Rotterdam	Tokyo	0.043	0.047	0.044

Table 15

Cost increase in percentage of the additional costs and cost of risk for a voyage through the arctic following designated routes.

NSR				
New York	Singapore	0.061	0.061	0.061
New York	Hong Kong	0.063	0.063	0.062
New York	Shanghai	0.064	0.064	0.064
New York	Tokyo	0.065	0.065	0.065

What we can conclude from this table is that the impact of the additional arctic related costs is small in comparison to the ratio cost associated to each cost.

The vast time savings associated with an Arctic transit from the departing port of Rotterdam or New York to its arriving destinations in Asia are so profound, that the vessels are able to travel 20% slower than along the traditional route, reducing the fuel consumption by 40%. We are aware of the major impact of the fuel cost on the total cost, where any change in this cost will have profound impact on the total cost.

Looking at the slow speed results, we see that the only realistic alternative, the NSR, becomes partially profitable in comparison with the traditional route between the departing ports of Rotterdam and New York ports and its voyage to the Asian destination ports.

By further applying the time saving of the slow speed (Table 11 and 12), we can observe that even with a reduction of 20% in the sailing speed, some vessels are still able to arrive at the destination before, or marginally later than if they used the traditional route. For example the voyage between New York – Tokyo using the NSR under slow speed, yields a cost saving (Table 13 & 14), while the vessel arrives 0.1 (2 hours and 24 minutes) day latter then along the traditional route. This is a relatively small difference, where we could argue that the vessel could utilize the route due to the cost saving. Another alternative could be for the vessels to sail in the time difference, using some more fuel. The Slow speed implementation reduces the amounts of trips through the arctic the

vessel is able to take, but comparing it to the alternative, along the traditional route, it is still preferable along the described routes that also yield a cost saving.

One curtail factor to keep in mind is that the transit cost along the NSR is in this calculation set at the maximum level, in extent meaning that the vessel in question probably receives an escort through the NSR. During the peak of summer it is highly likely that this cost will be lower than the maximum fee, allowing for the less cost intensive voyage along a larger number of NSR routes.

In addition, the production cost of an arctic classified vessel needs to be considered. It is assumed that these vessels are 65% higher than a normal vessel. Though the vessel production cost is higher, the need for arctic classified vessels will increase, possibly creating a secondary charter index covering the additional cost, due to the expected increase in shipping demand from Oil and Gas installations as well as of new exposed mineral mines (Appendix 1).

## **Prospective**

In this analysis it also becomes important to acknowledge the development that is likely to occur along the arctic routes, as most of the potential of the route is in the future. In the literature review and data collection, it was determined that all arctic routes would be open for voyages during the mid-century. From the results yielding in the two last calculations, with additional cost and cost of risk and slow speed, it becomes apparent that the maximum rate along the NSR has the possibility to almost/or fully eliminate the cost saving potential along the route. From the calculations we know that the additional cost of sailing through the arctic only range between 4.2% and 6.5% of the total cost, in relation to the 18%-29% of the total cost sailing through NSR. In the Slow speed calculation, one can observe that the voyages to the closest Asian ports via the arctic route, becomes profitable along the NSR, on a maximum transit fee.

It is reasonable to assume that the pricing of the transit fee is established in an effort to be the same or marginally less than what would be the total cost along the traditional routes. As has been clearly emphasised, the NSR fee is the maximum fee that can be claimed by the Atomflot, where it is reasonable to assume that the fee during the peak summer will be lower, increasing the cost saving potential for several routes through the NSR. The further north, up along the TSR vessels sail, the shorter the route becomes, and this is expected as the dynamics effect of the sea ice makes the sea ice cover expand and contract in relation to the season. Though as long as the operations are within the Russian defined sea, a request must be filed and a transit fee most likely charged, though as long as the vessels are within the Russian waters a transit fee will have to be assumed.

The question that presents itself in that relation is what competitive margin the Panama and Suez Channel is operating with, and how much the respective channel route is able to compete against a significant lower NSR transit fee. As with the NSR, the pricing of the Channel transits are probably established on the bases on the alternative cost of sailing either around Africa or South America.

With the future development of the TSR and NWP, it highly unlikely that these routes will continue to be free of transit charges, as they will need investments in infrastructure and mapping surveys as well as the establishments of emergency services. It is therefore possible to see the transit fees along the TSR and NWP in the range of the NSR fee, if not higher as the need of investments would be higher than along the NSR which has already started investing in the infrastructure needed for the facilitation of commercial shipping.

## Research Limitations

Before concluding this thesis it is necessary to highlight and acknowledge the limitations of the study. The first notion is that the scope of this study is only applicable to the commercial shipping sector, and applicable for vessels of subject. Though the results can be applied to other point of arrival and the departure, they are in this thesis only representable from the ports of subject.

Secondly, though the vessels within the study are from different companies, this is not done to compare the companies, but to highlight the difference of vessel types, and the results of each vessel should singlehandedly should not be compared.

Third, all sources are available or attainable for individual whom wish to access them, and all inquiries that may arise in connection to the collected values and sources will be on request. Because of limited access to sector market information, these values are based on some valuation principles which are argument for and justified, whereas market data would produce a more précises result.

Fourth, the thesis is off subject to certain assumptions, defined when the assumption is put forward, where it necessary for the reader to acknowledge these assumptions. Finally this thesis has been a subject to time restrictions, limiting its depth.

## Future research

The overall topic of transarctic voyages is interesting on many levels, such as environmental, community impact, as well as the impact on existing transit routes due to a shift in sailing patters, or if there is any at all. Relating to the results obtained in this thesis, a reproduction of this thesis with market insurance data would be strongly recommended in order to yield comparable results.

A second topic that would be of interest of further research is the one off which operational margins the different transitory authorities are operating with, and which competitive measures they can implement. Because of the amount of oil and gas reserves in the north, it is expected to see a lot of the traffic in the region to be of tankers. Therefor research regarding the environmental impact of an oil spill in the region would be appropriate.

When the, and if the TSR and NWP opens for transit, it would be interesting to do the conduct a new study to uncover their competitive abilities in comparison to the NSR, which would have had a decade or so to improve and develop its supporting transit features.

## Conclusion

With the documented climate changes in the Arctic, the highly restrictive arctic sea ice cover is diminishing at an astonishing rate, where it is expected that there will be an ice free arctic within 2050. The diminishing and eventual disappearance of the sea ice over allows for passage of commercial shipping vessels through the previously un-navigational Ocean.

In order to obtain and establish the cost factors associated with a commercial voyage, data was collected on the vessels OOCL Montreal (Container), Marinor (Tanker) and Nordic Odyssy (Dry Bulk), as well as distance measurements. The identified cost factors identified with commercial voyages through the traditional routes and arctic routes are:

- Fuel cost
- Lubrication oil cost
- Crew cost
- H&M and P&I insurance
- Maintenance cost
- Transit cost (max. fee)

Three sets of calculations were made. The first one was based on the factor costs with no additional cost of transit or cost of risk associated to sailing in the arctic. The first calculation showed that only the TSR and NWP presented a cost saving potential versus the traditional routes through the Panama- and Suez- Channel. The NSR becomes unprofitable because of the applied maximum transit fee along the NSR.

The second set of calculations incorporates an added cost in insurance, maintenance and crew cost, where all arctic routes becomes more costly, while only one route combination, the NWP Rotterdam – Singapore, becomes unprofitable in addition to the NSR versus the traditional routes. What differentiates the profitable NWP and TSR from the unprofitable NEP is that there is no transit fee along the NWP and TSR, which is a major cost for sailing along the NSR.

The major time saving of sailing along the NSR allows the arctic traveling vessels to use slow speeds, which is a reduction in 20% in speed, resulting in a 40% lower fuel consumption, while still being able to save some time along the shortest routes ( NSR: Rotterdam – Tokyo). Slow speed make the NSR less costly versus the traditional route, see table 13 and 14, where 3 route combinations along the Rotterdam – Asia connection, and 4 routes along the New York – Asia connection, even with the maximum transit fee of sailing along the NSR.

Since an alternative route however is assumed to also yield a reduction in voyage time, all of the New York route options can be disregarded as a commercial alternative. The New York - Tokyo route option however only need 0.1 days = 2 hours and 24 minutes longer to save 41,903.87 USD for OOCL Montreal and 117,877.20 USD for Marinor. The marginal time difference is not enough to offset this

route as a commercial viable alternative to the traditional Panama channel route. Along the two, NSR, Rotterdam – Asia connection, there is both a time and cost saving, giving the arctic route the commercial strength.

Currently, only the Rotterdam/New York – Tokyo through the NSR for OOCL Montreal and Marinor provides a cost saving opportunity, even with the maximum transit fee along the NSR, In the future the NWP and TSR will become ice free, opening for commercial operations. Though the NWP and TSR are currently without a transit fee, it is unlikely that this will be the case in the future as both routes need investments in infrastructure.

*Though the most values and results are presented in this thesis, because of the extensive size of the Excel calculation, all calculations and results have not been possible to present in this paper form. A CD with the excel calculations will follow this thesis, or will be made available upon request via: [alexander.nilsen@gmail.com](mailto:alexander.nilsen@gmail.com)*

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## Annex – Excel

Results that does not appear in the main text.

Cost of Fuel											
From:	To:	Nm:	OOCL Montera:	Marinor:	ordic Odyssey:	From:	To:	Nm:	OOCL Montera	Marinor:	ordic Odyssey
Rotterdam	Singapor	8389	756,645.1	762,847.2	738,629.8	New York	Singapore	12572	1,133,930.5	1,143,225.0	1,106,932.1
Rotterdam	Hong Kong	9806	884,451.3	891,700.9	863,393.0	New York	Hong Kong	9829	886,525.8	893,792.4	865,418.1
Rotterdam	Shanghai	10521	948,940.7	956,718.9	926,346.9	New York	Shanghai	10688	964,003.3	971,904.9	941,050.8
Rotterdam	Tokyo	11289	1,018,210.4	1,026,556.4	993,967.3	New York	Tokyo	11361	1,024,704.4	1,033,103.6	1,000,306.7
NWP						NWP					
Rotterdam	Singapore	10399	937,936.9	945,624.9	915,605.1	New York	Singapore	9971	899,333.5	906,705.1	877,920.8
Rotterdam	Hong Kong	9118	822,397.2	829,138.2	802,816.4	New York	Hong Kong	8690	783,793.8	790,218.4	765,132.1
Rotterdam	Shanghai	8378	755,653.0	761,846.9	737,661.3	New York	Shanghai	7950	717,049.6	722,927.0	699,977.0
Rotterdam	Tokyo	7624	687,646.0	693,282.5	671,273.5	New York	Tokyo	7196	649,042.6	654,362.6	633,589.2
NSR						NSR					
Rotterdam	Singapore	10095	910,517.7	917,980.9	888,838.7	New York	Singapore	12276	1,107,232.8	1,116,308.5	1,080,870.1
Rotterdam	Hong Kong	8814	794,978.0	801,494.2	776,049.9	New York	Hong Kong	10995	991,693.1	999,821.7	968,081.4
Rotterdam	Shanghai	8074	728,233.7	734,202.9	710,894.8	New York	Shanghai	10255	924,948.9	932,530.4	902,926.3
Rotterdam	Tokyo	7320	660,226.8	665,638.5	644,507.1	New York	Tokyo	9501	856,941.9	863,966.0	836,538.5
TSR						TSR					
Rotterdam	Singapore	9209	830,605.0	837,413.2	810,828.7	New York	Singapore	10919	984,838.3	992,910.7	961,389.7
Rotterdam	Hong Kong	7928	715,065.3	720,926.5	698,039.9	New York	Hong Kong	9638	869,298.6	876,424.0	848,601.0
Rotterdam	Shanghai	7188	648,321.1	653,635.2	632,884.8	New York	Shanghai	8898	802,554.4	809,132.7	783,445.9
Rotterdam	Tokyo	6434	580,314.1	585,070.8	566,497.1	New York	Tokyo	8144	734,547.4	740,568.3	717,058.2

Insurance calculations

H&M Suez vs. Arctic				No Associated Risk			Arctic			
Vessels	Value	Insurance	Insurance	Suez avrag	NSR	NWP	TSR	NSR	NWP	TSR
OOCL Montreal	110000000	550000		51051.41	43774.94	45326.71	39252.35	56907.43	58924.72	51028.06
Marinor	110000000	550000		51469.87	44133.75	45698.24	39574.09	57373.88	59407.71	51446.32
Nordic Odyssey	110000000	550000		49835.9	42732.68	44247.5	38317.77	55552.49	57521.76	49813.1
H&M Panama vs. Arctic				No Associated Risk			Arctic			
Vessels	Value	Insurance	Insurance	Panama a	NSR	NWP	TSR	NSR	NWP	TSR
OOCL Montreal	110000000	550000		56723.79	54907.86	41189.94	47981.05	71380.22	53546.92	62375.37
Marinor	110000000	550000		57188.74	55357.93	41527.56	48374.34	71965.31	53985.83	62886.64
Nordic Odyssey	110000000	550000		55373.22	53600.53	40209.22	46838.65	69680.69	52271.99	60890.24
P&L				No Associated Risk			Arctic			
Vessels	Value	Insurance	Insurance	Suez avrag	NSR	NWP	TSR	NSR	NWP	TSR
OOCL Montreal	100000000	500000		46410.37	39795.4	41206.1	35683.96	60333.49	51734.02	53567.93
Marinor	53759069.3	500000		48904.23	37445.4	41543.86	35976.45	63575.5	48679.02	54007.01
Nordic Odyssey	4965000	500000		50604.19	35717.6	40225	34834.34	65785.44	46432.88	52292.5
P&L				No Associated Risk			Arctic			
Vessels	Value	Insurance	Insurance	Panama a	NSR	NWP	TSR	NSR	NWP	TSR
OOCL Montreal	100000000	500000		51567.08	49916.24	39219.99	43619.14	64891.11	50985.98	56704.88
Marinor	53759069.3	500000		51989.76	50325.39	39541.46	43976.67	65423.01	51403.9	57169.67
Nordic Odyssey	4965000	500000		50339.29	48727.76	38286.18	42580.59	63346.09	49772.03	55354.76

The Commercial Viability Of The Arctic Sea Routes

Crew Cost																	
		OOCL Monteral:		Marinor:		Nordic Odyssey:				OOCL Monteral:		Marinor:		Nordic Odyssey:			
		Days:	Cost	Days:	Cost	Days:	Cost			Days:	Cost	Days:	Cost	Days:	Cost		
From:	To:	Nm:							From:	To:	Nm:						
Rotterdam	Singapor	8389.0	28.4	77857.6	28.7	78495.8	27.7	76003.8	New York	Singapore	12572.0	42.6	116679.7	42.9	117636.1	41.6	113901.6
Rotterdam	Hong Kong	9806.0	33.2	91008.6	33.5	91754.6	32.4	88841.8	New York	Hong Kong	9829.0	33.3	91222.1	33.6	91969.8	32.5	89050.2
Rotterdam	Shanghai	10521.0	35.6	97644.5	35.9	98444.9	34.8	95319.6	New York	Shanghai	10688.0	36.2	99194.4	36.5	100007.5	35.3	96832.6
Rotterdam	Tokyo	11289.0	38.2	104772.2	38.6	105631.0	37.3	102277.7	New York	Tokyo	11361.0	38.5	105440.5	38.8	106304.7	37.6	102930.0
NWP									NWP								
Rotterdam	Singapore	10399.0	35.2	96512.2	35.5	97303.3	34.4	94214.3	New York	Singapore	9971.0	33.8	92540.0	34.1	93298.5	33.0	90336.7
Rotterdam	Hong Kong	9118.0	30.9	84623.4	31.1	85317.0	30.2	82608.5	New York	Hong Kong	8690.0	29.4	80651.1	29.7	81312.2	28.7	78730.9
Rotterdam	Shanghai	8378.0	28.4	77755.5	28.6	78392.8	27.7	75904.2	New York	Shanghai	7950.0	26.9	73783.3	27.2	74388.1	26.3	72026.5
Rotterdam	Tokyo	7624.0	25.8	70757.7	26.0	71337.7	25.2	69073.0	New York	Tokyo	7196.0	24.4	66785.5	24.6	67332.9	23.8	65195.3
NSR									NSR								
Rotterdam	Singapore	10095.0	34.2	93690.8	34.5	94458.8	33.4	91460.1	New York	Singapore	12276.0	41.6	113932.5	41.9	114866.4	40.6	111219.8
Rotterdam	Hong Kong	8814.0	29.9	81802.0	30.1	82472.5	29.1	79854.3	New York	Hong Kong	10995.0	37.2	102043.7	37.6	102880.1	36.4	99614.0
Rotterdam	Shanghai	8074.0	27.4	74934.1	27.6	75548.3	26.7	73150.0	New York	Shanghai	10255.0	34.7	95175.8	35.0	95955.9	33.9	92909.7
Rotterdam	Tokyo	7320.0	24.8	67936.3	25.0	68493.2	24.2	66318.8	New York	Tokyo	9501.0	32.2	88178.0	32.4	88900.7	31.4	86078.5
TSR									TSR								
Rotterdam	Singapore	9209.0	31.2	85467.9	31.5	86168.5	30.5	83433.0	New York	Singapore	10919.0	37.0	101338.3	37.3	102168.9	36.1	98925.5
Rotterdam	Hong Kong	7928.0	26.9	73579.1	27.1	74182.2	26.2	71827.2	New York	Hong Kong	9638.0	32.6	89449.5	32.9	90182.6	31.9	87319.7
Rotterdam	Shanghai	7188.0	24.3	66711.2	24.5	67258.0	23.8	65122.9	New York	Shanghai	8898.0	30.1	82581.6	30.4	83258.5	29.4	80615.4
Rotterdam	Tokyo	6434.0	21.8	59713.4	22.0	60202.9	21.3	58291.7	New York	Tokyo	8144.0	27.6	75583.8	27.8	76203.3	26.9	73784.2

# The Commercial Viability Of The Arctic Sea Routes

## First calculation ratios

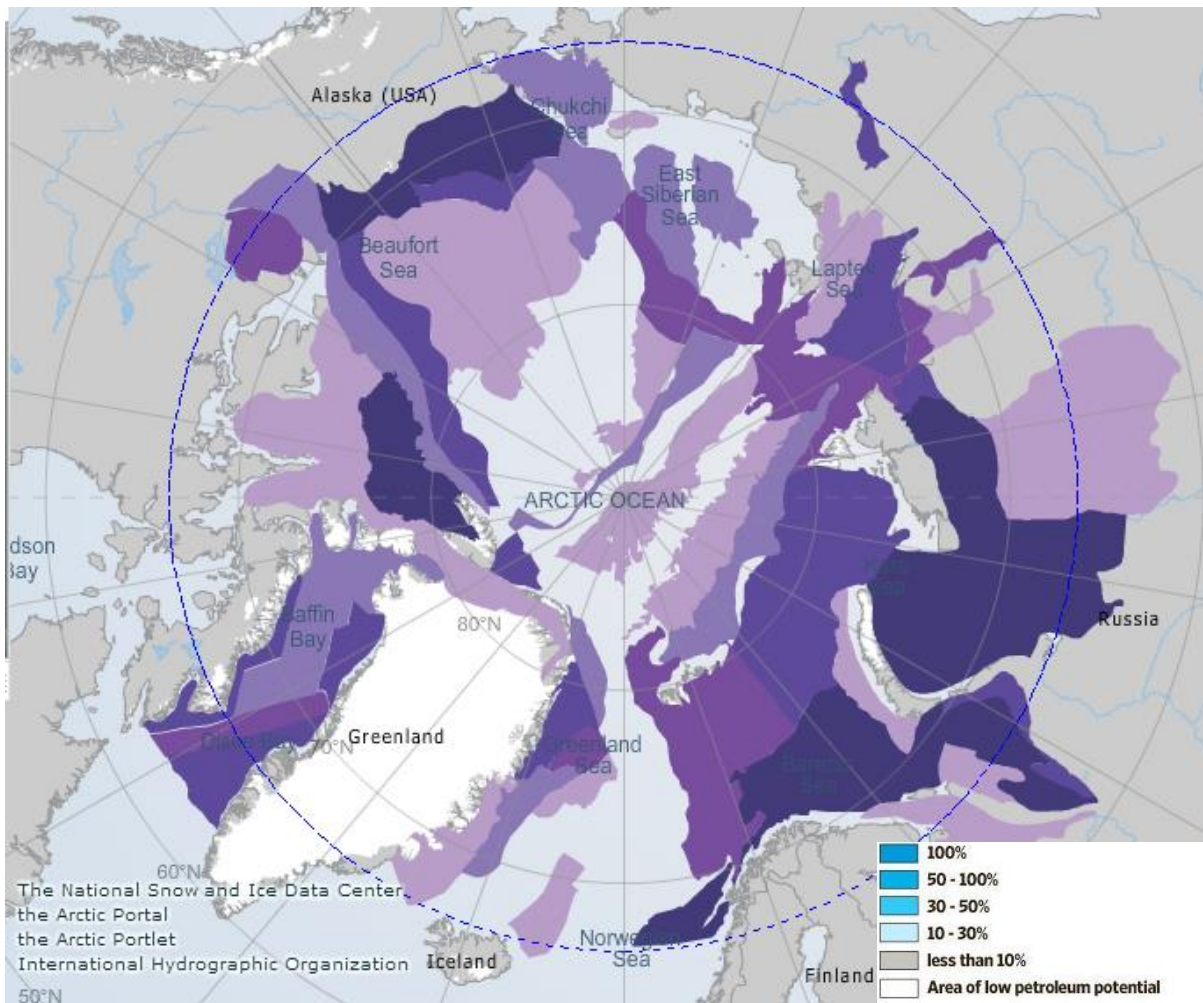
		Fuel cost			Lubrication			H&L and P&I Insurance			Crew Cost			Maintenance			Depreciation			Transit cost		
From:	To:	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od
Rotterdam	Singapore	0.320168	0.329767	0.321958	0.007393	0.007553	0.007616	0.04124	0.04339	0.04378	0.032945	0.033932	0.033129	0.107448	0.109769	0.110684	0.402156	0.410846	0.414269	0.088651	0.064743	0.068564
Rotterdam	Hong Kong	0.353182	0.363158	0.355046	0.006977	0.007116	0.007185	0.038919	0.040879	0.041303	0.036342	0.037368	0.036534	0.1014	0.103416	0.104421	0.37952	0.387067	0.390828	0.083661	0.060996	0.064684
Rotterdam	Shanghai	0.368469	0.378581	0.370359	0.006784	0.006914	0.006985	0.037844	0.039719	0.040157	0.037915	0.038955	0.038109	0.098599	0.100482	0.101522	0.369038	0.376084	0.379979	0.08135	0.059265	0.062888
Rotterdam	Tokyo	0.383975	0.394202	0.385888	0.006589	0.006709	0.006783	0.036754	0.038544	0.038994	0.03951	0.040563	0.039707	0.095759	0.09751	0.098583	0.358406	0.36496	0.368977	0.079007	0.057512	0.061068
NWP																						
Rotterdam	Singapore	0.407503	0.409209	0.402467	0.007591	0.007561	0.00768	0.037596	0.037753	0.037131	0.041931	0.042107	0.041413	0.092459	0.092091	0.093544	0.41292	0.411279	0.417765			
Rotterdam	Hong Kong	0.378245	0.379923	0.373301	0.008036	0.008006	0.008124	0.039799	0.039976	0.039279	0.038921	0.039093	0.038412	0.097878	0.097513	0.098954	0.437121	0.43549	0.441929			
Rotterdam	Shanghai	0.359727	0.361378	0.354862	0.008318	0.008288	0.008405	0.041194	0.041383	0.040637	0.037015	0.037185	0.036515	0.101308	0.100945	0.102375	0.452439	0.450821	0.457206			
Rotterdam	Tokyo	0.339473	0.34109	0.334715	0.008625	0.008596	0.008712	0.042719	0.042922	0.04212	0.034931	0.035098	0.034442	0.105059	0.104701	0.106113	0.469192	0.467593	0.473898			
NSR																						
Rotterdam	Singapore	0.302511	0.316363	0.283834	0.005805	0.006021	0.005579	0.027765	0.028115	0.025052	0.031128	0.032553	0.029206	0.070704	0.073341	0.067957	0.315764	0.327538	0.303494	0.246323	0.216069	0.284878
Rotterdam	Hong Kong	0.2758	0.289015	0.258068	0.006062	0.0063	0.00581	0.028993	0.029417	0.026088	0.028379	0.029739	0.026555	0.07383	0.076738	0.070768	0.329723	0.342712	0.316049	0.257213	0.226079	0.296663
Rotterdam	Shanghai	0.259266	0.27203	0.242189	0.00622	0.006474	0.005952	0.029753	0.030226	0.026727	0.026678	0.027991	0.024921	0.075765	0.078848	0.0725	0.338364	0.352136	0.323786	0.263954	0.232296	0.303925
Rotterdam	Tokyo	0.241503	0.253735	0.225189	0.006391	0.00666	0.006105	0.030569	0.031097	0.02741	0.02485	0.026109	0.023172	0.077843	0.081121	0.074355	0.347648	0.362286	0.332069	0.271195	0.238992	0.311701
TSR																						
Rotterdam	Singapore	0.382468	0.384166	0.377463	0.008045	0.008015	0.008134	0.034506	0.034659	0.034054	0.039355	0.03953	0.03884	0.097992	0.097627	0.099069	0.437633	0.436002	0.44244			
Rotterdam	Hong Kong	0.34979	0.35144	0.344931	0.008547	0.008517	0.008634	0.036657	0.03683	0.036148	0.035993	0.036163	0.035493	0.104101	0.103742	0.105158	0.464913	0.463308	0.469636			
Rotterdam	Shanghai	0.328987	0.330597	0.324249	0.008866	0.008837	0.008952	0.038026	0.038212	0.037478	0.033852	0.034018	0.033365	0.107989	0.107636	0.10903	0.482279	0.4807	0.486927			
Rotterdam	Tokyo	0.306129	0.307687	0.301548	0.009217	0.009188	0.0093	0.039531	0.039732	0.038939	0.0315	0.03166	0.031029	0.112262	0.111916	0.113279	0.501361	0.499816	0.505904			
Fuel cost																						
Lubrication																						
Insurance																						
Crew Cost																						
Maintenance																						
Depreciation																						
Transit cost																						
From:	To:	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od
New York	Singapore	0.38348	0.389959	0.37401	0.003939	0.00596	0.005903	0.036623	0.037241	0.035718	0.039459	0.040126	0.038485	0.095417	0.09624	0.09533	0.321415	0.324188	0.321123	0.119667	0.106287	0.129431
New York	Hong Kong	0.33029	0.336447	0.321326	0.00434	0.006577	0.006487	0.040346	0.041098	0.039251	0.033986	0.03462	0.033064	0.105117	0.106206	0.104759	0.35409	0.357759	0.352882	0.131832	0.117293	0.142231
New York	Shanghai	0.348074	0.354359	0.338912	0.004206	0.00637	0.006292	0.039101	0.039807	0.038071	0.035816	0.036463	0.034873	0.101874	0.10287	0.101611	0.343165	0.346521	0.342281	0.127765	0.113609	0.137958
New York	Tokyo	0.361259	0.367626	0.351968	0.004106	0.006217	0.006148	0.038178	0.038851	0.037196	0.037173	0.037828	0.036217	0.099469	0.100399	0.099275	0.335065	0.338199	0.33441	0.124749	0.11088	0.134786
NWP																						
New York	Singapore	0.395058	0.395756	0.38902	0.005117	0.007626	0.007742	0.035322	0.035385	0.034782	0.040651	0.040723	0.04003	0.106357	0.105679	0.107286	0.417494	0.414831	0.42114			
New York	Hong Kong	0.36472	0.365403	0.35882	0.00542	0.008079	0.008194	0.037417	0.037487	0.036812	0.037529	0.037599	0.036922	0.112664	0.111957	0.113545	0.44225	0.439475	0.445708			
New York	Shanghai	0.345497	0.346166	0.339713	0.005612	0.008366	0.00848	0.038744	0.038819	0.038095	0.035551	0.03562	0.034956	0.11666	0.115936	0.117505	0.457936	0.455093	0.461252			
New York	Tokyo	0.324455	0.325107	0.318823	0.005823	0.008681	0.008792	0.040197	0.040278	0.039499	0.033386	0.033453	0.032806	0.121034	0.120292	0.121834	0.475106	0.472191	0.478246			
NSR																						
New York	Singapore	0.338442	0.351724	0.318228	0.00356	0.005505	0.005144	0.032041	0.033298	0.030127	0.034825	0.036192	0.032745	0.074007	0.076286	0.071284	0.290506	0.299452	0.279817	0.226619	0.197542	0.262654
New York	Hong Kong	0.315411	0.328312	0.295856	0.003705	0.005737	0.00534	0.03334	0.034703	0.031273	0.032455	0.033783	0.030443	0.077006	0.079504	0.073994	0.302279	0.312085	0.290455	0.235804	0.205875	0.272639
New York	Shanghai	0.301235	0.313864	0.28214	0.003793	0.005881	0.00546	0.034139	0.03557	0.031975	0.030997	0.032296	0.029032	0.078852	0.08149	0.075655	0.309526	0.319881	0.296977	0.241457	0.211018	0.278761
New York	Tokyo	0.286075	0.298381	0.267517	0.003888	0.006034	0.005587	0.034994	0.036499	0.032724	0.029437	0.030703	0.027527	0.080827	0.083619	0.077427	0.317276	0.328235	0.303931	0.247503	0.216529	0.285288
TSR																						
New York	Singapore	0.413459	0.414157	0.407415	0.00489	0.007288	0.007456	0.040056	0.040894	0.042544	0.042616	0.041922	0.101647	0.100991	0.102604	0.399004	0.396428	0.402761				
New York	Hong Kong	0.38558	0.386268	0.37963	0.005167	0.0077	0.007816	0.04063	0.040702	0.040003	0.039676	0.039746	0.039063	0.107392	0.106709	0.108314	0.421556	0.418874	0.425174			
New York	Shanghai	0.367991	0.368669	0.362123	0.005341	0.007961	0.008076	0.042001	0.042078	0.041331	0.037866	0.037935	0.037262	0.111017	0.110318	0.111912	0.435785	0.433039	0.439296			
New York	Tokyo	0.348804	0.34947	0.343048	0.005531	0.008245	0.008359	0.043497	0.04358	0.042779	0.035891	0.03596	0.035299	0.114971	0.114254	0.115832	0.451306	0.448491	0.454684			

# The Commercial Viability Of The Arctic Sea Routes

## Second calculation ratios

		Fuel cost				Lubrication				H&L and P&I Insurance				Crew Cost				Maintenance				Depreciation				Transit cost						
From:	To:	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od				
Rotterdam	Singapore	0.320168	0.329767	0.321958	0.007393	0.007553	0.007616	0.04124	0.04339	0.04378	0.032945	0.033932	0.033129	0.107448	0.109769	0.110684	0.402156	0.410846	0.414269	0.088651	0.064743	0.068564										
Rotterdam	Hong Kong	0.353182	0.363158	0.355046	0.006977	0.007116	0.007185	0.038919	0.040879	0.041303	0.036342	0.037368	0.036534	0.1014	0.103416	0.104421	0.37952	0.387067	0.390828	0.083661	0.060996	0.064684										
Rotterdam	Shanghai	0.368469	0.378581	0.370359	0.006784	0.006914	0.006985	0.037844	0.039719	0.040157	0.037915	0.038955	0.038109	0.098599	0.100482	0.101522	0.369038	0.376084	0.379979	0.08135	0.059265	0.062888										
Rotterdam	Tokyo	0.383975	0.394202	0.385888	0.006589	0.006709	0.006783	0.036754	0.038544	0.038994	0.03951	0.040563	0.039707	0.095759	0.09751	0.098583	0.358406	0.36496	0.368977	0.079007	0.057512	0.061068										
NWP																																
Rotterdam	Singapore	0.387801	0.389988	0.383648	0.007224	0.007206	0.007321	0.045753	0.044576	0.043558	0.05188	0.052174	0.051322	0.114385	0.114095	0.11592	0.392957	0.39196	0.39823													
Rotterdam	Hong Kong	0.359501	0.361648	0.355435	0.007638	0.007621	0.007735	0.048373	0.047145	0.046024	0.048094	0.048376	0.047542	0.120936	0.120669	0.122484	0.415459	0.414542	0.420779													
Rotterdam	Shanghai	0.341627	0.343737	0.337627	0.007899	0.007883	0.007997	0.050028	0.048768	0.04758	0.045698	0.045976	0.045172	0.125074	0.124823	0.126624	0.429675	0.428814	0.435001													
Rotterdam	Tokyo	0.322107	0.324169	0.318207	0.008184	0.00817	0.008282	0.051835	0.05054	0.049278	0.043093	0.043366	0.042563	0.12959	0.129359	0.131143	0.44519	0.444397	0.450526													
NSR																																
Rotterdam	Singapore	0.29039	0.302641	0.272173	0.005572	0.005576	0.005535	0.037391	0.039875	0.037155	0.038848	0.040487	0.036405	0.088233	0.091207	0.084715	0.303112	0.313332	0.291026	0.236454	0.206698	0.273175										
Rotterdam	Hong Kong	0.264596	0.276268	0.247319	0.005815	0.006022	0.005568	0.039022	0.04169	0.038669	0.035397	0.036953	0.033087	0.09208	0.09536	0.088166	0.316328	0.327598	0.302885	0.246763	0.216108	0.284306										
Rotterdam	Shanghai	0.248644	0.259906	0.232017	0.005966	0.006185	0.005702	0.04003	0.042816	0.039602	0.033259	0.034773	0.031037	0.094459	0.097935	0.090292	0.324502	0.336442	0.310188	0.25314	0.221943	0.291162										
Rotterdam	Tokyo	0.231518	0.242304	0.215647	0.006127	0.00636	0.005846	0.041112	0.044028	0.040599	0.030974	0.032412	0.028851	0.097012	0.100706	0.092566	0.333274	0.345965	0.317999	0.259983	0.228225	0.298493										
TSR																																
Rotterdam	Singapore	0.362574	0.364186	0.357837	0.007627	0.007598	0.007711	0.045658	0.045861	0.045061	0.048507	0.048714	0.047862	0.120764	0.120315	0.122093	0.41487	0.413326	0.419436													
Rotterdam	Hong Kong	0.33107	0.332629	0.326482	0.008089	0.008061	0.008172	0.048427	0.048655	0.047756	0.044293	0.044501	0.043678	0.128088	0.127645	0.129394	0.440032	0.438509	0.444518													
Rotterdam	Shanghai	0.311068	0.312586	0.306603	0.008383	0.008356	0.008464	0.050186	0.050431	0.049465	0.041612	0.041815	0.041014	0.13274	0.132303	0.134025	0.456011	0.45451	0.460428													
Rotterdam	Tokyo	0.289133	0.290602	0.284826	0.008705	0.008678	0.008785	0.052113	0.052378	0.051337	0.038685	0.038866	0.038107	0.137838	0.137412	0.139097	0.473526	0.472063	0.477849													
New York																																
		Fuel cost				Lubrication				Insurance				Crew Cost				Maintenance				Depreciation				Transit cost						
From:	To:	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od	OOCL Mor	Marinor:	Nordic Od				
New York	Singapore	0.38348	0.389959	0.37401	0.003939	0.00596	0.005903	0.036623	0.037241	0.035718	0.039459	0.040126	0.038485	0.095417	0.09624	0.09533	0.321415	0.324188	0.321123	0.119667	0.106287	0.129431										
New York	Hong Kong	0.33029	0.336447	0.321326	0.00434	0.006577	0.006487	0.040346	0.041098	0.039251	0.033986	0.03462	0.033064	0.105117	0.106206	0.104759	0.35409	0.357759	0.352882	0.131832	0.117293	0.142231										
New York	Shanghai	0.348074	0.354359	0.338912	0.004206	0.00637	0.006292	0.039101	0.039807	0.038071	0.035816	0.036463	0.034873	0.101874	0.10287	0.101611	0.343165	0.346521	0.342281	0.127765	0.113609	0.137958										
New York	Tokyo	0.361259	0.367626	0.351968	0.004106	0.006217	0.006148	0.038178	0.038851	0.037196	0.037173	0.037828	0.036217	0.099469	0.100399	0.099275	0.335065	0.338199	0.33441	0.124749	0.11088	0.134786										
NWP																																
New York	Singapore	0.374568	0.375292	0.36887	0.004851	0.007232	0.007341	0.043537	0.043622	0.042875	0.05011	0.050196	0.049339	0.131093	0.130279	0.132248	0.39584	0.39338	0.399327													
New York	Hong Kong	0.345285	0.345988	0.339731	0.005131	0.00765	0.007758	0.04605	0.046144	0.045309	0.046192	0.046284	0.04545	0.138659	0.137811	0.139756	0.418683	0.416124	0.421996													
New York	Shanghai	0.326777	0.327465	0.321343	0.005308	0.007914	0.008021	0.047638	0.047738	0.046846	0.043711	0.043802	0.042986	0.143441	0.142574	0.144496	0.433124	0.430507	0.436309													
New York	Tokyo	0.306555	0.307223	0.301274	0.005502	0.008203	0.008308	0.049373	0.04948	0.048522	0.041013	0.041102	0.040307	0.148664	0.147777	0.149667	0.448894	0.446215	0.451922													
NSR																																
New York	Singapore	0.324717	0.336986	0.305914	0.003416	0.005274	0.004945	0.039964	0.041474	0.03765	0.043442	0.045082	0.040926	0.092307	0.095016	0.089083	0.278725	0.286904	0.26899	0.217429	0.189264	0.252491										
New York	Hong Kong	0.302452	0.314356	0.284282	0.003552	0.005493	0.005131	0.041561	0.043196	0.039064	0.040463	0.042049	0.038029	0.095995	0.098962	0.092429	0.28986	0.298819	0.279092	0.226116	0.197124	0.261973										
New York	Shanghai	0.288761	0.300405	0.271029	0.003636	0.005628	0.005245	0.042543	0.044258	0.03993	0.038628	0.04018	0.036253	0.098263	0.101395	0.094479	0.296709	0.306164	0.285281	0.231459	0.201969	0.267783										
New York	Tokyo	0.274131	0.285465	0.256905	0.003726	0.005773	0.005366	0.043592	0.045395	0.040853	0.036664	0.038187	0.034367	0.100688	0.103998	0.096662	0.30403	0.314026	0.291875	0.237169	0.207156	0.273972										
TSR																																
New York	Singapore	0.39198	0.392701	0.386274	0.004636	0.00691	0.00702	0.047396	0.047483	0.046706	0.052436	0.052528	0.051674	0.125276	0.124487	0.126464	0.378276	0.375891	0.381862													
New York	Hong Kong	0.365025	0.365731	0.359426	0.004891	0.007291	0.0074	0.050003	0.050099	0.049236	0.04883	0.048928	0.048077	0.132168	0.131346	0.133314	0.399083	0.396604	0.402546													
New York	Shanghai	0.34806	0.348755	0.342549	0.005052	0.007531	0.007639	0.051644	0.051747	0.050826	0.046556	0.046653	0.045815	0.136506	0.135666	0.137621	0.412183	0.409648	0.41555													
New York	Tokyo	0.329585	0.330271	0.324189	0.005226	0.007792	0.007899	0.05343	0.053541	0.052556	0.044091	0.044173	0.043364	0.141227	0.14037	0.142303	0.42644	0.423852	0.429689													

## Appendix 1 - Expected Oil & Gas Reserves



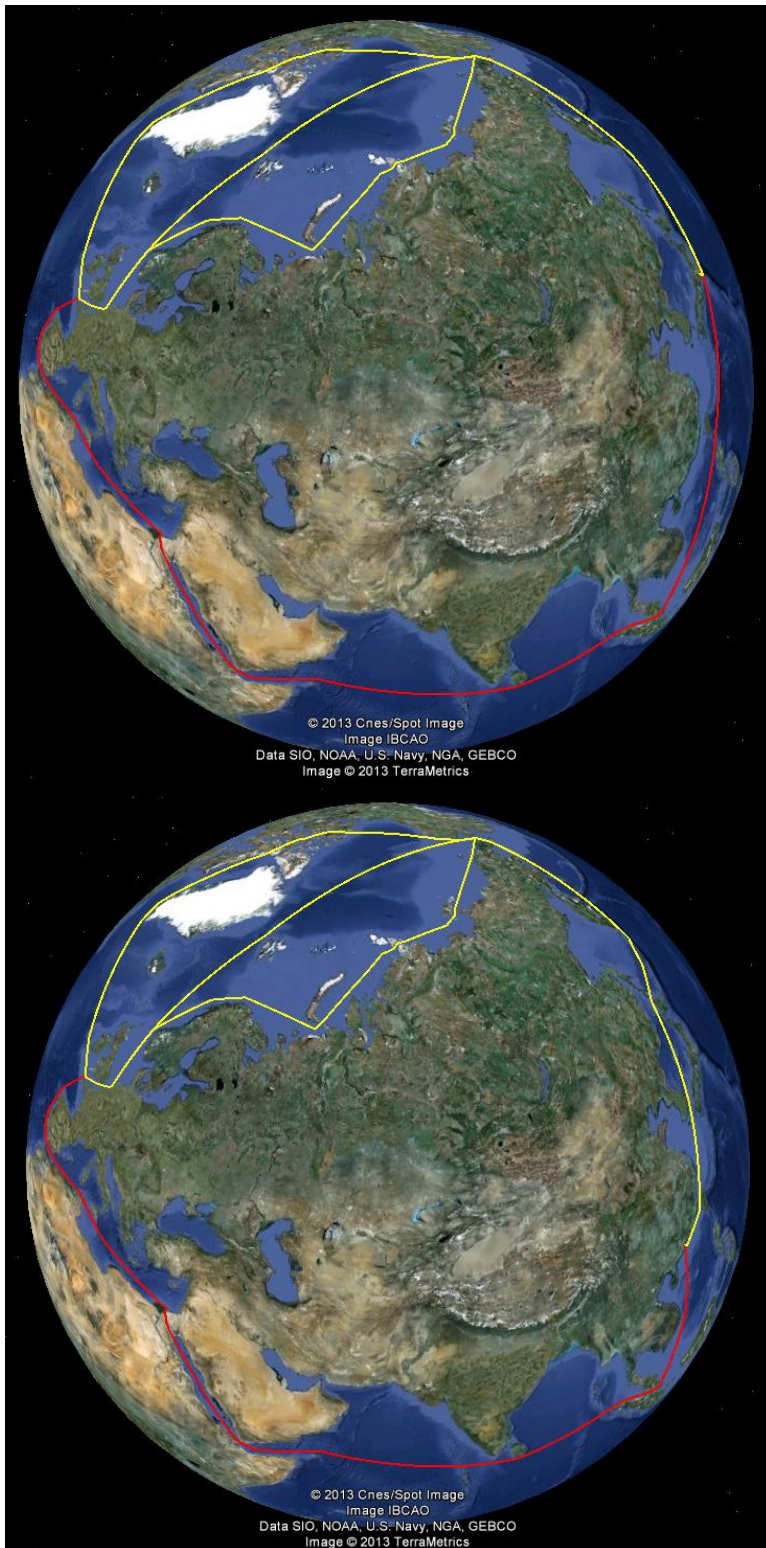
Indicating the assumed or known probability of oil or gas discoveries. With strong coloured purple as ha high possibility of finding resources.

<http://portal.inter-map.com/#mapID=49&groupID=304&z=1.0&up=311127.4&left=2001105.4> –  
accessed 12.04.2013

“In the recent years, the world’s attention has turned to the Arctic, not least because of its vast energy resources. Due to the climate change and its significant impact to the Arctic environment resources that have long been unreachable are becoming feasible for exploitation. It is estimated that up to fifth of the world’s undiscovered petroleum resources are to be found in the Arctic while the Arctic’s share of the world’s known resources today is around 12%.The following map shows the distribution and probability of these potential reserves. The map is built on information from the US Geological Survey (USGS).”

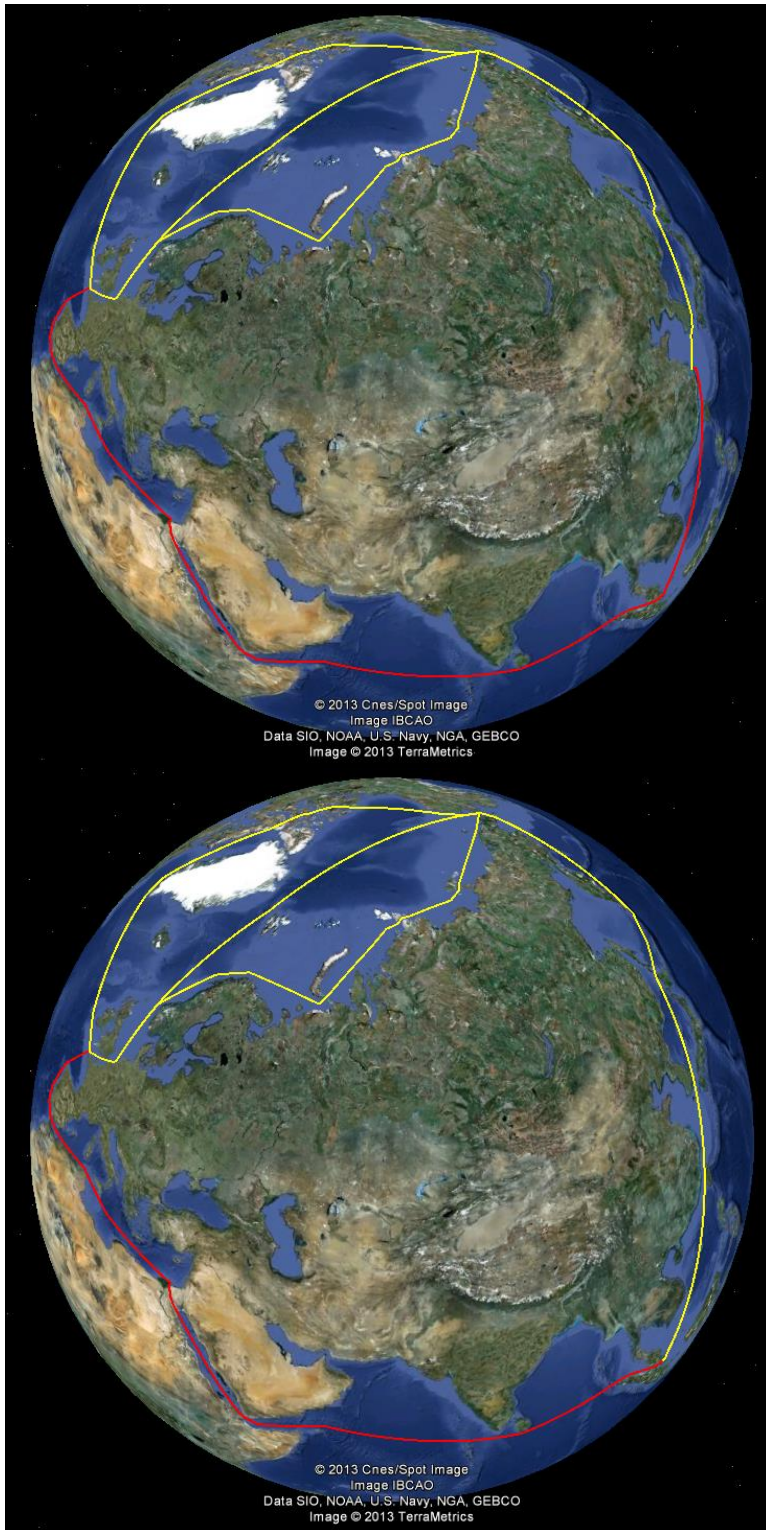
<http://portal.inter-map.com/#mapID=49&groupID=304&z=1.0&up=311127.4&left=2001105.4> –  
accessed 12.04.2013

## Appendix 2 – Google Earth plotting



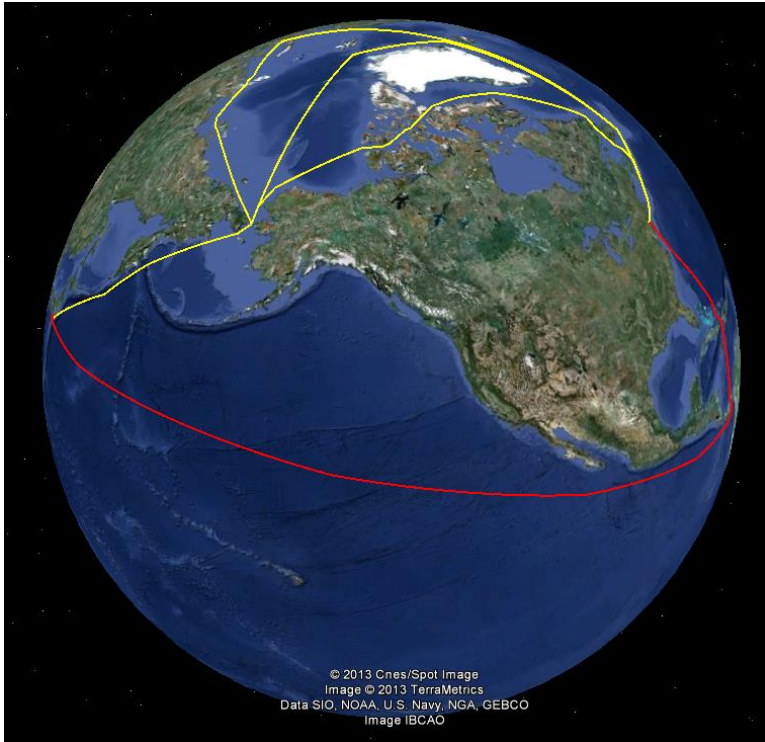
This image is the plotted route connecting Rotterdam and Tokyo through the various routes. The measurement data is available in the excel annex for consultation.

This image is the plotted route connecting Rotterdam and Shanghai through the various routes. The measurement data is available in the excel annex for consultation.



This image is the plotted route connecting Rotterdam and Hong Kong through the various routes. The measurement data is available in the excel annex for consultation.

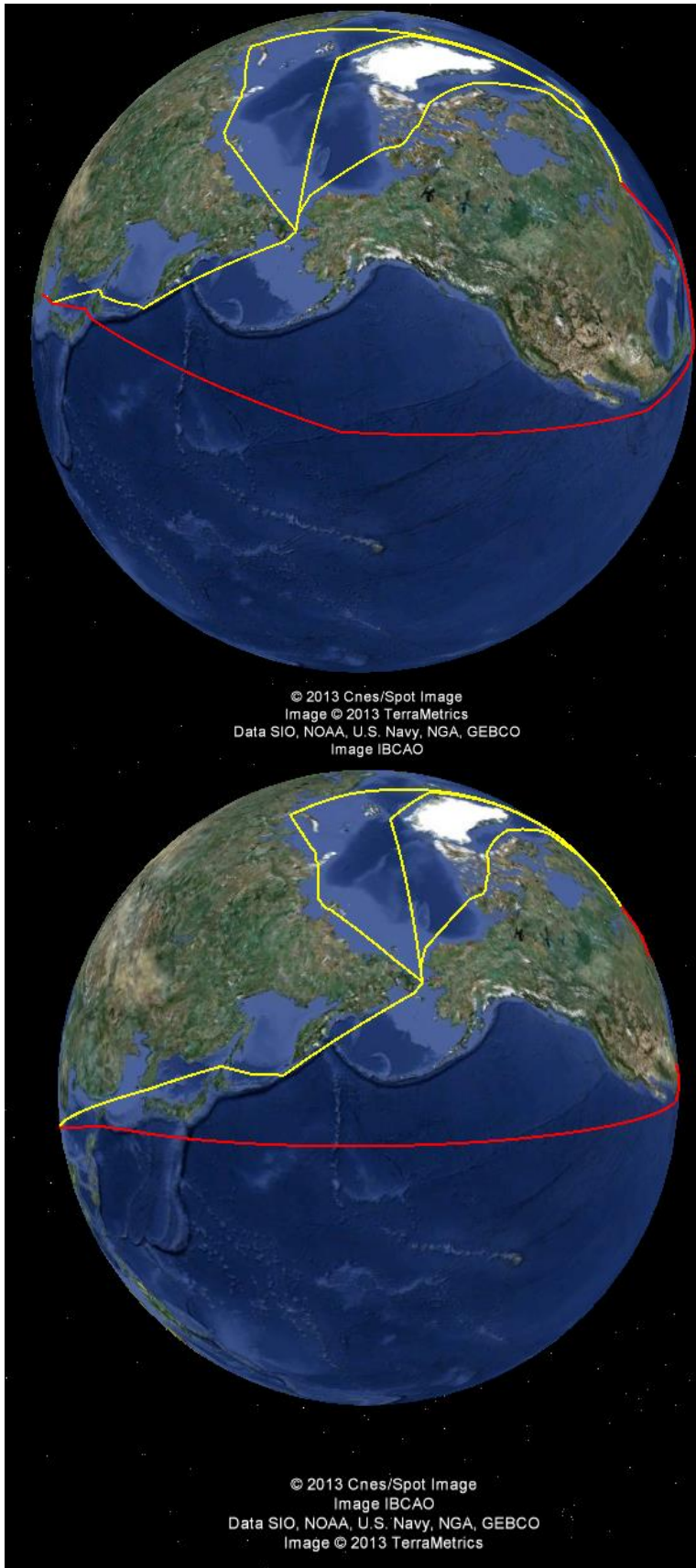
This image is the plotted route connecting Rotterdam and Singapore through the various routes. The measurement data is available in the excel annex for consultation.



This image is the plotted route connecting New York and Tokyo through the various routes. The measurement data is available in the excel annex for consultation.



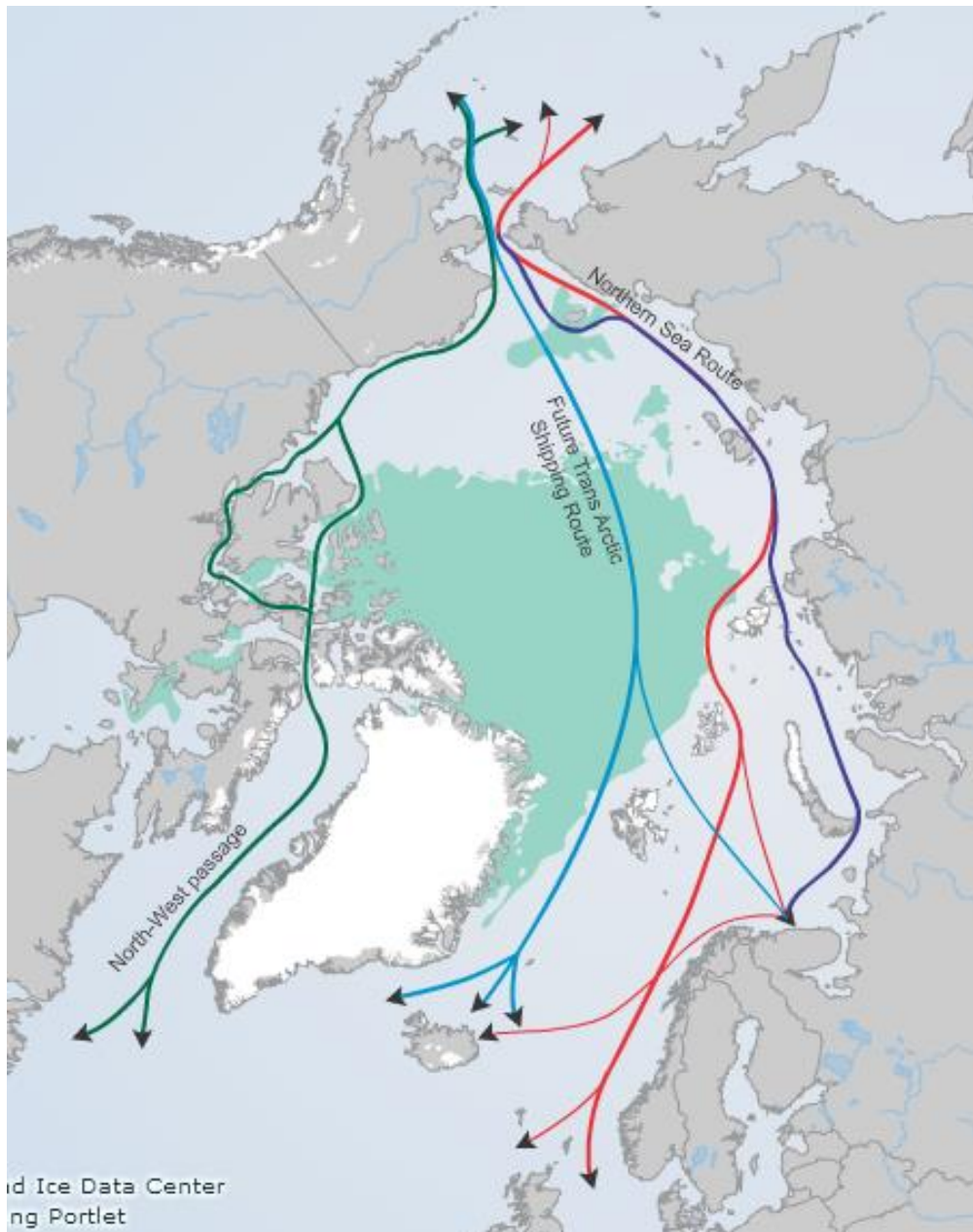
This image is the plotted route connecting New York and Hong Kong through the various routes. The measurement data is available in the excel annex for consultation.



This image is the plotted route connecting New York and Shanghai through the various routes. The measurement data is available in the excel annex for consultation.

This image is the plotted route connecting New York and Singapore through the various routes. The measurement data is available in the excel annex for consultation.

## Appendix 3 – Sea Ice Cover & Arctic September shipping Routes.



<http://portal.inter-map.com/#mapID=49&groupID=&z=1.0&up=213824.4&left=2001105.4>  
06.06.2013