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The Economic and Environmental Benefits of Container Shipping in the Northern Sea route

by

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Abstract

This paper set out to answer the research question of whether the Northern Sea Route (NSR) will be competitive with the Royal Road (Suez Canal Route) for container lines. The research question was formed as: *What are the economic and environmental benefits for container shipping in the Northern Sea Route and when will these benefits be maximized?* This was devised with the aim of measuring the costs and the CO_2 emissions of comparable lines for the NSR and Royal Road. These metrics were important because the liner industry has been focusing on reducing costs and the shipping industry is tasked with reducing CO_2 emissions by 2050. Both of these targets can be aided through a 40% shorter route in the NSR.

It was seen that the shipping in the NSR was experiencing a resurgence. However, container liners were rejecting this route owing to environmental, economic and safety related considerations. The paper researched and analyzed literature on container shipping in the Arctic and important considerations for developing a container line. It was found that the uncertainty of a reliable liner schedule owing to ice conditions and the increased operational costs were reasons for low container traffic in the NSR.

It was seen that ice conditions in the Arctic will melt to levels which will enable the safe transit and profitability of container carriers starting from the year 2030. Three scenarios were devised (2020, 2030 and 2050). Moreover, using generalizable models formulated, it was found that, while currently the NSR is neither economically nor environmentally friendly to operate in for liner companies (in comparison to the Royal Road). It will offer great cost savings and will emit lesser CO_2 per unit of cargo (TEU) carried by 2030 and 2050. Specifically, it was found that the NSR can potentially offer between 9-31% in cost savings and a 10-29% reduction in CO_2 emissions, when compared to the Royal Road between the years 2030 and 2050. Finally, it was also seen that in 2050 the liners can operate year-round with no reliability issues.

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[1] **Tables and figures without references are author's own creations**

List of Abbreviations

BAF	Bunker Adjustment Factor
BC	Black Carbon
CAPEX	Capital Expense
CO2	Carbon dioxide
Dwt	Deadweight
ECA	Emission Control Areas
ECO_2	Total emissions which can be expected from the whole loop
E_f	Emission Factor
FC	Fixed Costs
FEU	Forty-foot Equivalent Units
GHG	Greenhouse Gases
GT	Gross Tonnage
HFO	Heavy Fuel Oil
HMM	Hyundai Merchant Marine
IMO	International Maritime Organization
IMO	International Maritime Organization
ISO	International Organization for Standardization
LNG	Liquefied Natural Gas
LNG	Liquified Natural Gas
LSFO	Low Sulphur Fuel Oil
MDO	Marine Diesel Oil
MGO	Marine Gasoil
MSC	Mediterranean Shipping Company
NGO	Non-Governmental Organization
NM	Nautical Miles
NSR	Northern Sea Route (NSR)
NT	Net Tonnage
OPEX	Operating Expense
PESTEL	Political, Economic, Social, Environmental and Legal forces
P_F	Average price of bunker fuel in $/ton
SECA	Sulphur Emission Control Areas
SSR	Southern Sea Route
TEU	Twenty-foot Equivalent Unit
T_F	Total fuel consumed in tons for the entirety of the loop
TR	Transit fees
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
USA	United States of America
VOYEX	Voyage Expenses

Chapter 1: Introduction

1.1 Background

Since ancient times Arctic Exploration and ship led expeditions have demanded great bravery and courage, as this route was considered mostly perilous for ships (Johannessen, 2007). The industrial revolution and modern wars served well to increase the strategic significance of the Arctic and in particular the Northern Sea Route (NSR) (Johannessen, 2007). The Russian government was the first to realize the commercial significance of this route and built icebreakers as early as 1915, with the aim of navigating from east to west. Voyages in this region gradually grew till the collapse of the USSR and then tapered off (Johannessen, 2007). However, in recent years there has been a renewed interest in the NSR as a plethora of natural resources have been found and mined in the region. This has given rise to the emergence of bulk and LNG ship traffic to access these Ports. However, the flow of container traffic in this region remains non-existent, with only domestic Russian traffic of very small ships (North Sea Information Office, 2020c). This raises the question as to why major container lines have been hesitant to make use of this shorter route to cater to the massive trade between Asia and Europe.

Moreover, the temperature increase owing to global warming has caused the rapid melting of ice, which has led to the emergence of a new trade lane connecting the East and West (Humpert, 2011). However, the route is yet to realise its full potential as a container route owing to several limitations. The main concern among container lines for not using this route has been for the fear of exacerbating the already dire problem of melting ice in the Arctic (Jiang, 2019). The pristine environment and its wildlife have already been under threat from natural disasters such as, wildfires and progressively record-breaking temperatures over the years (Freedman, 2020). In recent years, the efforts taken by the nonprofit environmental advocacy group Ocean Conservancy, combined with rising concerns about climate change and the CO2 emissions from shipping, have caused container carriers such as CMA CGM, Hapag Lloyd, and MSC, along with several major shippers to pledge against the usage of the NSR (Nilsen, 2020). However, recent data seem to suggest that the ice in the Arctic circle is on a consistent decline and an ice-free Northern Sea Route may not be far off (Tidey, 2019).

Container shipping has been credited as one of the most revolutionary innovations to have occurred to liner shipping. For several years merchandise and goods were transported between ports in an inefficient break-bulk manner. However, the revolution of containers has taken the world by storm and ports which were early adopters of containerization have flourished and are now global hubs (Levinson, 2016). Therefore, snubbing the NSR and its surrounding regions entirely of container traffic may be acceptable for the short term but it can be hinderance to the overall development of the region. Since the last financial crisis in 2008 the speed at which container ships have sailed has slowed down by 25% (Chambers, 2020b). This phenomenon occurs because container companies try to maximize their operational savings by lowering speeds and maximizing savings on fuel costs. To reach Europe from Asia, container liners have to sail through the Suez Canal and this route is called the Royal Road (Verny and Grigentin, 2009). On the contrary, the economic savings the companies would make by traversing a 40% shorter route from Asia-Europe through the NSR would be enormous (Schøyen and Bråthen 2011).

The higher operational costs plaguing shipping lines, are brought on by regulatory hurdles focusing on curbing pollution such as the 2020 Sulphur cap (Shen, 2019). This paper is of importance because it will focus on the rejection of the Northern Sea route by container lines and will aim to answer the question to the problem: With Ice melting at faster rates in the Northern Sea Route, will it be profitable (will there be higher profits) and will it be environmentally sustainable for carriers to divert traffic from the Suez route to the northern sea route.

The International Maritime Organization (IMO) which is shipping's regulatory UN agency has taken steps to upkeep the 2020 Sulphur cap and many experts claim that, the implementation of this regulation which made shipping fuels cleaner, has been widely successful. However, ships will have to reduce the CO_2 emissions by 50% from the levels in 2008 (Bankes-Hughes, 2020). The 2050 Carbon reduction problem of shipping remains an elusive problem with no single solution to achieve the required CO2 emission reduction targets. The CO_2 emissions offset by a shorter route can also be an interesting measure for determining the feasibility of container shipping through the NSR.

It is seen that over $1 trillion will be needed to achieve the IMO's decarbonization goals (Saul, 2020). The need currently for container liner companies is for minimizing operational expenses, while also preparing for another regulatory tsunami. Therefore, this paper will aim to address these two problems by analyzing if the shorter NSR will be able to reduce costs and CO_2 emissions in comparison to the Royal Road route. This paper will construct comparable economic and environmental models to determine if the NSR can compete with the Royal Road and will also determine when it will be feasible to use the NSR.

1.2 Research question and objectives

Based on the discussions of the main problems, it is clear that the NSR is regaining its historical significance and is flourishing as it is experiencing a renaissance as a key route for bulk and gas shipping. However, container lines have decided not to use the route citing various environmental concerns as mentioned in the background. Therefore, this paper has devised the following research question to determine whether and when container lines should use the NSR:

Main Research Question: What are the economic and environmental benefits for container shipping in the northern sea route and when will these benefits be maximized?

Sub-Research Questions:

1. What are the cost implications for a container ship to use the North Sea route?
2. What is the emission related savings for the container ship when using NSR?
3. Scenarios of 2020, 2030, 2050?

This research question will quantify the operational expenses and carbon emissions for a container line operating between the north western Europe and East Asia through the NSR and compare it with the currently used Royal Road. The sub research questions are designed specifically to answer the main research question. Moreover, the use of 3 scenarios will allow to answer when the NSR will become viable to use if it is currently unusable owing to environmental and economic constraints.

1.3 Thesis Structure

Introduction: This section will contain the value of the research (including the problem and research question), beneficiaries, aims and objectives, short description of other chapters and their contents.

Literature review: Historical review of shipping in the Arctic, economic developments and shipping in the Arctic, container shipping in the arctic, shipping costs and economics of container shipping, design and considerations for a liner route, economic and environmental benefits of the NSR, the importance of ice thickness on ship operations, developments in safety and technology and theoretical framework.

Methodology: Type of research (Quantitative, deductive), reasons for using scenario development, sources used (secondary) & data collection methods, PESTEL, explanation on the model used and relationship with theory.

Results and analysis: Creation of NSR and Royal Road loops; 2020, 2030 and 2050 scenarios using PESTEL; calculations for each scenario based on the model; analysis of data.

Conclusion: Summary of results, conclusions based on the analysis, limitations and further research.

1.4 Problem and significance

The NSR has tremendous cost and CO_2 emission saving potential, given the current requirement for cost savings in the liner industry. A route which is cheaper and more efficient environmentally can solve the industry's problems and also result in the drastic reduction of sailing distance and times benefiting the whole industry by reducing the number of ships to offer reliable and frequent services to shippers. Therefore, for the container lines which are yet to decide their stance on using the Arctic this paper will be useful to make a decision which can give them a potential strategic advantage over those which have taken the pledge to not use the Arctic. It is also seen that the Russian government has great interests in developing the NSR to take advantage of this resource rich environment (Laurence, 2019). Therefore, this paper will also be important for Russian authorities in charge with social development as container traffic through any region will bring social gains and may pave the way for future Arctic container ports.

Chapter 2: Literature Review

2.1 Shipping in the Arctic Circle

2.1.1 Geography of the NSR

In order to pinpoint the NSR, one must first define the Arctic region properly. The most common accepted definition for the Arctic can be considered as the area north of the Arctic Circle (66 degrees and 32 minutes north) (Østreng et al., 2013). This is an area of 21 million square kilometres. However, the Bering strait, the White Sea, South Greenland and the Hudson Bay are not included in this definition (Østreng et al., 2013). This has led to a definition which takes into account the physical characteristics of the various neighbouring regions of the Arctic, some of the alternate definitions range from the continuous permafrost, the sea ice cover, boundary between cool and warm waters, etc (Østreng et al., 2013).

Nowadays, the Northern Sea route portrayed in figure 1, is considered to be the shipping lane, which runs from the Barents Sea close the Russian and Norwegian border in the west, across the North Pole to the Bering strait which lies between Siberia and Alaska In the East. This route connecting Eastern Russia and Asia to has navigational possibility for around 3-4 months per year (The Economist, 2018).

Figure 1: The Northern Sea Route (The Economist, 2018)

2.1.2 Historical overview

The history of sea exploration in the Arctic until the 21st century has been one of heroism as explorers sailing along the route had to battle adverse conditions, quite often resulting in tragedies. Norsemen between 870 and 890 A.D. navigated around the northern tip of Europe and the Barents and white seas were navigated well in the forthcoming years. These voyages documented the ice patterns, tidal conditions, weather, winds, islands and established routes across the north pole (Johannessen, 2007).

In the Late 19th Century and the early 20th century, the Russian government took great interest in the Arctic circle and research areas were expanded to coastal mapping which include the zoology and botany of the Siberian and other Arctic lands (Johannessen, 2007). As Russia arose as a world power, exploring lands and icebreaker-led sea routes became of strategic importance. The icebreaking ships Taymyr and Vaygach were credited to be the first Russian ships traversing the east to west passage of the NSR in 1915 (Johannessen, 2007). These voyages were crucial in mapping out the NSR for navigational and hydrographical purposes. It was also established that the ice cover of the region varied sporadically area wise and was also dependent on seasons (Johannessen, 2007).

Commercial shipping using the NSR began in the second half of the 19th century, the use of ice breakers in the 20th century along with the start of World War I, accelerated further the transport of cargo and other military equipment along the NSR (Johannessen, 2007). This increased presence, further aided exploration and the number of unsuccessful voyages were decreasing (Johannessen, 2007). The second World War brought with it further increases in cargo and supplies transported to Russian regions along the NSR. Cargo transported across the NSR reached its peak in the latter part of the 20th century when it stood at 6.57 million tons in 1987 (Johannessen, 2007). There was a steep decline after this, owing to the gradual decline and collapse of the USSR. Globalization took over and the NSR was declared open for foreign ships on 01 July 1991 as the export of gas and oil from Northern Russia to Europe became common (Johannessen, 2007). In 2000, the total cargo flow in the NSR declined gradually from its peak to 1.58 million tons due to environmental concerns (Johannessen, 2007).

2.1.3 Development of the NSR in the 21st Century

Until 2007, major shipping companies paid little interest to the NSR, however in 2007 the Northern Sea Route became ice free temporarily over the summer months (Humpert, 2011).

This phenomenon was replicated every summer and shipping of various types of cargo during the summer months flourished (Humpert, 2011). This climate change induced phenomenon has not only resulted in the NSR opening up to ships, but also aided the exploration of Oil and Gas along with fossil reserves such as coal mapped in figure 2. This resulted in the surge of bulk shipping, as countries along with various energy corporations are keen on exploiting the abundant natural resources of the region (The Guardian, 2015).

Figure 2: Resources in the Arctic (The Guardian, 2015)

Natural resource exploration in the Arctic has so far been focused on the land side, however the melting ice may also open up the Arctic to offshore drilling. The USA's Prudhoe Bay Oil field in Alaska and Russia's Tazovskoye Field are the main sources of oil production in the region (Guardian, 2015). In Figure 3, it can be seen that the number of Liquified Natural Gas (LNG) tankers traversing the NSR climbed to 507 in 2019, this was owing to the opening of the Yamal LNG plant which was opened in December 2018 (Bourne, 2019). This giant facility financed by Russia, China and France Liquifies natural gas extracted from the Yamal peninsula to service demand in China and Europe (Bourne,2019). Figure 4 shows that LNG dominates cargo shipped through the NSR.

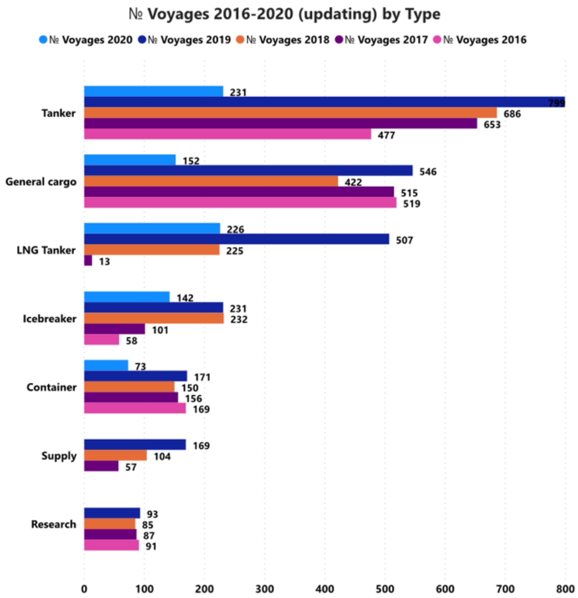

Figure 3: Yearly number of trips by vessel type (North Sea Information Office, 2020c)

In 2018 Russian cargo shipped across the NSR grew to 18 million tonnes (Laurence, 2019) owing to the various oil and gas plants in the region, It is a fair estimate that shipping in the NSR is set to grow as the Russian president ordered that the cargo shipped by Russian companies shipped across the region needs to reach 80 million tonnes by 2024 (Laurence, 2019). This will be achieved through increased bulk shipping of not only oil and gas but also bulk ores such as coking coal. The two coal terminals, at the Taymyr Peninsula, which is also a haven for Russian wildlife, is set to export almost 20 million tonnes of coal by 2024 (Laurence, 2019). While the prospects for growth in bulk shipping through the NSR remain optimistic and are a crucial part of the Russian economy, container shipping through the region has not picked up pace.

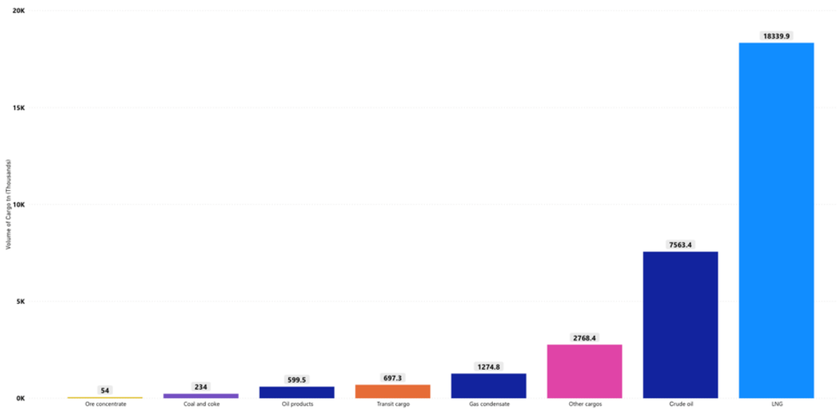

Figure 4: Top cargo transported in the NSR in 2019 (North Sea Information Office, 2020a)

2.2 Container shipping in the Arctic

In 2013 the Yong Sheng which is owned by the Chinese container carrier COSCO became the first container vessel to sail across the NSR on an East-West route to Europe from China (Eason, 2013). The 1,118 Twenty-foot Equivalent Unit (TEU) capacity vessel left the Chinese Port of Dalian, after completing stops at Shanghai and Busan, it traversed the NSR in 21 days to reach the Port of Rotterdam. This fully laden ship was an advertisement to the world of the record-breaking times offered by the NSR in comparison to the Royal Road route which is traditionally used (Mitchell and Milne, 2013). Moreover, acts of piracy and war which were prevalent at the time close to Suez further strengthened the case for liner shipping along the NSR (Mitchell and Milne, 2013).

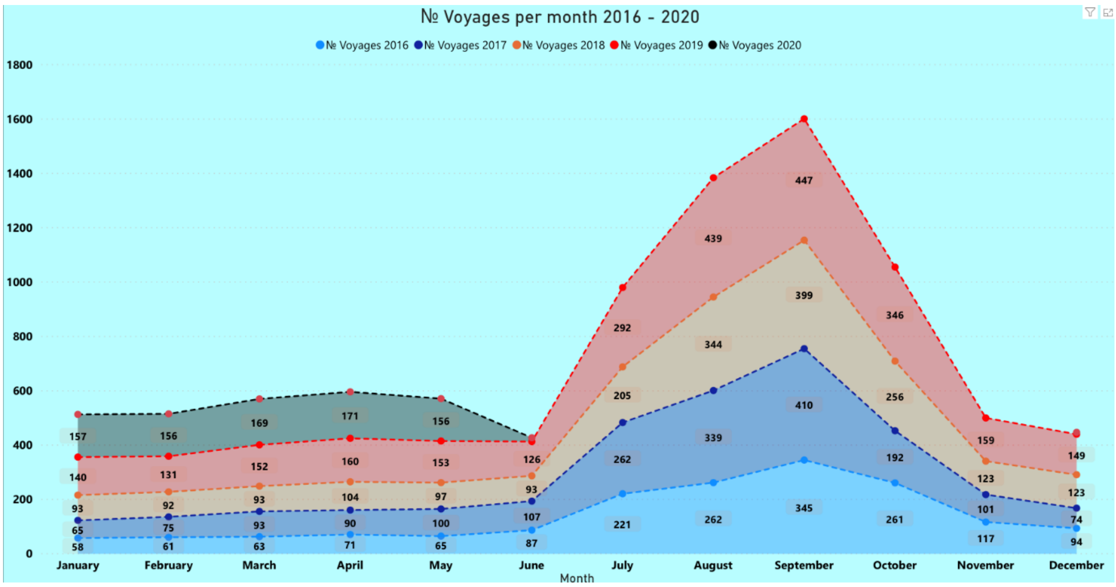

Figure 5: Monthly no. of vessels transiting the NSR (North Sea Information Office, 2020c)

The voyage occurred during the peak shipping months of August and September. Figure 5 portrays that the summer months of July and October experience the highest amount of ship traffic along the NSR. During this time COSCO has been the leading company which has taken advantage of this route which is 40% shorter compared to the Suez Canal route when considering the East to West trade (Schøyen and Bråthen 2011), the company also used specialized container carriers to transport equipment for the construction of the Yamal LNG facility (Humpert, 2019). According to, Noteboom (2006) the schedule reliability of liner shipping is a crucial factor which influences the demand for container carriers, mainly owing to the emergence of 'just in time' supply chain practices which rely heavily on lead times. However, Figure 5 portrays that the navigable days in the NSR have been increasing as a larger number of ships are traversing earlier in the month.

Following the Yong Sheng's completion of 2 other voyages in 2015 through the NSR from China to Europe (Offshore Energy Today, 2016). Maersk in 2018 deployed a newly built 3600 TEU ship, the Venta Maersk, on the NSR from the Korean port of Busan to the German port of Bremerhaven. The voyage was completed in 25 days saving 10 days, even though the voyage occurred in the peak summer of September, there was deviation from a shorter route due to unexpected buildup of ice and the company had to hire icebreakers to clear excess ice (Chambers, 2018).

In 2019, Russia's government announced plans to set up a state run container line, which would allow carriers to sail to the Transshipment ports of Murmansk in the Barents sea which is close to western Europe and on the other end, lines originating from East Asian countries can deposit containers at Kamchatka in the Far East (Jiang, 2019). These two ports will act as transshipment hubs for the East and west and a state-owned line will traverse the NSR between these two ports. This development was announced after several major liners, accounting for a considerable market share such as CMA CGM, Hapag-Lloyd and MSC officially denounced the use of the NSR by claiming environmental reasons as the main factor for doing so (Jiang, 2019).

2.3 Container Shipping

The first container ship was the Ideal-X which was a tanker vessel which was converted into a vessel capable of carrying lorry containers. The ship's first voyage with 58 containers, between New Jersey and Houston can be considered as the first modern container shipment, occurring on 26 April 1956. At the time handling a ton of containerized cargo was 97% cheaper than handling it break bulk (Stopford, 2009, p.508-509). This concept of standardizing the unit of carriage was conceptualized and executed through the Ideal X, by Malcolm Mclean. His idea was met by skepticism by several liner companies, but this was the greatest revolution for the general cargo liner industry who handled cargo predominantly in a break bulk manner (Stopford, 2009, p.509).

In the following years there were many obstacles faced by companies adopting containerization stemming from ship design which featured a cellular design and stacking containers on deck was unlike any other type of ship. Secondly, Terminals required a higher degree of mechanization as container cranes and gantry cranes were developed to service the changing type of cargo. Moreover, there was great uncertainty about the size of containers but the International Organization for Standardization (ISO) eventually developed standard dimensions for containers with several options, in recent years, 20- and 40-Foot sizes, often referred to TEU and FEU respectively have become the most commonly used standard sizes of containers (Stopford, 2009, p.510).

The concept of containerization came about to achieve greater efficiency in the supply chain of goods. The ultimate concept resulted in time reduction not only in ports as the mechanized ship to shore cranes as well as the yard cranes allowed the handling time to be reduced considerably (Stopford, 2009, p.511-512). Moreover, unitization allowed the easy transfer of the container between various modes of transport such as ships, trains and lorries. This led to the development of door-to-door transport of goods. The tackle to tackle nature of liner shipping soon changed to become one which also took into account the land-based logistics. As shipping companies pursued the goal of achieving greater economies of scale, they became further consolidated and so the liner business became dominated by a few large players offering shippers limited choice (Stopford, 2009, p.511-512).

2.3.1 Economic benefactor

According to Bottema (2020), the container trade usually grows at 2.6 times the rate of GDP. While this growth of containerization is caused owing to the growth in world trade which grows at 1.5 times the GDP. While this may be an economic simplification, figure 6 portraying the growth in container trade mirrors the world economic growth (UNCTAD, 2019). However, the opposite is also found to be true, containerization and investing in container facilities has led to development of several regions in the world. According to Hoovestal (2013), at the dawn of containerization the major ports which refused to invest in container handling equipment and infrastructure citing the lack of resources have been considerably reduced in their significance. Felixstowe was a minor port in the UK during the

1960s, it was one of the early adopters of container infrastructure and today is the largest container port in the country, eliminating the significance of many ports which were once giants (Levinson, 2016).

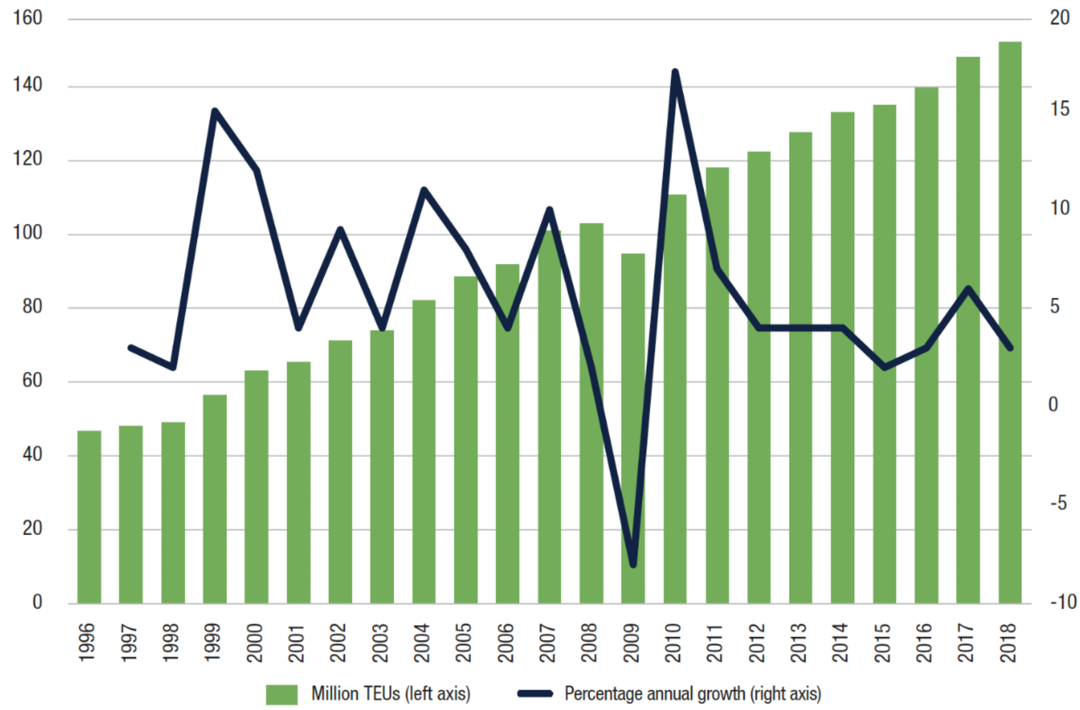

Figure 6: Growth of container trade in TEUs (UNCTAD, 2019)

This notion that investing containerization can create wealth is further strengthened by looking at the historical cases of China and the US West coast (Hoovestal, 2013). In China heavy investments in ports were made and factories which created wealth and cities grew next to these highly efficient ports which could facilitate the globalized demand for containerized cargo (Hoovestal, 2013). Traditionally the US east coast handled more traffic than the west, but the west invested heavily in container facilities and this resulted in the cargo traffic in the west coast far outpacing the east in the near future (Hoovestal, 2013).

2.4 The Demand for ocean liner transport

Competition in container shipping arises not from bulk trades such as ores and oil but from other modes of transport such as rail and air. Generally, products which are considered to be time sensitive and of high value are transported via rail. However, container liner transportation offers an economies of scale advantage which allows for the reduction in price. According to Rodrigue (2017), the cost is of transport is the most important factor in the modal choice of the shipper choice. Figure 7 further proves that with increasing distance sea freight becomes the most competitive in terms of price for shippers.

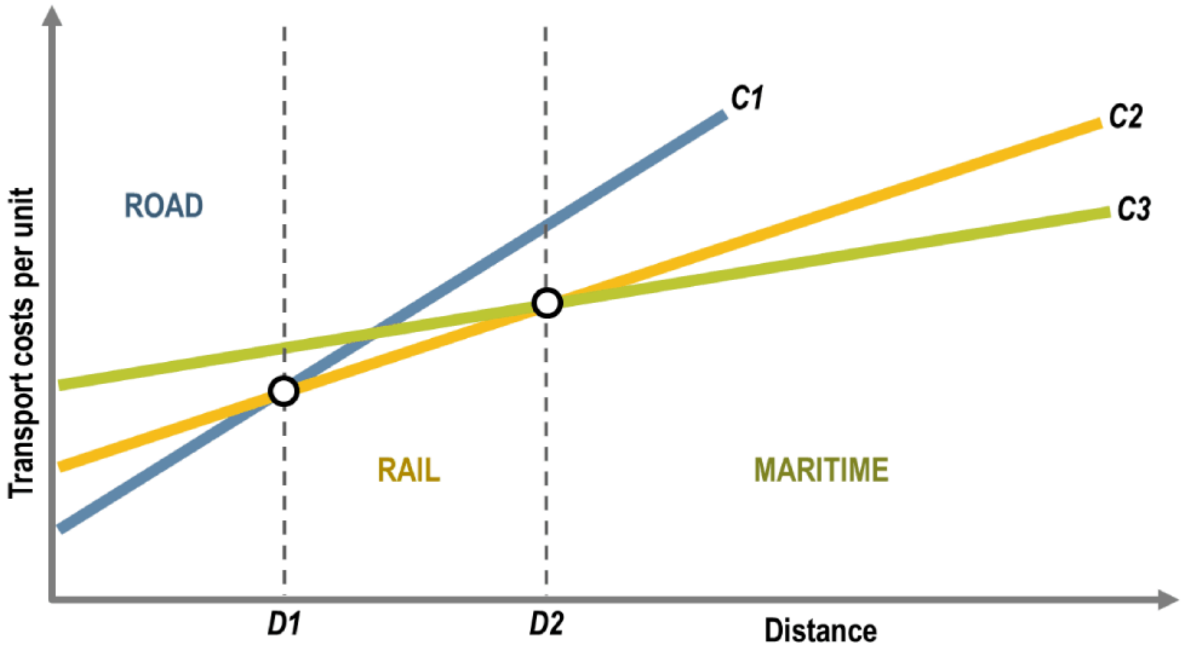

Figure 7: Relationship between cost and distance of transport modes (Rodrigue, 2017)

Apart from manufactured and semi manufactured goods other types of minor bulk cargo such as steel products, refrigerated cargo, forest products edible oil, foodstuffs etc., constitute the demand for containerized cargo (Stopford, 2009, p.519). The prices container companies charge shippers also varies for containers with regards to the value, nature and volume of the cargo transported (Stopford, 2009, p.519). Apart from this demand also varies based on seasonality, which is mainly influenced by the demand rush during the Christmas period (Stopford, 2009, p.518). For Ocean freight the period between August and October is considered to be the peak demand period (Freightos, 2019).

Another related factor is the trade imbalance between 2 destinations in a line, this phenomenon is common in the China to Europe lines, more cargo flows in the East to West direction than from West to East (Stopford, 2009, p.518). Looking at the Asia to Europe liner trade portrayed in table 1, it is seen that the westbound route is more significant than the eastbound one. In 2018 17.4 million TEUs were transported between East Asia and Europe while only 7.0 million TEUs travelled the other way.

Table 1: Yearly container trade in millions of TEU (UNCTAD, 2019)

	Trans-Pacific			Asia–Europe			Transatlantic		
	Eastbound	Westbound		Eastbound	Westbound		Eastbound	Westbound	
	East Asia–North America	North America–East Asia	Trans-Pacific	Northern Europe and Mediterranean to East Asia	East Asia to Northern Europe and Mediterranean	Asia–Europe	North America to Northern Europe and Mediterranean	Northern Europe and Mediterranean to North America	Transatlantic
2014	16.2	7.0	**23.2**	6.3	15.4	**21.8**	2.8	3.9	**6.7**
2015	17.5	6.9	**24.4**	6.4	15.0	**21.5**	2.7	4.1	**6.9**
2016	18.3	7.3	**25.6**	6.8	15.4	**22.2**	2.7	4.2	**7.0**
2017	19.5	7.3	**26.8**	7.1	16.5	**23.6**	3.0	4.6	**7.6**
2018	20.9	7.4	**28.2**	7.0	17.4	**24.4**	3.1	4.9	**8.0**
Annual percentage change									
2014–2015	7.9	-2.0	**4.9**	1.4	-2.6	**-1.4**	-2.4	5.6	**2.2**
2015–2016	4.4	6.6	**5.1**	6.3	2.5	**3.6**	0.4	2.9	**1.9**
2016–2017	6.7	-0.5	**4.7**	4.1	6.9	**6.0**	7.9	8.3	**8.1**
2017–2018	7.0	0.9	**5.4**	-1.3	5.7	**3.6**	5.8	6.8	**6.4**

2.5 Liner Strategies

Liner shipping employs two basic models, the first being the low-cost option and the second is offering a package of services of which liner shipping is a part (Stopford, 2009, p.520). This type of product differentiation allows the carrier to charge a higher price (Stopford, 2009, p.520). The liner industry has been aggressively integrating and consolidating horizontally from 2016 onwards (UNCTAD, 2018). Consolidation agreements between carriers are in the form of operational as well as strategic. The 2008 financial crisis threw the container industry into a plethora of financial problems from which the industry still hasn't recovered (UNCTAD, 2018). The top six carriers hold almost 71% of the market share in terms of TEU operated (Alphaliner, 2020).

The consolidation agreements and alliances within these top carriers themselves reflect that the industry is focused on offering better services and lower freight rates achieved by operational cost reduction (UNCTAD, 2018). The second model which focuses on capturing a larger market share by offering a package of shipping services has also been in use. The recent complete or partial acquisitions of logistics companies, terminals and freight forwarders by the top container carriers reflect this (Ince, 2019). Table 2 highlights the various strategies container lines employ to maximize benefits for shippers and themselves, however as consolidation has prevailed over the industry there is less differentiation among lines and lines need to find other ways of competing. Therefore cost savings has become the most important strategy for them.

Table 2: Product differentiation strategies of liner companies (Stopford, 2009, p.521)

Key attribute of the service	**Advantage for the shipper**	**Carrier benefit**
Vessel on-time arrival (Reliability) and speed	Emergence of globalized just in time supply chains requiring low lead times, make this an important characteristic for many shippers.	Liner companies can capture cargo from air and rail while charging a higher freight rates in exchange for reliability and fast speeds.
Frequency of sailings and space availability	Choice can be seen as an important aspect to shippers who want a resilient supply chain and having multiple options and the ability to accept last minute cargo bookings can be attractive to shippers.	Consolidation and space sharing agreements allows the carriers to increase frequency of the services and increase the individual capacities while reducing cost.
Cargo tracking, administration and door-door services (Vertical integration)	The shipper has one point of contact and has immense savings on their logistics expenditure, while also having a greater visibility for their supply chains.	Carriers achieve this through vertically integrating to provide a whole supply chain package so they can capture greater revenue.

2.6 Liner costs

There are 8 main factors according to Stopford (2009, p.540-548) which account as the costs for liner companies. Several of these factors are internal conditions and are not differentiable in publicly available information. These factors are the following:

Ship Characteristics: The trifecta of vessel speed, capacity (size) and the cargo handling efficiency which determines the days spent at a port are the key determinants of costs in this characteristic (Stopford,2009, p.540-548).

Service Schedule: The design of a service is usually a loop, where there is a weekly service between a selection of ports. The time taken at each port and the total days spent at sea dictate the number of ships needed for that service. This in turn dictates the number of vessels needed on the line to have a weekly service (Stopford,2009, p.540-548).

Capacity utilization: This is an important consideration as it determines the earnings of the carrier. Increasing the number of port calls means that the ship can increase its utilization at the expense of spending more time at port. However, as seen earlier in the East Asia-Europe route there is an inherent imbalance which exists in one direction of the loop (Stopford,2009, p.540-548).

Ship costs: This metric determines in dollars per day the cost of running a ship. It takes into account the Operating costs (OPEX), Capital costs (CAPEX) and the bunker price to arrive at the total cost of transporting one TEU (Stopford,2009, p.540-548).

Port Costs: The port fees charged based on the gross tonnage of the ship for each individual port call on the line. This excludes the terminal handling charges for the containers (Stopford,2009, p.540-548).

Container deployment: This defines the share of 20- and 40-foot containers onboard and also the efficiency metric of the fullness of containers are measured. Since eastbound route is often more imbalanced than the westbound route, the containers transported in this direction are often empty and do not contribute to earnings. Moreover, it also includes the inland repositioning costs of an empty container (Stopford,2009, p.540-548).

Container and handling costs: The capital cost of containers and the cost of maintenance along with the terminal charges of handling and storing containers are included here (Stopford,2009, p.540-548).

Administration costs: These are internal costs which depend on various aspects of the liner company (Stopford,2009, p.540-548).

When it comes to traversing the Arctic routes for shipping companies the most important economic consideration are the costs related to fuel. Tseng and Cullinane (2018), conducted surveys with various Taiwanese companies about the main consideration they would take into account before using the NSR. Their results found that after concerns about risks to crew and navigational safety the fear of high fuel costs dominated. The significance of the fuel costs which are a part of the OPEX for container lines further increased because it was seen that majority of the surveys were taken among container companies. Moreover, the savings in time and distance offered by the shorter route did not account for savings in fuel costs (Tseng and Cullinane, 2018).

2.5 The impact of ice thickness

According to Cariou et al. (2019), the reasons why liner companies do not operate lines on the NSR during the 3-month busy summer period where the route is ice-free is owing to reasons which are threefold. Firstly, the number of sailing days are affected because of the uncertainty of blockages by floating ice. Secondly, the integrity of schedule is impacted which can impact the supply chains of shippers. Thirdly, the most important cost factor of fuel is impacted owing to uncertainties caused by rerouting due to ice and the requirement for ice breakers (Cariou et al., 2019).

The main issue with regards to sailing in the arctic is the requirement for the use of ice classed vessels which have a fortified hull to break through the thick ice layers. It was found that the capital and operating costs for ice classed vessels was 1$/TEU higher during summer months and 4$/TEU higher during the winter months (Cariou et al., 2019).During months where ice is present on the route the hiring of icebreakers supplied by Russian companies will be necessary, the tariffs for these icebreaking services are classified based on the Gross Tonnage (GT) of the vessels (Ministry of Justice of Russia, 2014). Studies done so far calculating the operating costs in the NSR have used varied references, while many ignore the costs altogether (in the assumption that no ice breaker will be required), other studies have rates ranging from 3$/GT to 19$/GT (Theocharis et al., 2018).

Table 3: Ice classification of vessels (MAN, 2015).

DNV Class Notations	Equivalent Baltic (Finnish-Swedish) Ice class	Vessel Type	Ice Conditon	Impact Limits
ICE-C			Very light ice condition	
			First year ice and Broken channel:	
ICE-1C	1C		0.4 m ice thickness	
ICE-1B	1B	All ship types	0.6 m ice thickness	
ICE-1A (PC-7)	1A		0.8 m ice thickness	No ramming
ICE-1A* (PC-6)	1A Super		1.0 m ice thickness	
ICE-1A* F			1.0 m ice thickness	
ICE-05				
ICE-10			First year ice with pressure ridges	
ICE-15		Vessels intended for ice breaking		
POLAR-10		Built for another main purpose		
POLAR-20				Occasional ramming
POLAR-30			Multi-year ice with glacial inclusions	
ICEBREAKER		Icebreaking is main purpose		Repeated ramming

Table 3 indicates the various ice classifications of vessels, the Venta Maersk which was the latest container vessel to traverse the Northern Sea Route between Asia and Europe was classified in the highest possible 1A category (Humpert, 2018). During the voyage the vessel had to hire a Russian icebreaker as an 800 nautical mile stretch of the route had been covered by ice which required ramming to break up (Humpert, 2018). In Figure 8 showing the path taken by the Venta Maersk is portrayed, the red line indicates the route through the Sannikov strait where the ice breaker had to assist the vessel. This stretch is located in the East Siberian sea and this is seen to be the most ice ridden stretch of the NSR (Humpert, 2018).

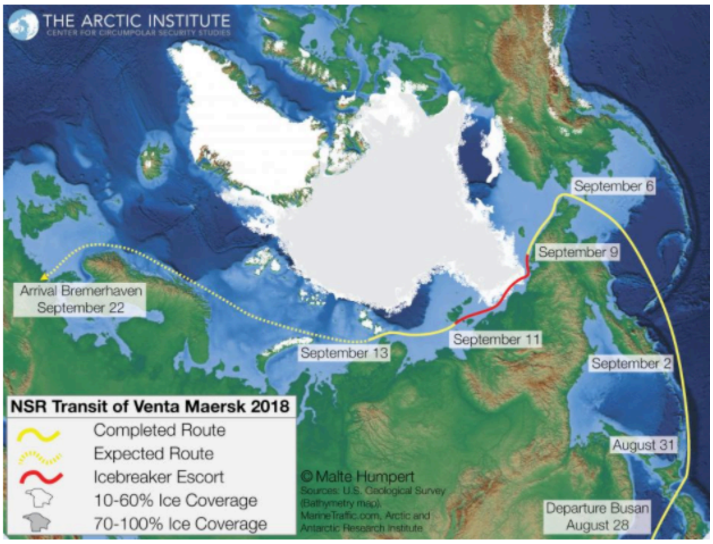

Figure 8: Path taken by the Venta Maersk (Humpert, 2018)

Currently ice breaking services are only provided by the Russian company Rosatomflot who operate nuclear powered icebreaking services across the NSR, the company is currently facing an ageing fleet of icebreakers (Humpert, 2018), however with the increase in traffic along the route even in the winter months which has prompted the Russian government to increase its nuclear icebreaking fleet. The NS Arktika will be entering into service in 2020 (Humpert, 2018). Recently, a Russian fund of around 12 billion dollars provided by various companies, banks and funds both national and international was created to develop the NSR as a viable competitor to the Suez route (Golubkova and Stokyarov, 2019). For this purpose, 37% (Golubkova and Stokyarov, 2019) of the fund will be dedicated to building 40 new vessels of which several icebreakers with 3 ice breakers which are classed as Lider (the most powerful type) (Schwedtfeger, 2020). The rest of the fund will be used to develop ports as well as hinterland connections in the Arctic, the most notable contributor to fund is the company DP world who operate many container terminals and ports around the world (Golubkova and Stokyarov, 2019).

2.5.1 Fuel costs, Emissions and Ice

According to Chou et al. (2017), around 50-70% of the costs for shipping companies are attributable to the fuel costs. In recent years the International Maritime Organization has increased the global requirement for fuels used onboard all vessels to be cleaner. The regulation known as the Sulphur cap had required shipowners to use fuels with lower Sulphur content which costed higher. While every container carrier was able to pass on a portion of this cost in the form of Bunker Adjustment Factor (BAF) surcharge to customers, they were forced to absorb a portion of the costs further increasing the fuel cost burden (Shen, 2019). While industry analysts feared the worst because of undersupply of Low Sulphur Fuel Oil (LSFO), the shipping industry has managed the transition to a cleaner fuel well (Chambers, 2020a).

In 2008 the IMO turned its focus to greenhouse gases especially the carbon dioxide emissions from ships, this issue is the next big transition faced by the shipping industry. It was mandated that the total CO_2 emissions of world shipping in 2008 which stood at 794.1 million tonnes must be reduced to 50% by the year 2050 (Bankes-Hughes, 2020). In 2020 the IMO published their latest (the 4th version) IMO greenhouse gas study, it was found that the CO_2 emissions had fallen from 2008 levels but had grown by 5.6% from 2012 levels to 740 million tonnes in 2018 (IMO, 2020). The study also found that other greenhouse gases from shipping such as methane were also experiencing faster growth rates. Currently the IMO does not regulate methane emissions from ships but future amendments to regulations may include this pollutant (IMO, 2020). According to Lindstad, Bright and Strømman (2016), the use of the NSR results in almost a 30% reduction in $CO_{2,}$ in comparison to the Suez route, however it was also when all Greenhouse house gas factors were considered the Arctic is less climate friendly than the Suez. Since this paper focuses on CO_2 emissions the other gases will not be considered.

According to, Noteboom and Cariou (2009), the consumption of vessels is related to their size and speed at which they sail. Figure 9 portrays the consumption based on speed of various container vessel sizes. Ships have been forced to sail at lower speeds to save on fuel costs while sacrificing schedule reliability. This is because the speed of the vessel correlates with the bunker fuel consumption which in turn influences fuel costs. The world average speed of all vessels has been significantly reducing since the 2008 financial crisis. It was seen that containerships were 25% slower in 2020 than their 2008 levels (Chambers, 2020b). As it was already seen that fuel costs are the most important factor for container vessels it makes financial sense for container vessels to slow down. In 2018 this translated to an average speed of 16.61 knots in the Asia-Europe trade lane and in the first few months of 2019 the speed fell even further to 15.6 knots (Knowler, 2019a). Consequently, the total Asia to Europe round trip times have increased further in 2020 and range between 10 weeks and 13 weeks (Offshore Energy, 2019).

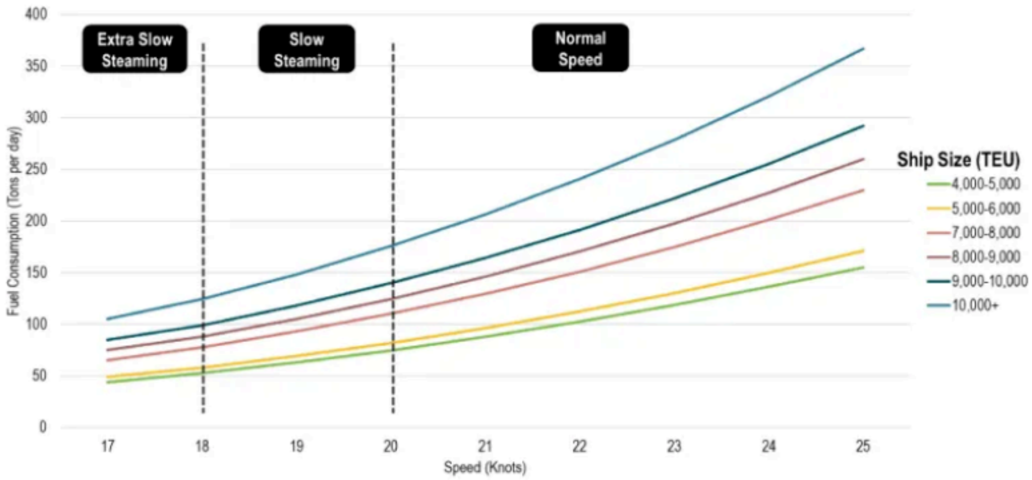

Figure 9: Ship size, speed and fuel consumption (Noteboom and Cariou, 2009)

However, the reduction in distance offered by the NSR does not directly correlate with savings in speed and time (Cariou et al., 2019). The changes in ice thickness which can be unpredictable at times have an adverse effect on speed and on the transit time and the engine efficiency which is influenced by changes in speed. This also influences fuel consumption and subsequently the CO_2 Emissions (Cariou et al., 2019). For a 1A ice class vessel like the Venta Maersk the optimal speed at which consumption are optimal is at 15 knots (70% of the design speed) (Cariou et al., 2019). As seen in figure 10, the speed begins to reduce when the ice level increases to 0.1m and at 0.5m the speed needs to be reduced to 5 knots. When the ice level reaches to 0.9m, icebreaker assistance is required to proceed. container vessels need to maintain speeds between 70-80% of the design speed to maintain optimal consumption of fuel (Cariou et al., 2019).

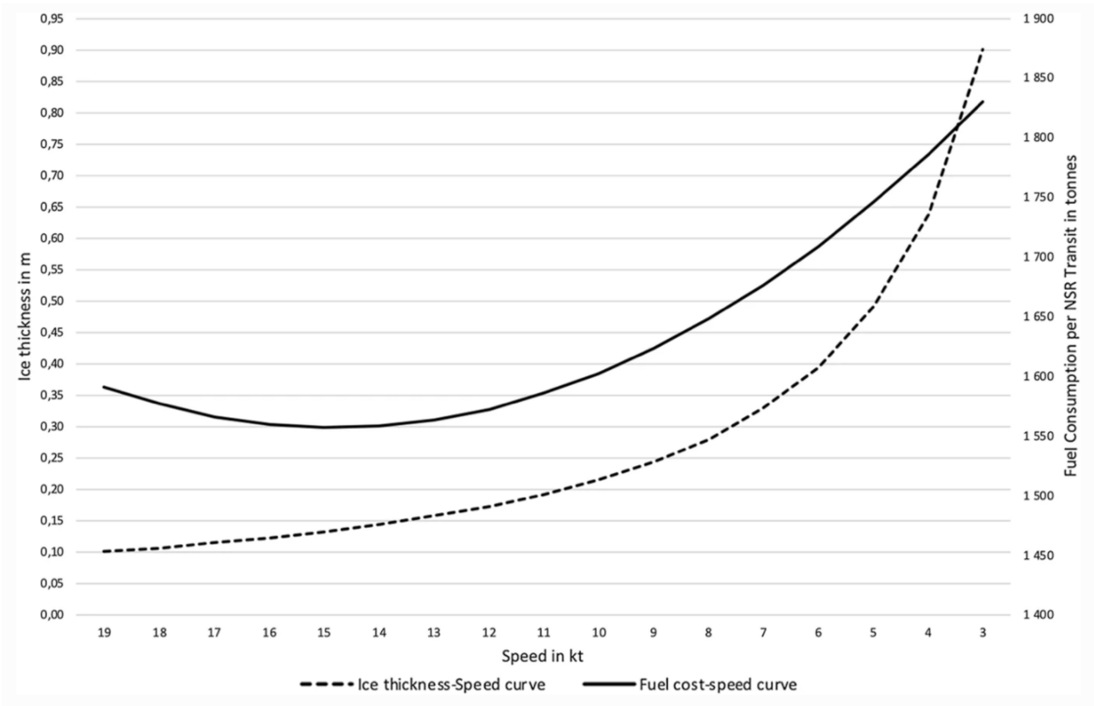

Figure 10: Impact of ice thickness on speed and cost (Cariou et al., 2019)

2.6 Ice the deciding factor

September of 2050 is the year the Arctic will be completely ice free for the first time according to the SIMIP Community (2020), in almost all of the simulations the research found that ice vanishes completely in the summer of 2050. Even with the current measures in place to curb global warming the findings point out that an ice-free arctic will be inevitable without considerable reform to policy. The worst-case scenarios also predict ice-free winters if change if current policy is not implemented properly (Digges, 2020). This recent study comprised of the latest climate simulation models from 21 world research institutes. Russia was also seen to be particularly vulnerable to climate change as its temperatures have increased at a rate of 2.5 higher than global rates (Digges, 2020). Moreover, wildfires and other phenomenon in the Arctic, in recent years have exacerbated the ice melt which has progressively broken records (Freedman, 2020).

Russian ambitions of making the route compete with the Suez Canal focus more on the short term and plans for development along the route are already underway as seen earlier. A former military base in the kola peninsula which is at the mouth of the NSR and close to Europe has been named a potential site for the construction of a container terminal in the future. Currently railway construction along the western coast of the Bay and the container terminal is likely to be situated here in the future (Staalsen, 2020).

2.6.1 Creation of a loop based on ice conditions

Verny and Grigentin (2009,) justify the competitiveness of the NSR by claiming that it connects the production cluster of Asia to the consumption cluster of western Europe. The NSR is 7,700 Nautical Miles long from Shanghai to Hamburg whereas the Royal Road route (Suez Canal) is 10,200 Nautical Miles, this translates to a saving of around 10 days.
The problem when designing comes from the fact nearly 2500 nautical miles of the Siberian coast between Murmansk and the Bering Strait are uninhabited, which means that there can be no stopovers in this region without the future development of ports. The Royal Road has multiple stopover potentials including transshipment hubs which can maximize profits and optimize the line by increasing the utilization rates (Verny and Grigentin, 2009).

The fictional line in the NSR travelled at an average of 15 Knots between June and December but in the winter months at a speed of 11 knots. However, they projected that due to global warming the vessel will be able to do 17 knots in the Russian portion of the NSR and 24 knots in the other regions and these were the speeds used for the simulation (Verny and Grigentin, 2009). After leaving Shanghai the vessel makes stops at the ports of Busan and Tokyo and proceeds through the Bering and Sannikov Strait till it reaches Rotterdam and then terminates at Hamburg (Verny and Grigentin, 2009). They assume a reasonable one day stay at each port and the vessel continues its eastbound passage with the same ports in reverse completing the loop. The whole loop takes place in 37 days which results in 9.8 loops per year, which means that 5.3 vessels are required to have a weekly service (Verny and Grigentin, 2009). From the findings of Cariou et al. (2019), it is seen that the speeds assumed for the vessel is very optimistic and with the assumption between 2015 and 2025 it can be safely concluded that the speeds of 17 knots to transit the NSR is infeasible in the near future.

In choosing the vessel apart from being an ice classed vessel they also took into consideration the draft restriction at the Sannikov strait which is set at 13m. The 4000 TEU vessel chosen was assumed to carry 2800 TEU in its westbound direction and 1200 TEU in its eastbound direction due to the trade imbalance explained earlier (Verny and Grigentin, 2009). In their cost calculations the capital expenses were also included along with ship depreciation, according to Stopford (2009, p.540) while these do constitute the ship costs per day they belong to the CAPEX and not the OPEXES. With regards to the crew costs there was no extra costs added than the regular costs, however they claim that having crew with experience of sailing the NSR will be beneficial (Verny and Grigentin, 2009). Theocharis et al. (2018), analysed 31 papers on the competitiveness of the Arctic sea routes from various sectors and found that the crew costs generally were taken between 10% - 28% while many studies ignored adding an increase and assumed similar costs for all routes.

While it is true that the absence of contact with shore is a safety issue, technology and the safety of vessels have advanced since the publication of this study. However, assumptions for insurance premiums for cargo and vessel are very varied and high as seen in Table 4. The reason for this is due lack of information coordination for insurance providers to properly assess the risk of shipping in the Arctic, this has led to insurance being provided on a case by case basis making it prohibitively expensive, however as the voyages through the Arctic are increasing the historical database of voyages is being made public to insurers to assess risks more accurately (Peter, 2019). Apart from the insurance obligations there are also fees relating to icebreaking which are termed as NSR tariffs. These tariffs depend on the Ice class of the vessel (higher the ice class lower the fees). According to Verny and Grigentin (2009) the administrative burden and the NSR fees which are higher than the Suez Canal fees will drive container liners away from the NSR. However, it was seen earlier that the Russian government is taking active steps to improve the competitiveness of the NSR.

Table 4: Insurance premium assumptions in Literature

H&M Insurance Premium	P&I Insurance Premium	Authors
5%	5%	(Song and Zhang, 2013)
50-80%	50-80%	(Lasserre, 2015)
200%	100%	(Pruyn, 2016)
100%	25%	(Zhao, Hu and Lin, 2016)
50%	25%	(Zhang, Meng and Ng, 2016)

Moreover, According to Drewry (2020) the OPEX consists of manning, stores, spares, lubricating oils, dry docking, management & administration, insurance and repair and maintenance costs which are usually measured in a fixed value denoted in $/day.

2.6.2 Fuel Choice

As previously discussed, the global Sulphur cap of the IMO is already in force. In accordance with Table 5, the fuel used in ships should not exceed 0.5% m/m of Sulphur. LSFO is the type of fuel most commonly used on ships which meets the required specifications of the Sulphur limit. Apart from this regulation there are several areas termed as Emission Controlled Areas (ECAs) where the fuel requirement is more stringent on

Sulphur. In this area which are located in North America, US Caribbean, North Sea and the Baltic, the use of fuel with Sulphur content lower than 0.1% m/m is mandated (IMO,2017). This type of fuel is usually called Marine Gasoil (MGO) or Marine Diesel Oil (MDO).

Table 5: Sulphur regulations (IMO, 2017)

Global Sulphur content in marine fuels shall not exceed

4.50% m/m	Prior to 1 January 2012
3.50% m/m	On and after 1 January 2012
0.50% m/m	On and after 1 January 2020

As a general rule, fuels with lower Sulphur content are costlier due to various dynamics of oil refining. Since the CO_2 Emissions are coming into focus there is more attention to fuels such as methanol. While LNG, which is a lower emitter than HFO and MDO, the emission of more persistent Greenhouse Gases which caused longer term damage to the environment were more prevalent as compared to MGO (Pavlenko et al., 2020). This makes methanol the cleanest fuel which could have widespread adoption in the future. Table 6 shows that LSFO, LNG and Methanol emit 2.9%, 14% and 57% lower CO_2 per gram of fuel burnt respectively in comparison to MDO.

Table 6: CO_2 emissions of various marine fuels (IMO,2020)

Fuel type	Carbon Content
HFO	0.8493
MDO	0.8744
LNG	0.7500
Methanol	0.3750
LSHFO 1.0%	0.8493

2.7 Theoretical Framework

Broadly there are three main factors with regards to costs which can be extrapolated from the literature. The Capital Expenses (CAPEX) relating to the expenses of purchasing the vessel, ice classification requirements bring with it an increased cost. Operational expenses which are related to the costs the running of the vessel. These two fixed costs are relatively fixed and can be directly compared between the NSR and The Royal Road route, with the Royal road route being the more economical option in many cases. The main variation in costs and emissions comes when computing the Voyage Expenses (VOYEX) and emissions.

2.7.1 VOYEX

Before setting the parameters for the associated costs, it is important to decide the Vessel type and sizes for the two routes, the ports in the rotation and thereby arrive at the distances for these routes. The current ice related draft restrictions along with the fact that it was the latest container vessel to successfully make the voyage across the NSR makes the hypothetical vessel 3600 TEUs similar to Venta Maersk. The laws of economies of scale dictate that, it would be commercially unviable for container companies to send a vessel of similar size on a voyage via the Suez Canal. It is for this reason the vessel traversing through the Royal road for comparison sake will be 15,000 TEUs, as this is the average size of vessel in this line (Offshore energy, 2019).

As seen earlier, the absence of a ports in the Arctic makes it so that the liner companies in their schedule designs will optimize their route by maximizing stops at other ports. It is for this reason the ports chosen by Verny and Grigentin (2009) will be taken as the default loop for the Royal Road and the NSR routes. The Westbound loop starts from Shanghai -> Busan -> Tokyo and then follows the NSR to Hamburg and then terminates at Rotterdam. The same ports are followed in the reverse order for the eastbound direction and this completes one loop. For the comparison with the Royal road the line starts from Tokyo -> Busan -> Shanghai and then sails through the Suez Canal to Rotterdam and then Hamburg, for the east bound voyage the same route in reverse order, completes a loop.

The speed of the vessel is seen to determine the fuel consumption and the time taken to arrive at various destinations, to determine this the various ice restriction along with other limitations such as sailing speed through the Suez Canal need to be considered. It was seen that fuel regulations are tightened in certain places especially in ECAs, however for ease of calculation most papers considered the same fuel for the entire route. This will be the same approach in this paper. once the speed and consumption are fully determined the emission factors of the fuel used (IMO,2020) for both routes will be used to determine the emissions. Finally, the voyage costs will have to include the icebreaker fees for the NSR and the canal fees for transiting the Suez Canal.

2.7.2 Other costs

The Capital Expense (CAPEX) of running the ship is the next consideration however this is a cost known to the company and the paper assumes that no company will build vessels specific for serving the Arctic. The case of the Venta Maersk shows that the highest level of ice class vessels still gets employed in other ice-ridden areas of the world. This paper will operate on the assumption that the difference in capital expense is not a deciding factor for liner companies when it comes to the Arctic.

Another cost which will have little variation and will be fixed for the liner company are the costs relating to Operating Expenses (OPEX). From the literature it is seen that the main variation for this category comes from some assumptions that crew costs, insurance and maintenance costs may be higher for the NSR than the Suez route. This will be included in the considerations within this paper.

2.7.3 The Rationale for Scenarios

Based on the literature review it can already be predicted that even in the best-case considerations the journey through the NSR will be uneconomical for a line to operate. The laws of economies of scale will make the smaller ship sailing through the NSR less profitable to justify choosing the route for container liners. It was also seen in the literature that the ice is melting in the NSR and as the route opens up further, the Russian government is also investing on improving the infrastructure in the region. This allows for the paper to explore hypothetical scenarios wherein the ice melting in the region will allow for greater savings as larger ships sail through the region. Therefore the scenarios will be 2020, 2030 and 2050.

2.7.4 Concluding figure

Figure 11 summarizes the various the variables required for the assessment of both routes. The route yielding the lower overall costs and emissions for the whole loop will be the one which is suitable for liner shipping companies to use to save costs and be CO_2 friendly.

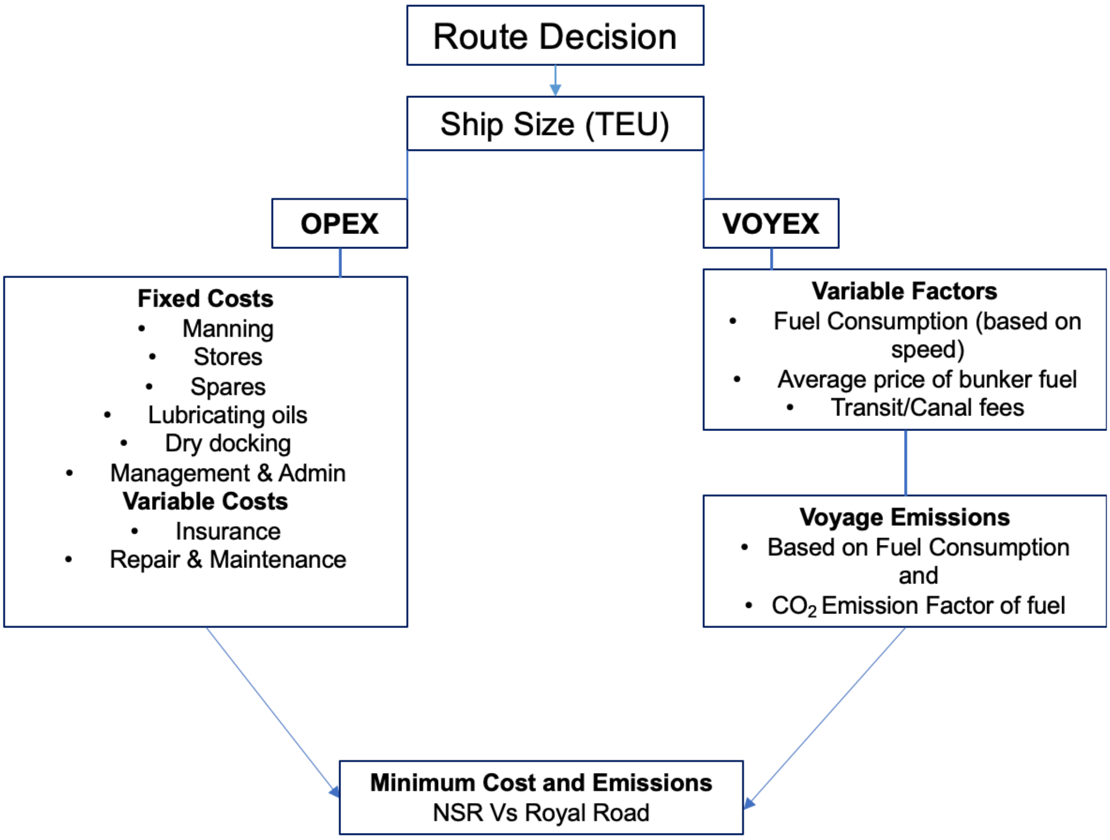

Figure 11: The Theoretical framework

Chapter 3: Methodology

Saunders, Lewis and Thornhill (2018, p.144-145), highlight the involvement and development of a theory for research. There are three approaches to the development of such theory. The deductive approach allows for the formation of a theory from the literature and this theory is tested by designing a strategy which allows for testing the validity of the theory. conversely the inductive approach involves the collection of data for the exploration of a phenomenon which allows the generation and building of new theory. The final approach termed as the abductive approach involves a combination of induction and deduction.

From the literature review it is clear that there is a pattern and a general agreement among authors that the ice levels in the NSR will be the key differentiating factor in determining the costs and consequent competitiveness of this route. From the literature it is still unclear when a container line across the NSR will be cost and CO_2 efficient, especially in modern day scenario where the sizes of vessels have increased exponentially in pursuit of economies of scale.

Therefore, this uncertainty will be employed to steer the research into a deductive one where the patterns and observations made in the literature review show that there is general consensus that the NSR is uneconomical compared to the Royal Road mainly due to the ice related limitations. However, there is strong literature to support the argument that in the near and far future, around 2030 and 2050 respectively, the effects of global warming along with Russia's ambitions of making the NSR a highway connecting the East and West will make it economically and environmentally competitive.

Deductive approach to research is prevalent in the natural sciences where the basis for explanation is explained by scientific laws. A tentative idea which is testable because it contains variables is used to form theory, this is done by using existing literature to specify conditions under which the theory needs to hold true. For this a testable proposition or multiple propositions are formed. It is also important that these new propositions need to add value and expand on pre-existing knowledge. These propositions are tested against appropriate collected data followed by analysis of the results. (Saunders, Lewis and Thornhill, 2018, p.144-145).

Another important characteristic is that the three approaches of induction, deduction and abduction are not always used exclusively, sometimes there is a certain degree of overlap of the research methods. One approach may be dominant but flavors of the other may be prevalent within the literature. The time period for the research makes the deductive approach the quicker of the three, however there is flexibility to incorporate elements of other types of approaches (Saunders, Lewis and Thornhill, 2018, p.149).

"Scenarios are consistent and coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present, and future developments, which can serve as a basis for action" (Van Notten, 2005). According to Varho and Tapio (2013), the use of scenarios is prevalent among scientists and policy makers when predicting and planning for multiple outcomes in the future. This paper will employ the simplest form of scenario work and reflect on these, this type consists of 3 steps:

a) The creation of definitions for the scenario
b) Development of methods for data gathering and analysis
c) The creation of alternative future scenarios to explore (Varho and Tapio, 2013)

While deductive methods call for a structural approach to scenario planning, the inductive nature research allows more freedom in the formation of scenarios through the formation of coherent stories generated from association and inferred patterns (Van Notten, 2006). In this way this paper has also employed elements from induction and generic scenarios will be created.

3.1 Research Design

The methodological choices for research vary between qualitative, quantitative or a mix of the two. The key differentiating factor between quantitative and qualitative data is that the former makes use of numerical data while the latter is usually related to textual data. It is seen that Quantitative research is associated with the philosophy of positivism (Saunders, Lewis and Thornhill, 2018, p.165-166). This means that only factual knowledge obtained from the collected data is true and takes a very objective approach to research (BRM, 2020). Choosing a predominantly quantitative methodology for this research is appropriate, because a deductive approach requires for theory to be tested with data which are easily quantifiable.

It is also seen that the relationship between variables are numerically measured and controls are defined to ensure the validity of the data (Saunders, Lewis and Thornhill, 2018, p.165-166). The number of methods used for collection of data may also vary and does not need to follow a singular source type. Another key factor that makes quantitative research viable for this topic is the fact that, this kind of research allows for generalizability, it is not opinion dominated as in qualitative and more fact driven which can make the model used in this research to be applied for future work or can help container lines make decisions on the NSR (Saunders, Lewis and Thornhill, 2018, p.165-168).

3.2 The Data

Data which has been already collected and is readily available can be termed as secondary data, the advantage of using primary data is highlighted by the cheapness and by the fact that it is more readily available as opposed to primary data (Statswork, 2020). The nature of this research is such that, the operational costs and data of the Arctic, which is such a contentious and distasteful topic within the shipping industry, owing to the environmental concerns, makes obtaining unbiased primary data a futile attempt.

It is for this reason this paper will make use of data contained within pre-existing literature such as peer reviewed Journal articles contained mainly within the literature review; latest reports by maritime consulting firms such as Drewry; publicly available online software and databases such as Searoutes.com and Ship&Bunker. It is also seen that secondary data is not solely limited to quantitative data but also consists of qualitative elements which will be employed in this research (Saunders, Lewis and Thornhill, 2018, p.318). Figure 12 represents various types of secondary data which are available and most of these types such as news articles from reputable dailies and reports from consulting firms such as ICCT and Deloitte will be utilized within this research to collected and translated to usable quantitative data.

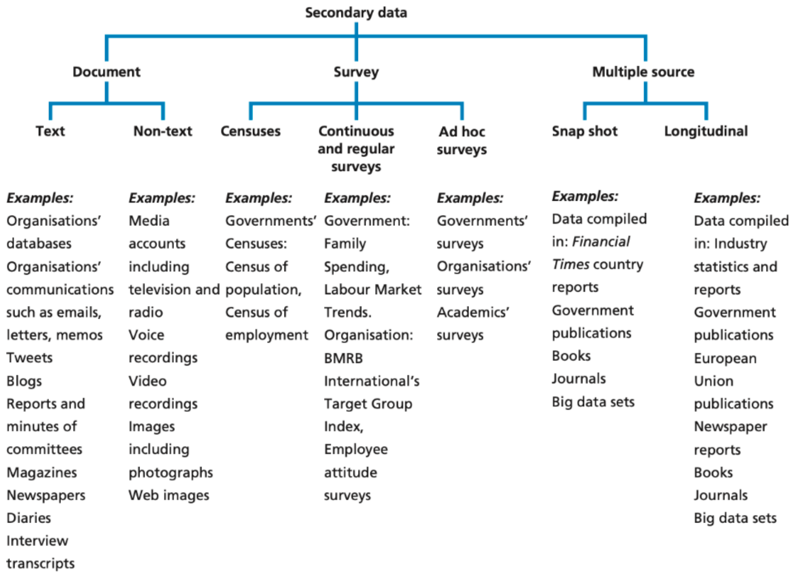

Figure 12: Types of Secondary data (Saunders, Lewis and Thornhill, 2018, p.319)

In order to collect relevant data, the following keywords and a combination of these, were used to search for secondary sources: Arctic, Ice melt, NSR, Royal road, Russian NSR, liner shipping in the Arctic, Container vessel consumption, Vessel consumption and speed relationship; Impact of ice thickness on speed; CO_2 emissions in the Arctic; Alternative fuels; Arctic in 2030; Arctic in 2050.

3.3 Data Analysis

For this purpose, the paper will propose a model in the next section which will be used to determine the voyage and operational costs for both the Royal Road and the NSR. The aim for this model will be to make the two routes as comparable as possible, while also maintaining the values of critical positivism. In doing so the criteria for generalization will also be satisfied. The variables deduced in the theoretical framework will be used to incorporate the quantitative and qualitative secondary data to arrive at the costs and emissions of the NSR and the Royal Road routes. This type of analysis is also similar to the methods followed by other authors (Verny and Grigentin, 2009) & (Lasserre, 2014) in assessing the NSR and Royal road for competitiveness.

It was also concluded after the literature review that, for the addition of maximum value by the researcher, the use of scenarios is vital, to see if the NSR will ever be a viable option for ocean lines to operate on and to determine the cost and environmental implications for liner companies. Since these future scenarios do not readily exist, further analysis will be done to construct scenarios. Quiceno et al. (2019), claim that scenario analysis provides companies with a tool that helps them to make strategic decision making. The use of scenarios in this paper is for a more predictive purpose wherein the uncertainty of the future is described in such a way the model of this paper can still be validly used. Conducting a PESTEL analysis which focuses on trends which affect the main variables of the model can help in sufficiently altering the data for the various futuristic scenarios (Quiceno et al., 2019). PESTEL refers to Political, Economic, Social, Environmental and Legal forces which influence the variables in the model in such a way that allows for the scenarios to be formed (Quiceno et al., 2019). The scenarios will be formed based on theory about ice level and major shipping related environmental regulations. It is for this reason the years 2020, 2030 and 2050 will be used as scenarios.

3.4 The models

Since it was seen that the level of ice along the arctic is not constant and will be dependent on the various scenarios developed. The model has to be one which can be used for all the scenarios and for both routes (The NSR and the Royal Road). Therefore the following models have been deduced based on the theory.

The Economic model is denoted by: $TC_{loop} = T_F * P_F + TR + FC$

The Environmental model is denoted by: $ECO_2 = T_F * E_f$

Here the TC_{loop} denotes the total costs in US dollars ($) for the whole loop i.e. costs for the westbound and eastbound voyages of the route; T_F denotes the total fuel consumed in tonnes for the entirety of the loop; P_F is the average price of bunker fuel in $/ton; TR denotes the transit fees (Ice breaker fees in the case of the NSR and Suez canal fees for the Royal Road route). Because the variables thus far only manage to capture the VOYEXs, FC denotes the fixed costs which includes OPEXs. From figure 11, the VOYEX the fuel consumption is T_F and P_F is the average price of bunker fuel and the TR is the transit/Canal fees. The OPEX under figure 11 is represented by FC, the additional variable costs of insurance and maintenance are added to the NSR route because only this route demands a higher premium.

ECO_2 denotes the total emissions which can be expected from the whole loop. It is calculated by multiplying the Total fuel consumed in tons with the emission factor (E_f) of the fuel used. The emission factor will be measured in tons of CO_2 emitted per ton of fuel burnt (IMO, 2020). From figure 11, the voyage emissions denote this factor of the model.

Although these models may seem simple and straightforward, additional complexity occurs when the fuel consumption is taken as a function of vessel speed. This is relevant because the vessel traverses through the NSR where the ice conditions dictate the speed. Moreover, the speed determines the total number of days taken to complete the loop. Additionally, port stays and consumption rates at ports need to be determined to have an accurate consumption rate and subsequently the CO_2 emission rate.

Chapter 4: Scenario development and Calculations

As discussed in the previous chapter, in this chapter the scenarios will be formulated, and the model applied for the NSR and Royal Road routes, the years and the scenarios will be developed for 2020, 2030 and 2050. A PESTEL analysis will be employed to develop each of the scenarios. Subsequently the variables in the model will be amended based on the data analyzed.

4.1 Scenario 2020

4.1.1 Political

It was seen in the literature that Russia has been accelerating plans to make the NSR a viable alternative to the Royal Road. This plan was undertaken under president Putin's administration. On the 1st of July 2020, the people of Russia overwhelmingly voted for constitutional reforms within the country which could potentially allow the Vladimir Putin to stay in power till 2036, after his current term ends in 2024 (Ellayatt, 2020). This means that Russia's plans for the NSR will not be radically changed in the coming years owing to a change in governmental policy, as the plans for the NSR have remained increasingly progressive over the years and is expected to become more aggressive in the coming years.

4.1.2 Economic and Social

In the early months of 2020, the COVID-19 virus was named as a global pandemic forcing countries to go into lockdown to prevent the spread. The scramble for countries to stock up on medical supplies led to international supply chains to break down and for countries to airlift essential equipment and low value goods. This resulted in the prices for traditionally low value goods such as masks to skyrocket, the reason countries were forced to airlift essentials was because of the race against time to save the most critical patients in their countries (Morris, Booth and Beck, 2020). However, this begs the question were there a fully functioning NSR, could it have resulted in a social benefit? owing to the shorter lead time from Asia to Europe.

The container freight rates took a major hit as a result of the pandemic, table 7 shows that the decline in container volume between February of 2019 and 2020 was almost 17.5% in the far east. In response to this fall in demand the carriers idled almost 2.5 million TEUs in total which accounted for 10.6% of the total fleet (ITF, 2020). There was also a major fall in oil prices resulting in the availability of cheap bunker and to avoid paying Suez Canal fees many container operators rerouted via the Cape of Good Hope, this reiterates the need for alternatives to the Royal Road (ITF,2020). This rerouting of vessels meant that carriers were happy to burn more fuel and thereby increase CO2 emissions in order to enjoy savings on VOYEXs.

Table 7: Change in container export volumes (ITF,2020)

	Change Jan 2019 to Jan 2020 (%)	Change Feb 2019 to Feb 2020 (%)
Far East	0.0	- 17.5
Europe	0.7	- 4.0
North America	- 0.3	- 7.0
Australasia and Oceania	- 6.5	- 2.8
Indian Subcontinent and M. East	3.7	6.1
South and Central America	2.4	2.8
Sub-Saharan Africa	5.4	7.4

4.1.3 Technological

Russia's new generation of ice class vessels which are called the Lider class (Leader in English), began construction on the 28th of August 2020. Russia's Zvezda shipyard has set the delivery date for the first Lider class vessel as 2027 (Vorotnikov, 2020). This nuclear vessel which is part of a fleet of 3 giant icebreakers capable of breaking up to 4.3 meters of ice sheets and have a continuous operational capability of 8 months are aiming to allow for the year-round navigation of the NSR by 2035 (Vorotnikov, 2020).

4.1.4 Environmental

Recent studies by the Russian Hydrometeorological Centre show the safety of sailing through the Arctic is improving. However, in July 2020 the NSR was fully ice free and had attained the lowest recorded level historically, it was also the earliest the route had become fully ice free (Vorotnikov, 2020). However, other scientists argue that the low ice levels do not necessarily mean increased safety of navigation for ships. There may be free floating chunks of ice which are not easily picked up by navigational equipment and could pose significant Hazards (Vorotnikov, 2020).

4.1.5 Legal

Key advancements in Arctic regulation has not come from governments but from major shippers and shipping lines self-declaring that they will not use the Arctic as strategic decisions and environmentally motivated pledges (Nilsen, 2020). The pledge was facilitated by the Non-Governmental Organization (NGO) Ocean Conservancy, the main signatories to this pledge to boycott all Arctic shipping include companies such as Ralph Lauren, Kuehne

Nagel (freight forwarders), PUMA, H&M Columbia and Gap Inc. These companies cite the impact of climate change on the Arctic and the decline of sea ice as major threats (Nilsen, 2020). Liner companies such as MSC, CMA CGM and Hapag Lloyd who occupy 35% of the container market share have decided and also pledged to not use the NSR (Nilsen, 2020).

Researchers argue that such a strong aversion towards development of the Arctic region will come at social costs as it will deprive an entire region from significant economic development, just so that the brand images can be protected (Nilsen, 2020). It was earlier seen that it was the same liner companies who decided that the monetary savings in canal fees would be worth the sacrifice in releasing higher emissions released by sailing around the Cape of Good hope (ITF, 2020).

4.1.6 Calculations Royal Road

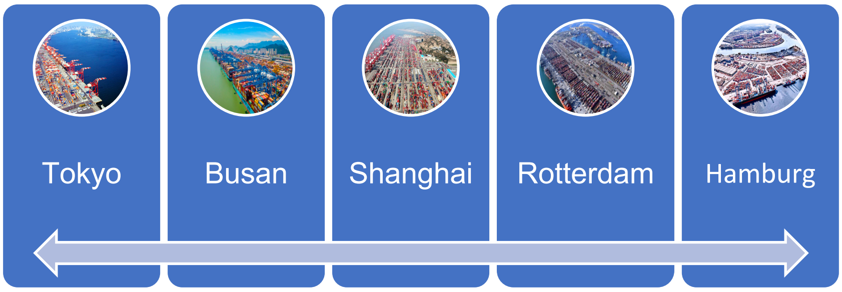

Figure 13: The Royal Road loop

Figure 13 indicates the route for the loop, the vessel transiting this route will be 15,000 TEU in size and will be 5 years old. The Vessel departs from Tokyo, table 8 indicates the average turnaround times at the container ports in the loop and the journey terminates at Hamburg. The total journey is 11,894 Nautical Miles (NM) (Searoutes, 2020). The average world speed in 2018 of container vessels is taken as the speed for this vessel (Knowler, 2019a), it is seen that the total sailing days for this vessel at sea will be 29.14 Days at a speed of 17 Knots and the total days spent at port and transiting the Suez will be 3.74 days (Table 8). This results in the total number of days taken to complete a loop to be 65.76 days.

Table 8:Average turnaround time at container ports (UNCTAD, 2019)

Turnaround time of Ports	Days
Tokyo	0,35
Busan	0,6
Shanghai	0,62
Rotterdam	0,78
Hamburg	0,79
Total Days at Port	3,14

At a speed of 17 Knots the consumption of an 18,000 TEU vessel is seen to be 120 Tons per day (Ge et al., 2019). This number is also consistent with the findings under table 9, as the consumption of a vessels in the 12,000-14,999 TEU range also is approximately 120 Tons per day (Le et al., 2019). It is calculated that the vessel consumes 3496.8 tons per sea leg. However, according to the EIA (2020), vessels only consume around 5% of their regular consumption when at ports, it was assumed that the consumption at ports and during the additional time spent in the Suez the consumption will be 22.44 tons (SCA, 2020). The total consumption of fuel for the whole loop (T_F), is obtained as 7,038.48 tons.

Table 9: Consumption of container vessels based on Speed (Le et al., 2019)

Speed (Knots)	Voyage Time (days)	<3,000 TEUs	3,000–5,999 TEUs	6,000–7,999 TEUs	8,000–11,999 TEUs	12,000–14,999 TEUs
14	2.98	91.1	142.7	193.1	210.9	243.0
15	2.78	97.7	150.9	201.2	221.5	258.3
16	2.60	105.1	160.4	211.2	234.1	276.0
17	2.45	113.3	171.2	222.8	248.6	295.8
18	2.31	122.3	183.2	235.9	264.8	317.7
19	2.19	132.1	196.3	250.5	282.6	341.5
20	2.08	142.6	210.5	266.5	302.0	367.2
21	1.98	153.8	225.7	283.9	322.9	394.7
22	1.89	165.8	242.0	302.5	345.3	424.1
23	1.81	178.4	259.3	322.4	369.0	455.2
24	1.74	191.7	277.5	343.4	394.2	488.0
25	1.67	205.6	296.8	365.7	420.8	522.5
26	1.60	220.2	316.9	389.2	448.7	558.7

*It is assumed that the voyage distance is 1,000 nautical miles for ease of comparison.

Next the price of one ton of LSFO in Rotterdam for the month of August was taken as $315/ton ($P_F$) (Ship&Bunker, 2020). It was seen that for a 15,000-18,000 TEU vessel the Suez Canal fees was between $700,000 to $900,000 (JOC, 2019). TR was obtained by assuming the Westbound transit will cost $900,000 and the Eastbound journey cost as $700,000; i.e. TR = 1.6 million for the loop. The Fixed costs are taken for a 5-year-old, 15-17,999 vessel obtained from Table 10, this figure for OPEX which is denoted in $/day is multiplied by the total days for the loop to obtain the Fixed Costs (FC) which is $628,008.

Table 10: Operating costs per day 15-17,999 TEU (Drewry, 2019)

	Vessel age		
	Newbuild	5-yr old	10-yr old
15-17,999 teu			
Manning	2,850	2,850	2,970
Insurance	910	970	1,070
Stores	460	510	510
Spares	420	450	470
Lubricating oils	1,990	2,010	2,050
Repair & maintenance	340	360	380
Dry docking	-	940	990
Management & administration	1,460	1,460	1,460
Total	**8,430**	**9,550**	**9,900**

Therefore, TC_{loop} is given by = 7,038.48 * 315 + 1,600,000 + 628,008 = **$4,445,129.2**

The CO_2 emissions for the whole loop will be given by $ECO_2 = T_F * E_f$

Since T_F was found to be 7038.48 it is multiplied with emission factor for LSFO which can be calculated from Table 6 as 0.8493 tons of CO_2 for every ton of fuel burnt.

ECO_2 = 7038.48 * 0.8493 = **5,977.78 tons of CO_2**

4.1.7 Calculations NSR

For this voyage it was decided earlier to closely simulate that of the Venta Maersk as it would be the most realistic for 2020 ice conditions. Since, freely available software cannot chart an accurate path for the NSR, the distance of Verny and Grigentin (2009) were used to divide the NSR in the Asian and European segment (5273 NM), the Russian segments ridden with Ice (800 NM) and the Ice-free regions (1977 NM). The transit was assumed to be in the peak of summer in August since this is when the ice would at its lowest and ice-breaker fees would also be low. The vessel is 3,600 TEUs and is also assumed to be 5 years old.

The tariff for NSR depends on the Ice class of the Vessel, and also the requirement for Ice breakers. Comparing the path taken by Venta Maersk in figure 8 with the division of the Arctic zones in figure 14, it can be clearly seen the 800NM (Humpert, 2018) stretch of zones 4, 5 and 6 is where the vessel would need ice breaking assistance. The Ice breaking fees for the summer/fall season was calculated to be 1,032,070$ (Cariou et al., 2019) for a one-way trip and to complete the loop it would cost 2,064,140$ (TR).

The 7 NSR zone subject to Icebreaker Fee

Source: Authors based on http://d-maps.com/carte.php?num°car=3193&lang=fr

NSR fees [in USD] as a function of the number of zones with icebreaker assistance

Class	Season	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6	ZONE 7
1A	Summer/Fall [USD]	191 127	229 345	267 572	305 799	344 026	382 245	382 245
	Winter/Spring [USD]	477 812	573 371	668 930	764 498	860 057	955 625	955 625

Figure 14: Ice breaker zonal fees (Cariou et al.,2019)

The vessel can maximize its speed in the Asian and European regions, and it sails at 17 knots. According to, phone communications with Kushal Bagi; A Phone message (Bagi, K. 2020, personal communication, 02 September) (A sailor with 12 years of experience), it was seen that ice navigation with icebreakers will reduce the speed of the vessel to about 7 knots. While this results in the engine using lower power, it does not translate to savings in consumption as the engine will need to be kept warm and consumption will be kept at similar levels to a vessel's normal speed (Bagi, 2020). The consumption for each speed levels were calculated using data from table 9. As seen from table 11, the vessel completes the loop in 54.78 days.

Table 11: Scenario 2020 NSR

NSR	Distance in NM	Speed	Days	Consumption of 3600 TEU Vessel (Tons per day)	Fuel Consumption
Asian + European Segment	5273	17	14,01	69,87	978,88
Ice Ridden Russian Arctic Segment	800	7	4,76	47,88	227,91
Ice Free Russian Arctic Segment	1977	15	5,48	54,28	297,45
Port			3,14	3,4935	10,97
Total			27,39		1515,21
Loop			54,78		3030,42

The P_F is assumed to be the same, the OPEX is calculated based on table 12, the total OPEX for the vessel in $/day is seen to be 6,190. However, based on reasonable assumptions from table 4 the insurance is cost is doubled and the maintenance cost is increased by 20% based on (Lasserre, 2014). This increases the OPEX to 6772 $/day which results in the OPEX for the whole loop being $370,970.16 (FC). Bagi (2020) also claims that the crew costs will remain the same as companies usually retain seafarers with experience in Ice voyages in the same regions and thereby will not need to spend extra in hiring or training fees for NSR navigating crew.

Table 12: 3-4,999 TEU vessel OPEX per day (Drewry, 2019)

	Vessel age				
	Newbuild	5-yr old	10-yr old	15-yr old	20-yr old
3-4,999 teu					
Manning	2,630	2,630	2,760	2,900	3,040
Insurance	440	470	520	590	620
Stores	220	240	240	250	250
Spares	200	210	230	240	230
Lubricating oils	780	790	810	820	840
Repair & maintenance	200	210	220	230	220
Dry docking	-	560	590	610	590
Management & administration	1,080	1,080	1,080	1,130	1,130
Total	**5,550**	**6,190**	**6,450**	**6,770**	**6,920**

TC_{loop} is given by = 3030.42 * 315 + 2,064,140 + 370,970.16 = **$3,389,693.40**

ECO_2 = 3030.42 * 0.8493 = **2573.73 tons of CO_2**

4.1.8 Conclusion

It is clear from this scenario that the NSR cannot compete with the Royal road, neither economically nor environmentally. Due to the restrictions based on ice, a larger ship going through the NSR in 2020 in infeasible. Thus, the Royal Road has an economies of scale advantage. It is also worth noting that for container navigation a maximum of 3 months may be allowed owing to less ice. This negates the possibility of having a regular service for the loop.

4.2 Scenario 2030

The year 2030 is a significant year for analysis in this paper owing to several important reasons it marks an important milestone in Russia's ambitions for the NSR and also is a significant checkpoint in the IMO and the shipping industry's 2050 decarbonization targets.

4.2.1 Economic

It is expected that the container export volume of China, the US, South Korea, Japan and Thailand will grow at a rate of 4.8 percent every year until 2025 and slow down to 4.3 percent in 2030 (Knowler, 2019b). In their latest port trends Deloitte (2020), point out that the NSR will become a major alternative to the Royal Road, this will also coincide with the demand for European products in China as the middle class becomes richer. This would result in balancing of the West and Eastbound trade volumes between Asia and Europe. There is also predicted to be a shift of labor-intensive low-cost products from China to South-East Asian countries (Deloitte, 2020). The need for finished products will gradually decline as the local production flourishes and ship sizes cease to increase any further (Deloitte, 2020).

4.2.2 Technological

It was seen from the literature that one of the major factors which affected the insurance premiums in the NSR was the lack of data to accurately measure and predict risk in the region (Peter, 2019). According to, Deloitte (2020) there will be increased collaboration among shipping lines in 2030 which will result in the sharing of data which can help vastly improve the safety of navigating of the NSR. Moreover, the current pandemic has benefitted shipping lines by increasing and accelerating the level of digitalization within organizations.

Russia is also taking measures to increase the number of research and rescue vessels in the NSR, the fleet is said to consist of two 18 megawatt multipurpose vessels, three 7 megawatt vessels and one four-megawatt vessel. Moreover, 10 firefighting tugs will also be built. The Arctic already has five research and rescue centers, there are plans to build 3 more of these centers by Rosatom, who are the Russian State Nuclear Energy Corporation (Vorotnikov, 2020).

4.2.3 Environmental

While most studies predict an Ice-free Arctic only in the year 2050, recent studies which do not relate to pollution but to natural phenomenon of the Oceans predict that the Arctic ocean can be ice free by 2030 itself (Tidey, 2019). The study done by the American Geophysical Union, found that a natural phenomenon known as Interdecadal Pacific Oscillation (IPO), which causes an increase in ocean temperatures, along with manmade global warming will combine and result in ice free summers in the Arctic by 2030 (Tidey, 2020). The authors of this study claim that they plotted the IPO change in tandem with real world changes and this is a more accurate prediction which would result in the melting of ice earlier (Tidey, 2020) than the 2050 predictions (SIMIP Community, 2020).

4.2.4 Political / Legal

Heavy Fuel Oil (Including LSFO) is the lowest quality of fuel oil in the refining process and is said to emit Black Carbon (BC) which is harmful to the Arctic ice and causes faster melting. These soot-like black particles is said to be 3200 times more harmful for the environment on a 20-year timescale (Comer et al., 2020). The IMO in February 2020 has proposed the use of LSFO in the Arctic. This ban will come into force from the 1st of July 2024. This means that ships sailing through the NSR from this date onwards will have to make use of Fuels such as MGO, LNG or other cleaner distillates (Comer et al., 2020). It must also be noted that this ban is not an absolute ban and that certain ships satisfying certain criteria can obtain exemption certificates to traverse the Arctic with LSFO. Nevertheless, from July 2029 this ban will be absolute, and all ships will have to switch to alternate fuels. This ban is also expected to improve safety of navigation as it is known that HFO is more persistent in cold temperatures and MGO the lighter distillate will be easier to cleanup in case of a shipboard oil spill (Comer et al., 2020).

4.2.5 Social

Container lines will be on an acquisition spree, currently new deliveries of 24,000 TEU vessels are already occurring. The South Korean line HMM has ordered 12 vessels of this size and has already taken delivery of two of these vessels in 2020 (Offshore Energy, 2020). Other lines have also revealed plans for similarly sized vessels, which will be deployed in the Asia-Europe line (Offshore Energy, 2020). It can be safely estimated that due to the cascading effect of container capacity the main line through the royal road will deploy mostly 20,000 TEU this will be a 5000 TEU increase form today's average of 15,000 TEU.

The shipping industry has been praised for reducing the intensity of CO_2 emissions by 30% in 2018. The IMO had set a reduction target of 40% by 2030, however this requirement would be met easily at current practices. It was seen that this was mainly due to low freight rates, overcapacity and high bunker price induced constraints, which forced industry slow steaming (Farand, 2020). It was seen earlier that currently the speed for containers averaged between 16-17 Knots. These findings meant that the IMO will impose more stringent regulations by 2030, which will be decided sometime in the year 2023 (Farand, 2020). While the industry is yet to find concrete solutions on its other aim of reducing CO_2 levels by 50% within 2050 it seems to be on the right path towards reducing the CO_2

intensity by 70% by 2050 (Farand, 2020). The world's largest container line Maersk has pledged that it will achieve carbon neutrality in all its operations and will have commercially viable vessels to achieve this goal, developed by 2030 (Farand, 2020).

4.2.6 Calculations Royal Road

The average vessel size in this route increases to 20,000 TEU, the speed and other parameters such as the route are assumed to be the same. The consumption of such as vessel is seen to be 129 tons/ton (Ge et al., 2019). Therefore, the total consumption for the whole route increases to 7038.48 tons (T_F). Since the vessel size increase, the OPEXs also increase. It is seen that for a 5-year vessel over 18,000 TEUs the cost in $/day in 2019 was $9,950 (Drewry, 2019). This number was forecasted to increase to around 11,000 $ in 2024 (Drewry, 2019). This will be the number taken for the calculation. It is seen that 20,000 TEU vessels also currently pay the same as 15,000 TEU vessels to transit the Suez canal (Van Marle, 2020), since the will become a competitor to the Royal Road, it can be assumed that the increased user power will force the Suez authority to keep the tariffs relatively the same.

Therefore, TC_{loop} is given by = 7566.37* 315 + 1,600,000+ 723,360= 4,706,765.29
ECO_2 = 7566.37 * 0.8493 = **6426.12 tons of CO_2**

4.2.7 Calculations NSR

It is estimated that by 2030, 15,000 TEU vessels can travel through the NSR, this is mainly owing to the new state of the art icebreakers along with developments in the Russian regions. Moreover, it is assumed that Ice breaker assistance will only be needed for one region of the Arctic during the summer loop (Zone 6) (Figure 13). The TR for the loop considerably reduces to $764,490. The Total consumption on the route (T_F) is 4,956.17 based on data from (Ge et al., 2019) and (Le et al.,2019).

In 2030, the use of MGO becomes mandatory in the NSR, it was found that the differential between MGO and HFO as of 06 September was $44.86 (Ship&Bunker, 2020). A similar differential will be assumed for the situation in 2030. The P_F is taken as $359.86 (Ship&Bunker, 2020). With regards to the OPEX it was found that the cost in $/Day for a vessel of 15,000 TEU would be around $10,500 in 2024 (Drewry, 2019). Additionally, $1500 for the insurance and $500 for the maintenance and repair have been added to result in a FC for the loop of $643,000 (Table 13).

Table 13: Scenario 2030 NSR

NSR	Distance in NM	Speed	Days	Consumption of 15,000 TEU Vessel (Tons per day)	Fuel Consumption
Asian + European Segment	5273	17	14,01	120	1681,20
Ice Ridden Russian Arctic Segment	265	7	1,6	81,54	130,46
Ice Free Russian Arctic Segment	2512	15	6,97	92,91	647,58
Port			3,14	6	18,84
Total			25,72		2478,09
Loop			51,44		4956,17

Therefore, TC_{loop} is given by = 4956.17* 359.86 + 764,490+ 643,300= **$3,191,018.56**

Since MGO is used from table it is seen that for every ton of MGO burnt 0.8744 tons of CO_2 is released.

ECO_2 = 4956.17 * 0.8744 = **4333.67 tons of CO_2**

4.2.8 Conclusion

In this scenario, the efforts of Russia and the IMO have seemed to be paid off. The navigational season in the Arctic remains only 3-4 months. However, the economic and environmental benefits have already started to show. The Russian government is marketing the NSR hard, to showcase its benefits as a major competitor for containers. The government is able to recoup its losses made by the low transit fees using the year-round transit fees charged for bulk and LNG vessels. Increased development has and data exchange has led to lower insurance costs. The NSR can accommodate larger vessels and already the savings from economies of scale are highly apparent. Even though, the IMO mandated cleaner and more expensive fuel is in use for this route.

4.3 Scenario 2050

Predicting to the year 2050 brings with it several uncertainties. However, there are two things which will happen for certain based on the previous sections of this paper, there will be a shift towards cleaner fuels. Environmental concerns will be prioritized in policy making and in almost every aspect. Based on several studies discussed earlier an ice-free northern sea route will be a reality and shipping companies and other shippers will be forced to use this route. There will also be a shift in trade routes as China becomes an importer (Deloitte, 2020). However, this factor is out of the scope of this paper, but it will be taken into consideration later in the discussion about load factors. It is also unclear, for how long Russia will be able to sustain its aggressive NSR policy.

This final scenario will therefore focus on only these two main variables of a zero ice NSR and the switch to methanol as a fuel in calculating the viability of the NSR. It is assumed that vessel sizes stop growing after 2030 and are stagnant at 20,000 TEU in 2050 for the Asia-

Europe route. Methanol becomes the most widely used fuel and the price of methanol is assumed to be the same as the current HFO price in 2020 because of its wide availability.

This makes the cost calculation of the Royal Road similar to the 2030 scenario, However the CO_2 emissions is now 0.3750 tons of CO2 per ton of Methanol burnt (IMO, 2020).

Therefore, the Royal Road ECO_2 = 7566.37 * 0.3750 = **2837.39 tons of CO_2**

4.3.1 Calculations NSR

2050 would be the year that the NSR can be fully comparable with the Royal Road, the TEU size through the NSR will also be 20,000 TEU. At 17 knots the vessel can sail the whole loop in 48 days. Using the same assumptions for a 20,000 TEU vessel the total consumption is found to be 5409.49 Tons (T_F). It is assumed that by 2050 the role of the NSR's Russian Authority is more as a provider for navigational and safety aids rather than the traditional role of providing ice breaking assistance. The Transit fees (TR) for the whole loop is assumed to be $1 million. There is no increase in OPEX costs as compared to the Royal Road.
Therefore, the total costs for the loop is given by:
TC_{loop} is given by = 5409.49* 315 + 1,000,000+ 526,900= **$3,230,888.09**
the NSR's ECO_2 = 5409.49* 0.3750 = **2028.56 tons of CO_2**

4.3.2 Conclusion

By 2050 developments in the ice conditions will allow ships of all sizes to traverse the NSR and will make it far more competitive than the Royal Road. The route will potentially be open all year round. This will allow for the creation of a liner schedule between Asia and Europe for the NSR. The NSR allows a loop time of 47.90 days this is a 30% shorter than the royal road. This means that the NSR in 2050 can potentially offer 7.6 trips per year, this is almost two more trips in comparison to the 5.5 offered by the Royal Road. Therefore, shippers can not only reduce their CO_2 footprint but also ensure that their lead times are reduced while being provided a reliable service without any uncertainties through the NSR.

4.4 Overall Results

The primary results of the model are portrayed in table 14, the main takeaways from this are that the NSR offers a time advantage over the Royal Road irrespective of the usage of ice breakers and the reduction in speed needed to navigate through the ice in the 2020 and 2030 scenario. At its worst performance the NSR still offered a 17% time decrease over transiting the Suez. It was seen that while time is an important factor to shippers, they value certainty of a fixed schedule higher than the savings produced by a lower lead time. For the ease of calculation and comparison, the paper assumed an 1600NM stretch of thick ice. However, in reality the ice could be present in a variety of uncertain combinations. This makes the NSR an unviable route for the year 2020. The years 2030 and 2050 are seen to offer a time saving of 22% and 27% respectively.

Table 14: Summary of results

Loop Stats	Royal Road			NSR		
	2020	2030	2050	2020	2030	2050
Transit Days (Days)	65,76	65,76	65,76	54,78	51,44	47,90
Fuel Consumption (Tons)	7.038,48	7.566,37	7.566,37	3.030,42	4.956,17	5.409,49
VOYEX (TF * PF + TR) ($)	3.817.121,20	3.983.405,29	3.983.405,29	3.018.723,24	2.548.018,56	2.703.988,09
OPEX (FC) ($)	628.008,00	723.360,00	723.360,00	370.970,16	643.000,00	526.900,00
Total costs (TCLoop) ($)	4.445.129,20	4.706.765,29	4.706.765,29	3.389.693,40	3.191.018,56	3.230.888,09

Looking at the costs directly without considering the carrying capacity of the vessel is unmeaningful and often misleading. On paper the NSR seems to offer savings in all cases by looking at table 14. However, the load factor/Utilization rate for each leg of the route is important to consider obtaining the cost per TEU. There was clear evidence form the theory that the Westbound route from the production center of Far-East Asia to the consumption center of Europe is more fully loaded than the West to East route. It is for this reason in 2020 it was assumed that both ships on both routes were 80% full on their westbound voyages and 60% on the Eastbound leg. However, for the 2030 and 2050 scenarios, the consumption rates of China achieve certain amount of parity with Europe. Moreover, there is also greater sharing of data and collaboration among carriers (as seen from the PESTLE analysis), this would lead to capacity for the Eastbound and Westbound routes fairly matching each other.

Table 15: Results based on utilization rates

Loop Stats	Royal Road			NSR		
	2020	2030	2050	2020	2030	2050
Total Capacity (TEU)	30.000	40.000	40.000	7.200	30.000	40.000
Westbound Utilization (%)	80	80	80	80	80	80
Eastbound Utilization (%)	60	80	80	60	80	80
Total TEU transported (TEU)	21.000	32.000	32.000	5.040	24.000	32.000
Cost per TEU ($/TEU)	211,67	147,09	147,09	672,56	132,96	100,97

Based on these assumptions, table 15 shows that the NSR becomes competitive with the Royal Road in the year 2030 itself, it is approximately $14 cheaper to transport one TEU in a loop as compared to the Royal Road. It must be noted that this is highly significant as the vessel deployed across the NSR is at a disadvantage due to its smaller size, but the lower transit fees and consumption ensure that the NSR becomes cost competitive in 2030 itself. In 2050 with the melting of Ice and the opening of international waters (which considerably reduces transit fees for the Arctic) it is seen that the NSR is $46 cheaper than the Royal Road route. Moreover, it must be noted that during this period there are no extra operating costs as a non-ice classed vessel will be able to transit through the Arctic without any assistance.

In Late May 2020, the first instance of serious oil spill the Arctic came to light, In the city of Norilsk in Northern Russia, a storage tank of Diesel oil collapsed causing a spill of over 12 miles long. This type of diesel is akin to MGO and is more poisonous for microorganisms which sustain the life of many endangered organisms of the Arctic (Glanville, Cage and Law, 2020). This was a wake-up call to the risks of an oil spill from ships which would be much more difficult to locate and cleanup than this kind. It is therefore correct that shipping companies as well as shippers are abandoning the NSR for 2020. However, from figure 15 it is seen that from 2030 the NSR starts getting progressively more CO_2 friendly. This also coincides with the safety improvements promised by Russia to the NSR, along with greater collaboration and digitalization of liner companies. All these factors will not only make the Insurance and maintenance costs cheaper for the NSR but will also result in the restoration of confidence in exploring the NSR as a viable alternative to the Royal Road.

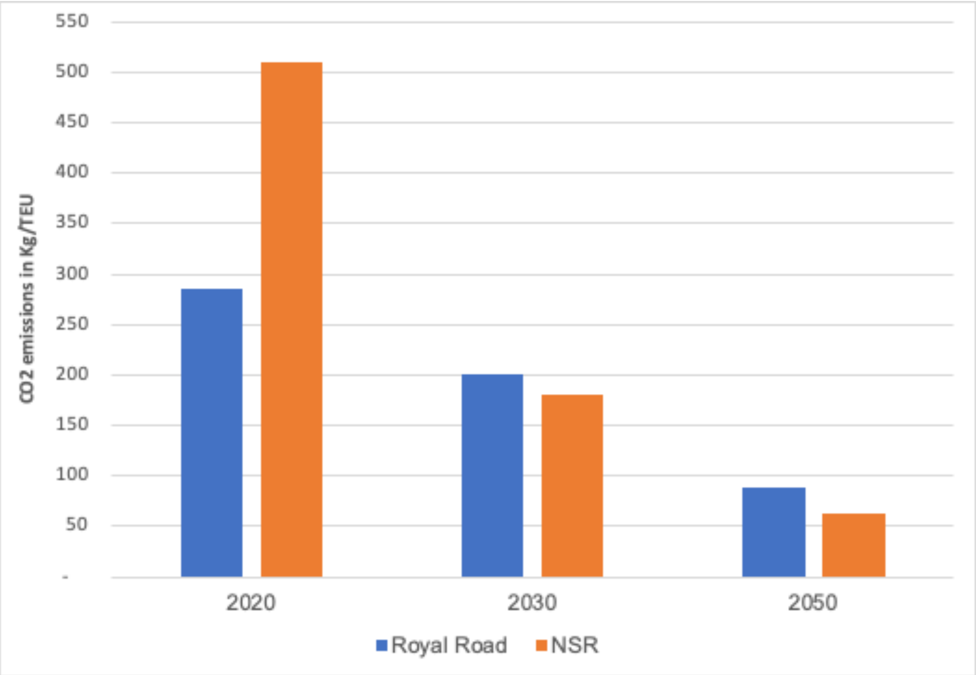

Figure 15: CO2 emissions for different scenarios

Chapter 5: Conclusion

This Thesis set about to research the important question of whether the NSR would offer benefits for container shipping. It was found that recently container lines had decided against using the route which provide a viable alternative to the Royal Road. The NSR was seen to be a shorter route which connected the consumption center of Europe and the production center of East Asia. Shipping liner companies have been navigating an environment of subdued earning while also feeling the pressure of various environmental burdens which increase their costs in recent years. Therefore, this study was focused on aiding such decision makers as well as benefactors of the Route such as Russia to find out the economic and environmental benefits of the NSR. The paper was designed to focus specially on CO_2 emissions because the upcoming IMO regulations will have a strong focus on reducing CO_2 levels of shipping.

The NSR which was a historically significant route was seen to have regained its importance in recent years because of the discovery and the extraction of fossil fuels in the Russian Arctic, this led to the prevalence of year-round LNG and bulk shipping in the NSR. However, there was evidence that many Container lines were against the use of the route, therefore the study started with the premonition that currently the NSR is not feasible to be very well comparable with the Royal Road and this is the reason the question of when the route would become a viable alternative was added. From the literature it was quite evident of the historical benefits of the route, it was further found that the Route is a major source of Income to Russia due to its vast fossil reserves. Furthermore, it was seen that traffic other than containers where increasing in the region. This raised the question as to why container lines don’t operate as freely in the NSR. The case of Maersk and COSCO were analyzed in combination regarding the various factors necessary and important for liner operations.

It emerged that due to factors which involve the unreliability of ice on the route, along with high OPEX, and VOYEX costs were the main reasons for shipping companies not using this route. Various studies relating to fuel consumption, ice levels and the cost of sailing containers in the Arctic where analyzed to extract the most important factors which would determine the formation of a theoretical framework. Moreover, the relationship between speed, consumption and emissions were also investigated to determine the path to take to answer the environmental part of the research question.

It was also postulated that the formation of various scenarios was needed based on the ice levels forecasted by various studies. The methodological approach was decided to be scenario development using a PESTEL analysis and to compute the environmental and economic parameters for each of these, two generalized models were created, based on the required variables from the theoretical framework. After this, the study calculated the costs and emissions for three scenarios. 2020, 2030 and 2050 costs and emissions for the NSR and Royal Road routes were obtained based on the discussions and literature review. Finally, it was found that shipping lines were not losing out on any saving environmentally or economically by not adopting the NSR in 2020. However, the use of NSR was found to be both economically profitable and environmentally superior in terms of CO_2 from the year 2030 and becomes the route of choice in 2050. It was also seen that in the year 2050, under the assumptions of this paper the NSR will be the preferred route of choice shippers.

Therefore, the main research question: “What are the economic and environmental benefits for container shipping in the Northern Sea Route and when will these benefits be maximized?”, was answered by finding out that between 2030 and 2050 the NSR can potentially offer between 9-31% in cost saving and a 10-29% reduction in CO_2 emissions, when compared to the Royal Road. Moreover, it was found that in 2050 the NSR can truly be maximized as a viable alternative route to the Royal Road.

5.1 Limitations of the study

The study set out to find a generalizable model which can compare the NSR and Suez routes. Many researchers argue that these routes cannot be commercially compared, owing to many factors such as the vessel size differences and the unreliability of the NSR. However, this study managed to find commonality by using the most comparable variable and based on the reasonable assumptions made in this paper, it was found that the NSR will be more profitable and more CO_2 friendly by the year 2030 and will be fully able to compete with the Royal Road in 2050. The absence of unbiased primary data is a major hinderance to the accuracy of this research.

Moreover, the assumptions in this paper were made based on publicly available data on climate research and calculated assumptions based on a PESTLE analysis. Therefore, future studies on climate and drastic changes can result in the assumptions being made obsolete. However, the model is easily adaptable since it can be modified to account for these factors. Another important fact is that the assumptions are based on current economic factors which are projected to be the same in the future, such an assumption was needed for comparison sake.

5.2 Further Research

It was seen in the paper that emissions other than CO_2 such as methane and BC will be more tightly regulated in the future. Therefore, future studies should focus on these factors. The type of marine fuel used in the future is most likely to be a diverse mix, the calculation of various emissions based on fuel use for the various routes will be of major benefit for environmental regulators. Moreover, this paper simplified the calculations to include only comparable metrics for lines between the NSR and Suez, as the ice melts in the NSR and larger vessels start going through the NSR, the use of more data to compare costs such as the CAPEX and Port/Terminal fees will also allow for a more detailed analysis. Finally, the scenarios can include the upcoming Arctic container ports which may be a reality by 2050.

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