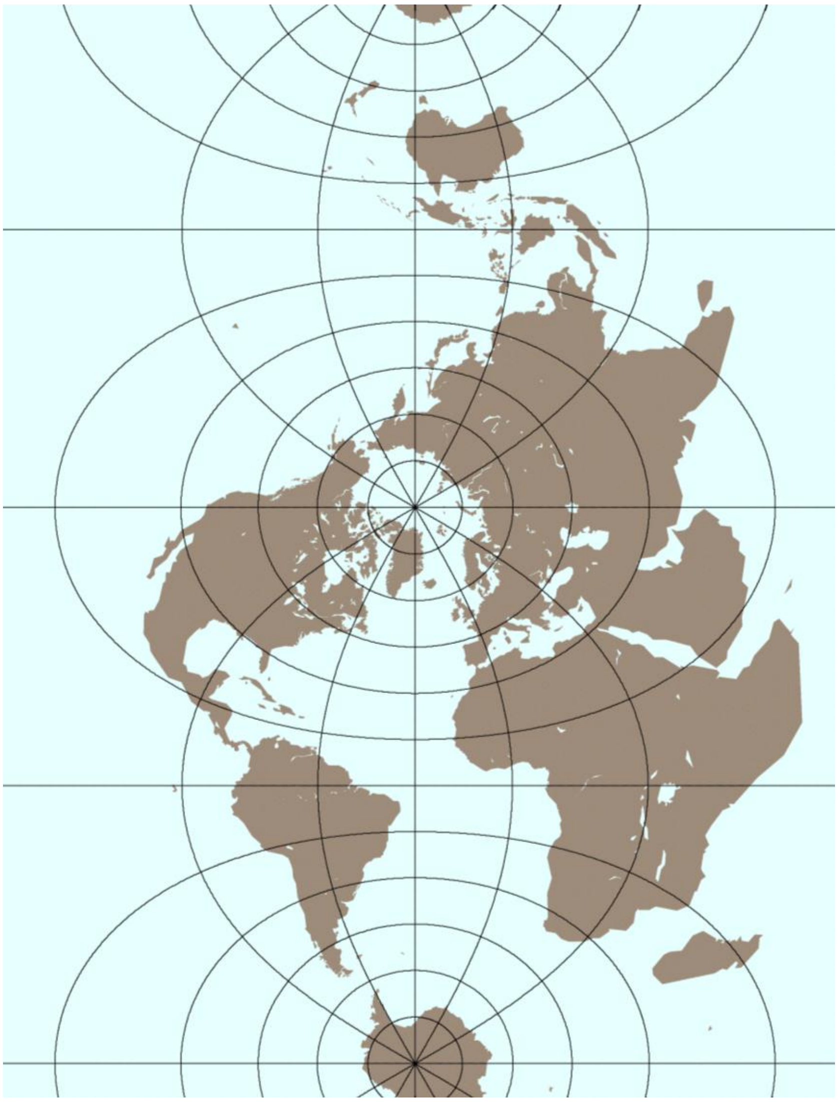
Effects of the Arctic Sea Routes (NSR and NWP) Navigability on Port Industry



IAPH
International Association of Ports and Harbors
PPDC
Port Planning and Development Committee

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1. Mission of the Project

1.1 Background

Port Planning and Development Committee (PPDC) of IAPH had decided a work plan 2011/2013 which includes the project on "Effects of the Arctic Sea Routes (NSR and NWP) Navigability on Port Industry". Dr. Masahiko FURUICHI, vice-chair of PPDC, was awarded to take initiative of the project by organizing the task force together with Dr. Natsuhiko OTSUKA (member of PPDC), and closely working with Tomakomai Port Authority (Japan/IAPH member port) which showed a strong interest on the future navigability of NSR.

The task force had intensively worked on literature review and made a field survey to visit Gothenburg Port Authority (Sweden/IAPH member port), Chalmers University of Technology (Sweden), Tschudi Shipping (Norway), Fridtjof Nansen Institute (Norway), Norlisk Nickel (Russia), Rosatomflot (Russia), etc. Consequently, the task force together with IAPH Headquarters organized open workshop at Tomakomai receiving some 100 participants.

Interim report was presented at PPDC meeting of the IAPH Mid-term Conference (http://www.iaphworldports.org/Portals/100/PDF/committee_room/1205_Port_Planning_and_Development_Jerusalem_2012.pdf) in Jerusalem, May 2012.

1.2. Terms of Reference

(1) To analyze Arctic Sea Routes (NSR and NWP) focusing on their cost comparison to the existing sea routes.
(2) To report the output of the project at the LA World Ports Conference in May 2013.

1.3. Structure of Taskforce and PPDC

(1) Dr. Masahiko FURUICHI, Japan International Cooperation Agency (JICA), vice-chair of PPDC
(2) Dr. Natsuhiko OTSUKA, North Japan Port Consultant (NJPC), Co. Ltd., member of PPDC
(3) Tomakomai Port Authority (Japan), IAPH member port

2. Arctic Transformation

2.1 Global Climate Change

In 2007, IPCC AR4[1] reported that eleven of the latest twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature since 1850. And since 2000, nine of the ten warmest years have occurred in latest twelve years in the record from 1850 (Figure 2.1). The global average surface temperature in 2011 was the ninth warmest since 1850, and was 0.51°C warmer than the mid-20th century baseline. In this way, global surface temperatures have been warming continuously since 1880 and it became faster since the end of 20th century.

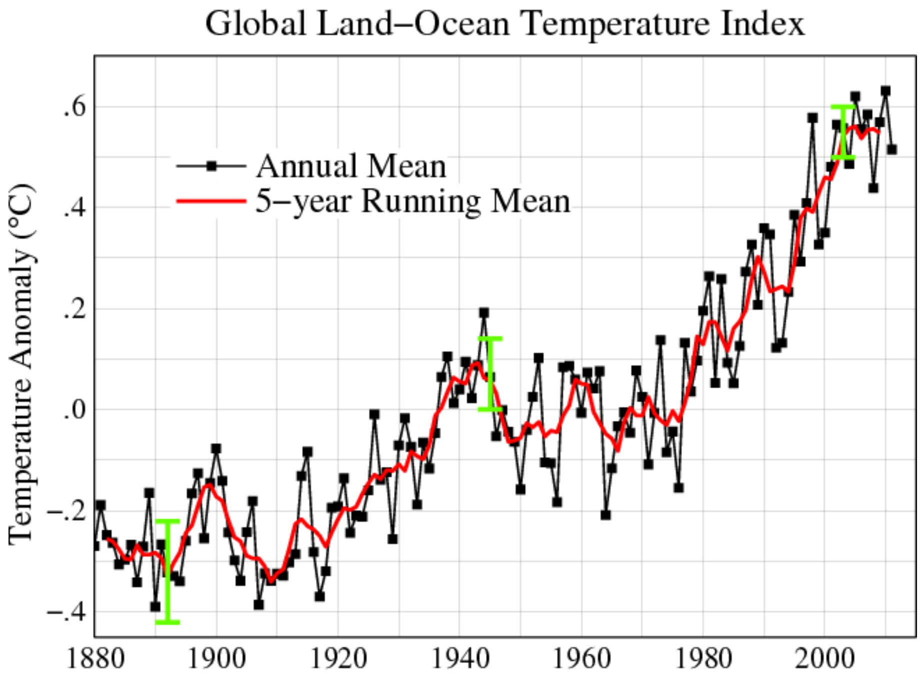


Figure 2.1 Global Annual Mean Surface Air Temperature Change[2]

Thus, warming of the climate is now evident from above observations, and the earth has experienced evidently higher temperatures in the first decade of the 21st century compare to the middle and late 20th century. And this warming trend can be seen more notably in northern latitudes than in low and southern latitudes (Figure 2.2). Here, annual average surface temperature rise in the northern latitudes of the northern hemisphere from 23.6N to 90N is twice as high as global average.

[1] IPCC Fourth Assessment Report: Climate Change 2007 (AR4)
[2] NASA Goddard Institute for Space Studies (GISS) Surface Temperature Analysis

The drivers of this climate change were discussed in the IPCC AR4.

The radiative forcing of the climate system is dominated by the long-lived GHGs. The GHGs emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. And there is high confidence that the global average net effect of human activities since 1750 has been one of warming causes, with a radiative forcing of +1.6 W/m^2. As a result, most of the observed increase in global average temperatures since mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations.

According to the projections of future climate changes by AR4, continued GHG emissions at or above current rates would cause further warming that would very likely be larger than those observed during the 20th century, which can be seen in Figure 2.3.

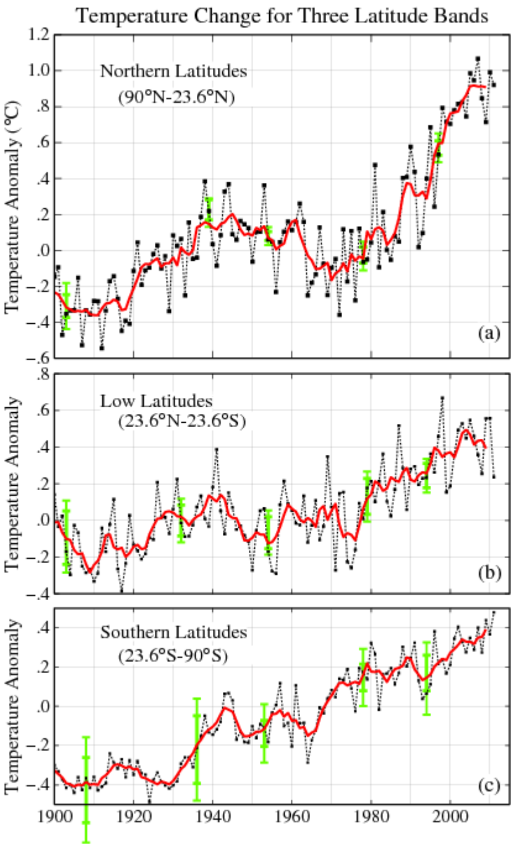


Figure 2.2 Temperature Change for Three Latitude Bands

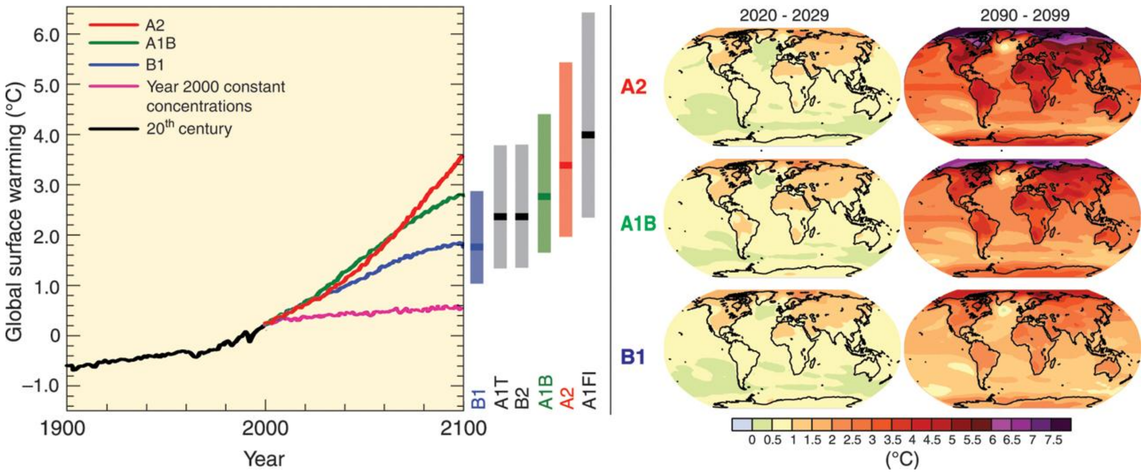


Figure 2.3 Atmosphere-Ocean General Circulation model Projections of Surface Warming[3]

Anthropogenic warming would continue for centuries due to the time scales associated with climate processes and feedbacks. Thermal expansion would continue for many centuries due to the time required to transport heat into the deep ocean.

[3] IPCC AR4, "Climate Change 2007 Synthesis Report", Figure 3.2

2.2. Implication of Global Climate Change for the Arctic Ocean

2.2.1. The Arctic

Geographically the Arctic is defined as the region north of 66º33’39’’ parallel north where the sun doesn’t rise and set in the winter and summer solstices respectively. Arctic Ocean and the tundra climate region may collectively be termed the Arctic. The CAFF (the biodiversity working group of the Arctic Council, Conservation of Arctic Flora and Fauna) has concluded that the polar tree-line is a well-defined criterion to delimit the Arctic, where mean July temperatures to be about 10 to 12 degrees in Celsius.

Eight nations of Norway, Sweden, Finland, Russia, United States, Canada, Denmark (Greenland) and Iceland possess territories in the Arctic.

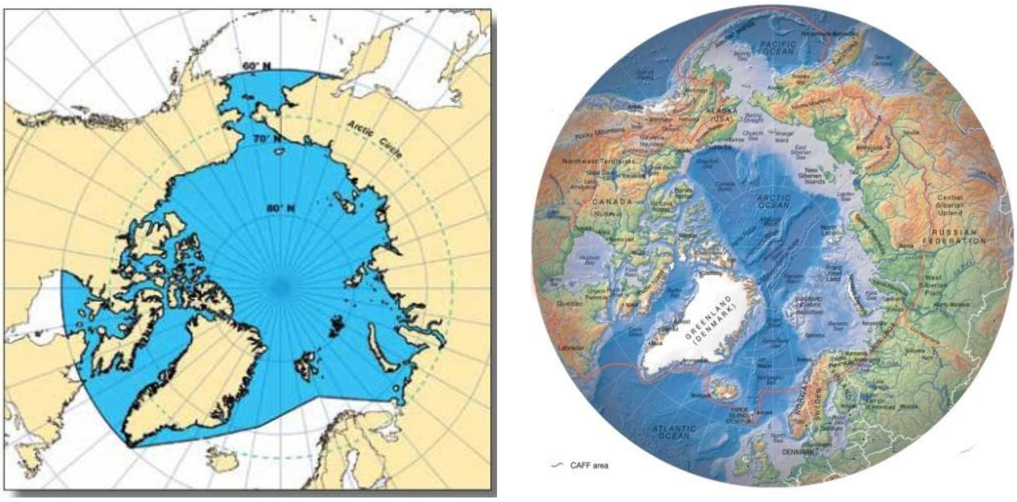


Figure 2.4 The Arctic Ocean
(left; defined by IMO, right; bathymetry of the Arctic Ocean by CAFF)

The Arctic Ocean is surrounded by Eurasian continent, North American continent and Greenland and some islands, and is the world’s smallest ocean covering an area of 1,400km^2. Western end is connected to the Atlantic Ocean through the Norwegian Sea and Greenland Sea. Eastern tip of the Arctic Ocean is connected to the Pacific Ocean through the Bering Strait, where the width of it is only about 80km.

Under the influence of the clouds and fogs characteristic in the Arctic, and high albedos of the snow and ice, summer temperature in the Arctic is not so high. The air temperature at a surface of the Arctic Ocean varies only about 30 degrees in Celsius, due to huge heat capacity of sea water. The area where multiyear ice dominates, the surface temperature of ocean is fairly constant about 0 degrees in Celsius because of the latent heat of melting ice. Because of low heat conductivity and high albedo of sea ice, the heat exchange and transfer between ocean and atmosphere is deeply affected by sea ice condition.

2.2.2. Sea Ice Retreat in the Arctic Ocean

The main projected biophysical effects to the Arctic due to global warming are reductions in thickness and extent of glaciers, ice sheets and sea ice, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators[4]. The average temperature in the Arctic has been rising at almost twice the rate of the rest of the world in the past few decades. This temperature rise accelerates melting of glaciers particularly in Greenland and decreases ice covered area and ice thickness in the Arctic Ocean especially in summer.

The effects of global warming to the Arctic can be seen in the Arctic sea ice extent. Figure 2.5 shows the ice covered area of the Arctic Ocean in summer from July to November. Compared with the average sea ice extent from 1979 to 2000, it is obvious that the sea ice in recent years is drastically diminished. In September 2007, recorded low sea ice extent of 4.2million km^2 was experienced since the beginning of satellite observations and both along the Eurasian and North American coastal waters became ice free. This record was broken only in five years. In September 2012, arctic sea ice extent dropped to 3.41 million km^2. This is 18% below 2007 and 49% below the 1979-2000 average. Figure 2.6 shows the Arctic sea ice covered area in September 2011. It is obvious that the Arctic Ocean along the Eurasian continent became ice free again.

According to the projections of IPCC AR4, the current scientific consensus indicates that the Arctic Ocean may experience ice free summers in the 2030's.

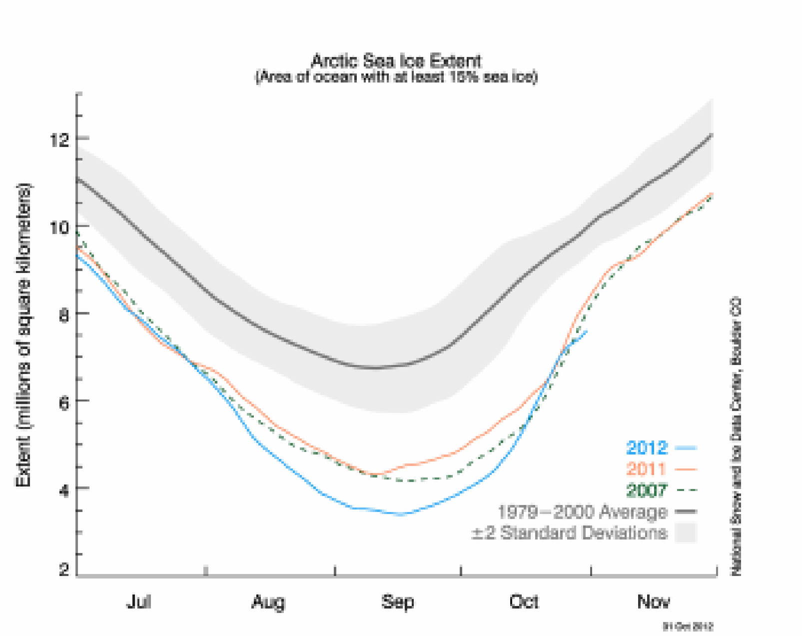


Figure 2.5 Arctic sea ice extent in summer[5]

[4] AR4; WGII 15.4, SPM

[5] SEARCH Sea Ice Outlook, viewed on Jan. 2012, http://www.arcus.org/search/seaiceoutlook/2010/summary)

Figure 2.6 Arctic sea ice extent in September 2011[6]

[6] National Snow and Ice Data Center, University of Colorado, http://nsidc.org/arcticseaicenews/

3. World's Interests in the Arctic Ocean

3.1. Arctic Sea Routes

3.1.1. Historical Background[7]

The Arctic Sea Route provides new sea route between the Atlantic Ocean and the Pacific Ocean linking Europe and East Asia/west coast of North America, as shown in Figure 3.1. The route along the Russian coastal waters is called the North East Passage (NEP) and the route along the North American continent is called the North West Passage (NWP).

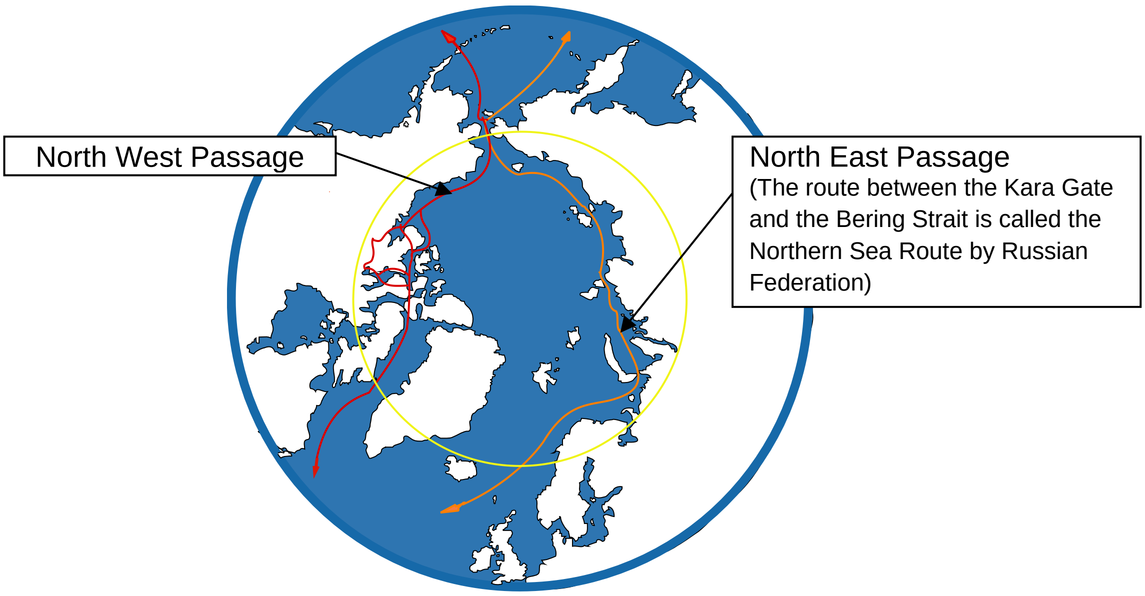


Figure 3.1 Arctic Sea routes

Regarding the North East Passage, Russia defines the route between the Kara Gate and the Bering Strait as "Northern Sea Route; NSR". The distance between Europe and East Asia is shortened by approximately 40% by using "Northern Sea Route", compare to the current Suez Canal route. However, the shipping routes in the Arctic were of little interest to the international commercial shipping market in the 20th centuries, because of the accumulation of drift ice and thick multi-year ice, which can be seen even in summer.

In the 10th century, Vikings had reached the White Sea and settled in Iceland and Greenland. They also settled in Newfoundland. By the 14th century, the Basques ventured from Biscay Bay toward the Labrador Sea on the purpose of whaling and rediscovered Newfoundland. The Basques were soon followed by whalers from the Netherlands and England. In their search of whaling grounds, knowledge of the Arctic Ocean was expanded.

[7] Ship and Ocean Foundation, "The Northern Sea Route"

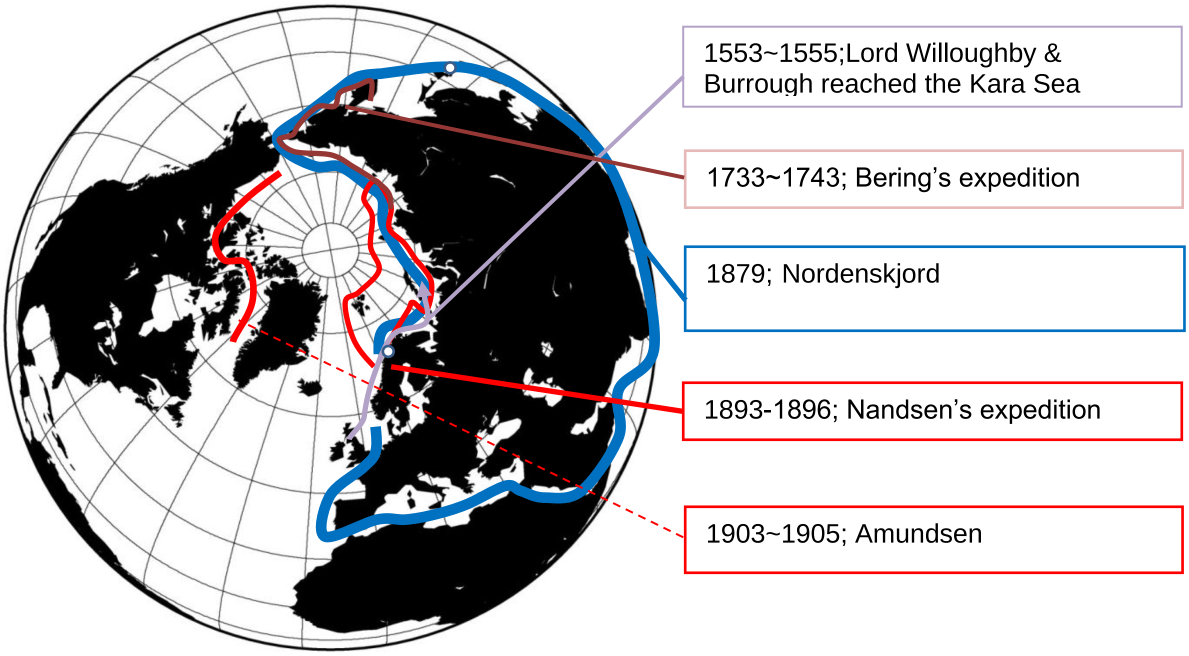


Figure 3.2 Historical expedition of the Arctic Ocean

In the Age of Discovery in the 15th century, quest for a new sea passage across the Arctic Ocean toward East Asia had begun by seafaring European powers for the purpose of finding trade routes. In the middle of the 16th century, Novaya Zemlya was discovered and the sea route to the coast of Siberia via the Kara Sea was found. In the 18th century, Bering explored the Kamchatka Peninsula, the East Siberian Sea and the Being Sea on the course of so called the "Great Northern Expedition". This expedition provided a lot of geographical information along the Siberian coast. However, complete voyage through the Arctic Ocean was not made yet. Also in the 18th century, James Cook ventured the Arctic Ocean through the Baring Strait but was blocked by sea ice at the latitude of 70N.

In the late 19th century, Nordenskjord successfully completed to voyage through the entire North East Passage from Tromso to the Bering Strait and then he visited Yokohama. However, his purpose was to find later called the Kara Sea Route which connects Europe and Ob-Yenisei river basin, and the Lena river basin. For the purpose of trading of the region's natural resources, 122 voyages were conducted from 1876 to 1919 between 5
Europe and Siberia via the Kara Sea Route. However, these voyages were perilous and many of them were wrecked.

In contrast to the North East Passage, opening of the North West Passage fell behind because of the harsh condition of the passage. In 1903, Amundsen sailed into the NWP from Lancaster Sound north of the Baffin Island, passing through the Peel Sound southward, westing along the Victoria Island and finally sailed into Beaufort Sea in 1905 as the first complete voyage of NWP. Then in the mid-20th century, Larsen[8] and the Canadian ship St. Roch made the second complete voyage of NWP by the same route as Amundsen's. It was the first voyage from the West to East. The St. Roch was then completed a westward voyage in one year via Lancaster Sound, went southward through the Prince of Wales Strait and reached off the Alaskan coast. After the St. Roch, Canadian icebreaker Labrador completed an eastward voyage in one year.

Thus, lured for new territory, fishing and whaling ground, and natural resources, world had been exploring the Arctic Ocean for many centuries. Then in the late 20th century, the North East Passage and the North West Passage entered on new phases respectively. In recent years, it become evident that the global climate change is causing the Arctic sea ice retreat drastically. And today, both passages are expected to become a new shipping route between the Atlantic Ocean and the Pacific Ocean, which could give several advantages such as shorter distances compared with the current southern shipping routes.

3.1.2. Overview of the NEP and Northern Sea Route

a) Background of the Northern Sea Route

Russia historically defines the part of the North East Passage between the Kara Gate and the Bering Strait as "Northern Sea Route; hereinafter referred to as NSR". After the World War II, the NSR acquired its importance regarding defense strategy and resource exploitation for the Soviet Union. For example, roughly half of the materials for Yakutia military base in the Laptev Sea coast were delivered by the NSR. And also in the time of Russian Federation, the NSR was used for many years to deliver commodities to the coastal villages and military bases by ice class cargo ships escorted by nuclear icebreakers.

In 1980's, the Soviet Union launched 19 icebreaking cargo ships which were built in two Finnish ship yards. These ships were called SA-15 type with dimension of 170m long, 24m wide, 9.0m draft and 15,000DWT. The ships were built to an ice class with capacity of continuous icebreaking in up to 1m thick. At the same time, the Soviet Union built seven nuclear icebreakers and seven diesel-electric icebreakers from 1970's to 1990's. Supported by these powerful icebreakers, SA-15 type cargo ships were put into commission to the NSR shipping along the Russian Arctic coast.

[8] Henry Larsen, Canadian.

Figure 3.3 The SA-15 class icebreaking cargo ship[9]

Figure 3.4 Nuclear icebreaker[10]

In 1987, Secretary General Goebachev declared that the NSR was opened to foreign vessels under the Russian law of the Northern Sea Route. However, only several voyages were conducted by foreign vessels to cruise all along the NSR between the Kara Gate and the Bering Strait until recently.

b) Geography of NEP and NSR

From the west to the east, the North East Passage starts from the Barents Sea off the Scandinavian coast, and the Kara Sea overreach between Novaya Zemlya and Severnaya Zemlya. The Laptev Sea expands from the Severnaya Zemlya toward the New Siberian

[9] STX Finland, Retrieved on Mar. 2013., http://www.stxeurope.com/sites/Finland/Products/Pages/Arctic%20Cargo%20vessels%20and%20Gas%20Carriers/Tiksi.aspx

[10] ROSATOMFLOT, Retrieved on Mar. 2013., http://www.rosatomflot.ru/index.php?menuid=35&lang=en

Islands, and from there the East Siberian Sea expands toward the Wrangel Island. And then, the Chukchi Sea expands toward the Bering Strait. The Climatic and hydrological conditions vary from sea to sea and from season to season as follows.

Table 3.1 Climatic conditions along the NEP

Western part	From the Barents Sea to the western Kara Sea
	Relatively warm under influence of the northern tip of Gulf Stream. The Barents Sea is mostly ice free even in winter. Thus, the ports of Kirkenes and Murmansk are ice free.
Central part	From eastern Kara Sea through the Laptev Sea to the western East Siberian Sea
	Extremely cold in winter.
Eastern part	From the eastern East Siberian Sea to the Chukchi Sea
	Sea ice is moderate compare to the central part due to the influence of inflow from the North Pacific Ocean.

There are a series of straits which lay between the islands or between the islands and continental coast on the NEP. A list of the major straits through which ships must pass includes the Yugorskiy Shar Strait, the Kara Gate, the Vilkitskiy Strait, the Shokalskiy Strait, the Dmitriy Laptev Strait, the Sannikov Strait and the Long Strait.

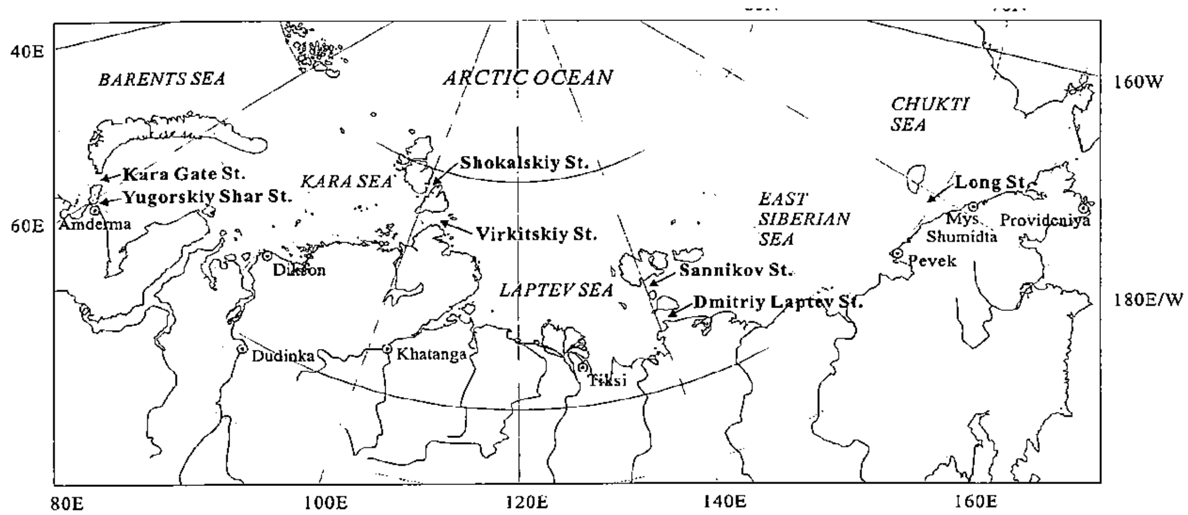


Figure 3.5 The Seas, Islands and Straits along the NEP[11]

As the NEP lies over the continental shelf of Eurasia, there are many shallow zones along the route including some straits. The Barents Sea is mostly deeper than 100m. In contrast, the minimum water depth of the Kara Gate, which is an entrance to the Kara Sea, is only about 21m. There are many shallow areas in the Kara Sea ranging from several meters to 20m. The continental shelf narrows among the Laptev Sea and water depth reaches to over

[11] The Northern Sea Route ~The shortest sea route linking East Asia and Europe, Ship and Ocean Foundation, pp.67 and WP-167, 2000.3

1,000m. However, along the New Siberian Island, the Dmitriy Laptev Strait and the Sannikov Strait are about 20m deep. The East Siberian Sea is less than 20m in the western part, and around 40m in the eastern part. Bottom topography of the Chukchi Sea is moderate and water depth of its center part is about 50m. Depth of the Baring Strait that consists of the Big Diomede and Little Diomede Islands is about 50m deep to the west and 60m to the east.

c) Port Distance via the NSR

The NSR is the shortest sea route between Northern Europe and East Asia. Through the NSR, the distance can be shortened by about 30~40% compare to the Suez Canal route. Figure 3.6, Table 3.2 and Table 3.3 show port distance between major European ports and Asian ports via the NSR and the Suez Canal route. Figure 3.6 compares port distances from Rotterdam via the NSR and conventional routes. Distance from Rotterdam via the NSR is equivalent to that via the Suez Canal route in somewhere between Hong Kong and Singapore.

Distance via the NSR becomes the shorter in the northerlier ports. Table 3.4 shows the route distances via the Panama Canal from the ports in the Pacific coast to northern Europe. Between Los Angeles and Rotterdam, the port distance of the two types of route, as NSR and Panama Canal Route, is almost equal (Figure 3.6).

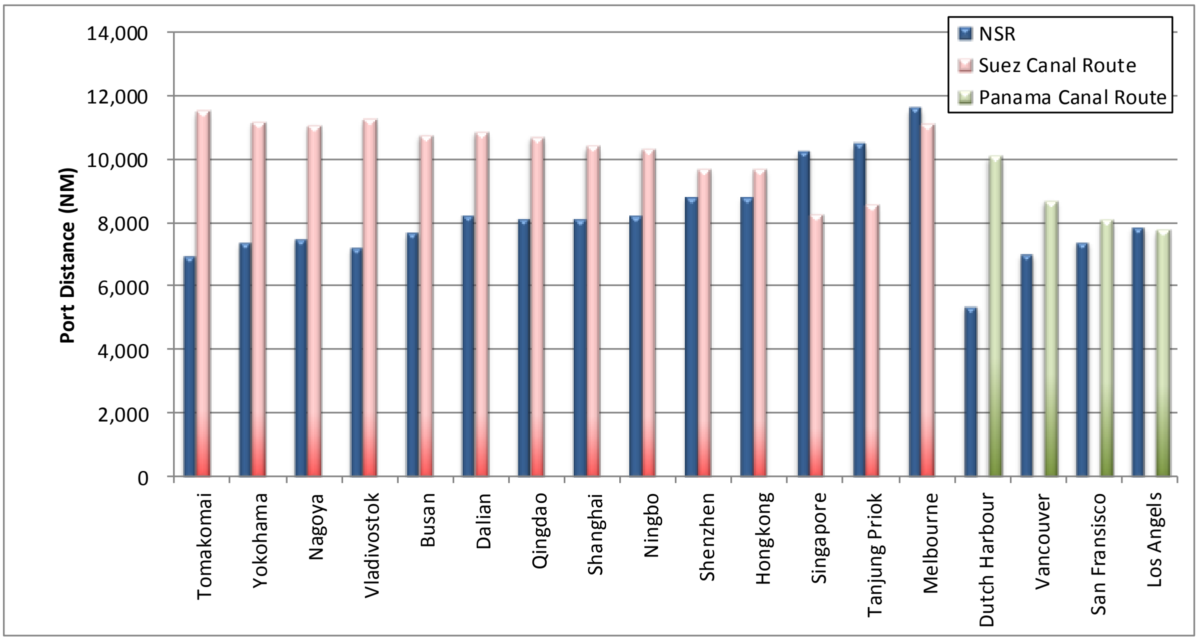


Figure 3.6 Port Distance from Rotterdam via the NSR and the Suez Canal Route

Table 3.2 Port distance via the NSR

via NSR	Bering Strait	Kirkenes	Murmansk	St. Petersburg	Hamburg	Rotterdam	Antwerpen	Le Havre	Itaqui
Kushiro	2,156	5,230	5,230	7,711	6,819	6,830	6,905	6,988	
Tomakomai	2,292	5,366	5,366	7,847	6,955	6,966	7,041	7,124	
Yokohama	2,693	5,767	5,767	8,248	7,356	7,367	7,442	7,525	
Nagoya	2,819	5,893	5,893	8,374	7,482	7,493	7,568	7,651	
Vladivostok	2,535	5,609	5,609	8,090	7,198	7,209	7,284	7,367	
Busan	3,000	6,074	6,074	8,555	7,663	7,674	7,749	7,832	
Dalian	3,559	6,633	6,633	9,114	8,222	8,233	8,308	8,391	12,032
Qingdao	3,472	6,546	6,546	9,027	8,135	8,146	8,221	8,304	
Shanghai	3,458	6,532	6,532	9,013	8,121	8,132	8,207	8,290	
Ningbo	3,530	6,604	6,604	9,085	8,193	8,204	8,279	8,362	
Shenzhen	4,162	7,236	7,236	9,717	8,825	8,836	8,911	8,994	
Hong Kong	4,139	7,213	7,213	9,694	8,802	8,813	8,888	8,971	
Singapore	5,560	8,634	8,634	11,115	10,223	10,234	10,309	10,392	
Tanjung Priok	5,805	8,879	8,879	11,360	10,468	10,479	10,554	10,637	
Melbourne	6,934	10,008	10,008	12,489	11,597	11,608	11,683	11,766	
Dutch Harbour	690	3,764	3,764	6,245	5,353	5,364	5,439	5,522	
Vancouver	2,332	5,406	5,406	7,887	6,995	7,006	7,081	7,164	
San Francisco	2,720	5,794	5,794	8,275	7,383	7,394	7,469	7,552	
Los Angels	3,175	6,249	6,249	8,730	7,838	7,849	7,924	8,007	
Murmansk	3,074	0	0	2,481					

Table 3.3 Port distance via the Suez Canal

via Suez Canal	Le Havre	Antwerpen	Rotterdam	Hamburg	St. Petersburg	Kirkenes	Murmansk	Suez	Itaqui
Kushiro	11,430	11,624	11,631	11,880	13,119	12,806	12,806		
Tomakomai	11,303	11,498	11,505	11,754	12,993	12,968	12,968		
Yokohama	10,968	11,163	11,169	11,417	12,656	12,680	12,680		
Nagoya	10,854	11,049	11,056	11,304	12,543	12,567	12,567		
Vladivostok	11,055	11,249	11,256	11,504	12,743	12,767	12,767		
Busan	10,553	10,747	10,754	11,003	12,242	12,266	12,266		
Dalian	10,657	10,851	10,858	11,106	12,345	12,369	12,369	7,917	13,071
Qingdao	10,484	10,679	10,686	10,935	12,174	12,198	12,198		
Shanghai	10,207	10,402	10,409	10,657	11,896	11,920	11,920		
Ningbo	10,135	10,330	10,336	10,585	11,824	11,848	11,848		
Shenzhen	9,492	9,686	9,693	9,942	11,181	11,205	11,205		
Hong Kong	9,483	9,677	9,684	9,933	11,172	11,195	11,195		
Singapore	8,063	8,258	8,265	8,513	9,752	9,776	9,776		
Tanjung Priok	8,341	8,536	8,542	8,791	10,030	10,054	10,054		
Melbourne	10,884	11,079	11,086	11,334	12,573	12,597	12,597		
Itaqui		4,105	4,112	4,361				5,154	
Murmansk		1,675	1,600	1,589					

Table 3.4 Port distance via the Panama Canal

via Panama Canal	Le Havre	Antwerpen	Rotterdam	Hamburg	Kirkenes	Murmansk	Itaqui
Dalian							11,645
Dutch Harbor	9,902	10,089	10,096	10,344	10,963	10,963	
Vancouver	8,498	8,686	8,692	8,940	9,559	9,559	
San Francisco	7,881	8,069	8,075	8,323	8,943	8,943	
Los Angels	7,553	7,740	7,746	7,995	8,614	8,614	

d) Sea Ice Conditions along the NSR

Except for the western part of the Barents Sea, the Arctic Ocean along the NEP is completely covered by sea ice for about six months from November to April. Fast ice, which consists of first-year ice and multi-year ice, is present along the coastline. Off the fast ice, drift ice zone spreads far beyond. In normal years, summer lasts from June to September and the sea ice melts rapidly so that the most of the coastal area become ice free. However, sea ice is still present in the Laptev Sea and the East Siberian Sea. Dense drift ice zone may be found in the Vilkitskiy Strait and the Long Strait. The ice massifs, which appear every year in the same locations, are mixture of multi-year ice that drift from the central Arctic Ocean and accumulated remnants of fast ice.

However, global warming is changing ice conditions in the NSR. In 2008 and 2012, the route became ice free in September (Figure 3.7).

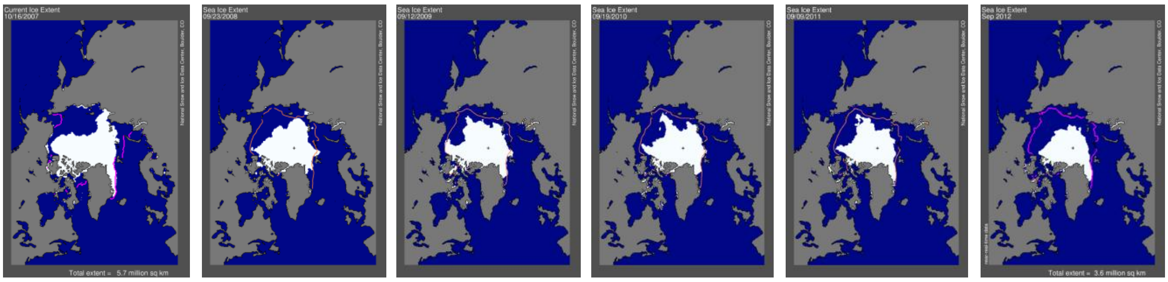


Figure 3.7 Sea ice extent in September from 2007(left) to 2012(right)[12]

As described in the Chapter 2, the Arctic is warming as twice as faster than world average. The IPCC forecasted in the AR4 that the Arctic sea ice would disappear entirely in summer under the high-emission A2 scenario in the later part of the 21st century. And many scientific studies after AR4 indicate that the Arctic summer sea ice will entirely melt around 2030.

[12] The National Snow and Ice Data Center, University of Colorado, Boulder, http://nsidc.org/

3.1.3. North West Passage

The NWP is consisted of several different sea routes that pass between more than 19,000 islands in the Canadian Arctic Archipelago. Canada claims strait baselines for connecting islands and all the waterways of the NWP as internal waters. In this regard, Canada indicates that this claim is based upon the fact that these waters and sea ice were historically used by Inuit peoples. On the other hands, the United States argues that foreign ships have the right of transit passage to the NWP as international straits. However, this disagreement over the legal status of the NWP has not become a real issue, and in 1988, both nations come to an agreement.

Sea ice condition along the NWP is much harder than that of NSR and it changes drastically. So the first voyage through the NWP, which was completed by Amundsen in the beginning of 20th century from Lancaster Strait to Beaufort Sea, took three years. In 1944, westbound voyage was completed within a year for the first time. It was 1954 when the eastbound voyage was completed within a year. In this manner, opening of the NWP was far behind to the NSR. Furthermore, there is no icebreaker in these waters that can assist cargo ship. Thus, it is still not easy to sail through the NWP and there is only a limited maritime activity along the NWP at this moment.

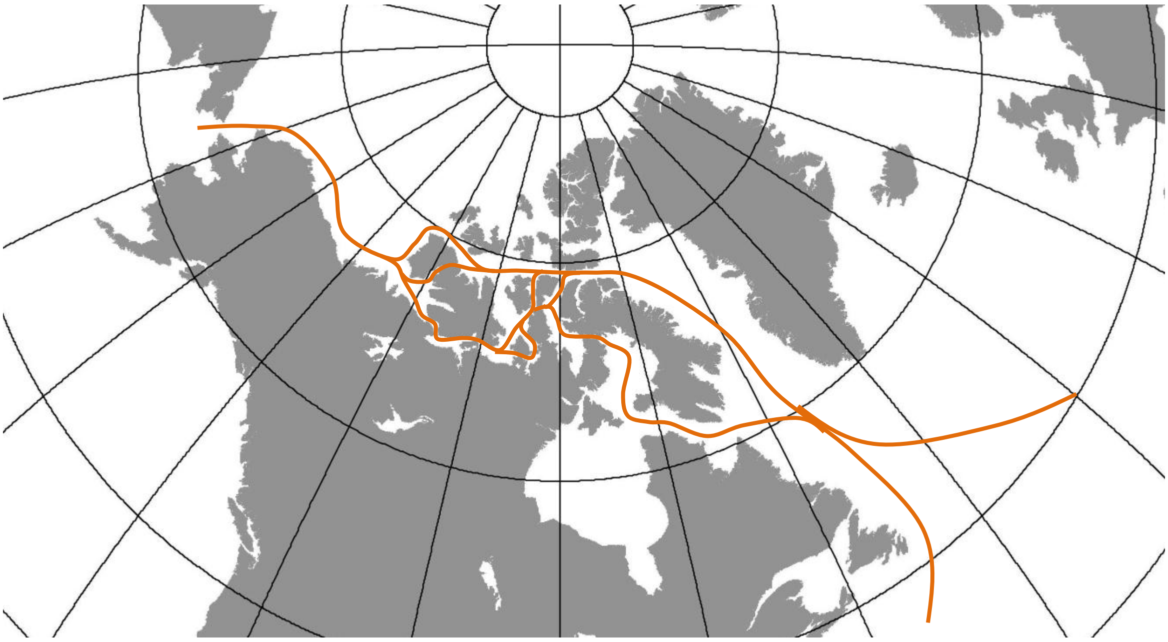


Figure 3.8 North West Passage

3.1.4. Maritime Rules in the Arctic Ocean

Ships operating in ice-infested waters such as the Arctic Ocean and Antarctic waters must pay special attention to the surrounding harsh environment and unique risks. Harsh weather conditions, sea ice of varied characteristics, lack of detailed charts and navigational aids, poor search and rescue systems and so forth make navigation difficult and increase a risk of accident. So the maritime society has been discussing and implementing maritime rules and regulations for the navigation in the ice infested waters.

a) MALPOL 73/78

The International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL), proposed in 1954 and enforced in 1958, was the first international agreement on marine pollution. Following the OILPOL, the International Maritime Organization (IMO) was established as a United Nation's specialized body with responsibility for the safety and security of shipping and the prevention of marine pollution by ships in 1958. Since then, the IMO had adopted some amendments to the OILPOL. In 1973, taking over to the OILPOL, the MALPOL73 (International Convention for the Prevention of Pollution from Ships, 1973) was adopted at the IMO, however, it did not entered into force. Against a background of a series of tanker disasters from December 1976 to January 1977, the IMO held the Conference on Tanker Safety and Pollution Prevention and the 1978 Protocol was adopted. The combined instrument entered into force in 1983. After numerous amendments, MARPOL 73/78 is now the world's foremost convention governing maritime pollution from ship.

In Appendices I and V of MARPOL73/78, a revision, which was adopted in 1990 and made effective in 1992, added the Antarctic region to the special areas in which provisions were strengthened regarding oil spillage and waste from ships. However, MARPOL does not contain any special requirements for the prevention of pollution in Arctic waters, although the Arctic countries have agreed to implement MARPOL's special area requirements for ships sailing in Arctic waters.

b) the United Nations Convention on the Law of the Sea; UNCLOS

The United Nations Convention on the Law of the Sea of 1982 known as UNCLOS, is a comprehensive convention establishing laws to deal with all areas of marine pollution, concerning territorial waters, contiguous zone, the continental shelf, the high seas and the deep sea floor. Part XII (Preservation and Protection of the Marine Environment) of the convention establishes measures to protect and preserve the marine environment, and to prevent, reduce and regulate pollution of the oceans. In Section 8 of Part XII, "Ice covered Areas", Article 234, gives coastal states the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from ships in ice-covered areas within the limits of the exclusive economic zone. Countries possessing coastlines on the Arctic Ocean are permitted to pass their own legislation for the purpose of protecting the natural environment of the Arctic Ocean. On this basis, Russia and Canada both established their own regulations for ships navigating in their arctic EEZ.

> <UNCLOS Part XII Section 8, Article 234>
> "Coastal States have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climate conditions and the pressure of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence."

c) Classifications for Ships in Ice-infested Waters

Ships are classified into a number of categories according to type and function by the classification societies and other relevant organizations. The structural and machinery requirements for ships navigating in ice infested waters are established by several classification societies such as Russian Maritime Register of Shipping, Lloyd's Register of Shipping, the American Bureau of Shipping (AB), Norway's Det Norske Veritas and Class NK. In addition, the Finish-Swedish Ice Class Rules (FSICR) and Arctic Shipping Pollution Prevention Regulations (ASPPR, Canada) are applied to the Baltic Sea and the Canadian Arctic waters respectively. In these regulations, rules for design and operation of ships navigating in icy waters are established. Russia proclaims the "Regulation for Navigation on the Seaways of the Northern Sea Route" since 1990.

In the above classification society regulations, ships are categorized into "ice-strengthened ships" and "icebreakers". Each category is further divided into some "ice classes" regarding ice condition, ice breaking capability and navigating condition. To each ice class, appropriate rules are applied.

Table 3.5 Type of the ice class ship

Ice breaker	Purposing to provide support and emergency assistance for other ships in ice-infested waters.
ice-strengthened ship	A ship with sufficient durability to withstand the pressure of surrounding ice. In general, ice-strengthened ships are cargo ships designed under milder condition than ice breaker.

These classifications have their own rules; some were in common but varied in detail. In 1993, IMO established a working group aiming to harmonize the multiple classifications for ships operating in ice-infested waters and drafted "the International Code for Safety for Ships Operating in Polar Waters" in 1998. Although this code was not adopted, the "Guidelines for Ships Operating in Arctic Ice-Covered Waters (MSC/Circ.1056-MPEC/Circ.399)" was adopted in 2002. In 2009, noting a request by the Antarctic Treaty

Consultative Meeting (ATCM) to amend the Guidelines to render them applicable to ships operating in ice-covered waters in the Antarctic Treaty Area, the "Guidelines for Ships Operating in Polar Waters (A26/Res.1024)" was adopted. At this moment, IMO is developing a draft International code of safety for ships operating in polar waters (Polar Code), which would cover the full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in the two poles[13].

The maximum extent of the Arctic waters in the Polar Code is shown in the figure below. Table 3.6 shows the seven of polar ship classes. Here, PC1 is the most capable ship which can operate year-round in all waters, whereas PC7 is the least capable, operating in summer/autumn in thin first-year ice conditions.

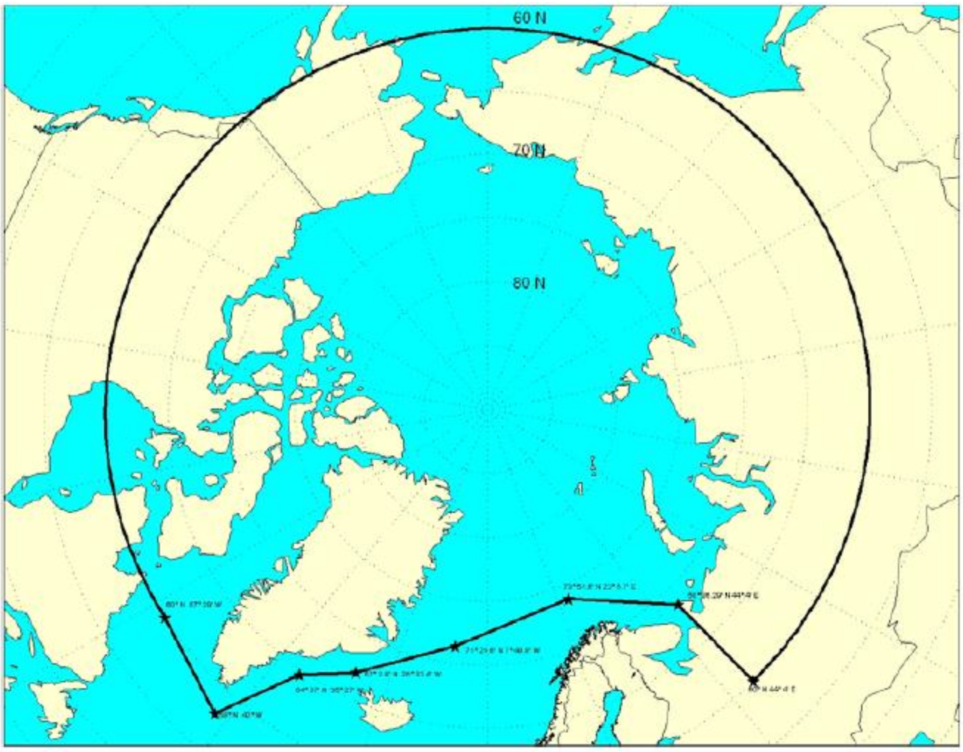


Figure 3.9 Maximum extent of Arctic waters application in the Polar Code[14]

[13] IMO Web Site, http://www.imo.org/mediacentre/hottopics/polar/Pages/default.aspx, viewed on May 2012.
[14] IMO, Ships Operating in Polar Waters, Figure-1

Table 3.6 Ice class descriptions

POLAR CLASS	GENERAL DESCRIPTION
PC 1	Year-round operation in all ice-covered waters
PC 2	Year-round operation in moderate multi-year ice conditions
PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions
PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

Note: Ice descriptions follow the WMO Sea Ice Nomenclature.

Here, all Polar Class ships and the equipment to be carried in accordance with the Guidelines should be designed, constructed and maintained in compliance with applicable national standards of the administration or the appropriate requirements of a recognized organization which provide an equivalent level of safety for its intended service. Special attention should be drawn to the need for winterization aspects. Ships intending to operate as an icebreaker are to receive special consideration.

In the process of above mentioned guidelines for navigation in the ice-infested waters, International Association of Classification Societies (IACS) had established an Ad-hoc Group for Polar Ship Unified Requirements, which was resulted in the IACS Unified Requirements for Polar Ships. These requirements, which came into effect in 2008, harmonize the rules to be used in the construction of all ships meant to operate in ice-covered waters.

Table 3.7 Ice class equivalency[15]

Polar Class	RS Ice Class	Det Norske Veritas	Lloyd's Register of Shipping	Class NK
PC1	---			---
PC2	*Arc9*			---
PC3	*Arc8*			---
PC4	*Arc7*			---
PC5	*Arc6*			---
PC6	*Arc5*	*ICE-1A*, ICE-10*	*1SS*	*IA Super*
PC7	*Arc4*	*ICE-1A, ICE-05*	*1A*	*IA*
---	*Ice3*	*ICE-1B*	*1B*	*IB*
---	*Ice2*	*ICE-1C*	*1C*	*IC*
---	*Ice1*	*ICE-C*	*1D*	*ID*

[15] Class NK, Guidelines for Navigating Ice Covered Seas in Russian Territorial Waters, 2009.

3.2. Maritime Transport via Northern Sea Route

3.2.1 Russian Regulation for the Northern Sea Route

a) Back ground

Citing the article 234 of the UNCLOS, Russian government requires for all foreign vessels traversing the NSR to obtain advance permission by the "Regulations for Navigating on the Seaway of the Northern Sea Route", which was approved in 1990 by the USSR's Ministry of Merchant Marine. It also rules the requirements for ship structures, experience of the crew in ice navigation, route controls, compulsory escort of ships by icebreakers and criminal penalties. In 1996, the Ministry of Defense issued the "Guide to Navigating through the Northern Sea Route", which provides detailed information on navigational aids, indications of entry of straits and so forth. These regulations require the vessels to take ice certificate, 4 months in-advance application for the voyage, terms of navigation such as compulsory icebreaker escort, and to pay transit fees.

The transit fees include icebreaker escort fee, which are charged per voyage as a flat-rate fee regardless of the frequency of the escort. The fee is given as a function of gross tonnage, ice class, season and area of operations, and is specified up to 20,000GT. It should be noted that final transit fees are subject to negotiation with Russian administration, which provides the icebreaking services. Thus the following table should be taken as an approximation[16].

Table 3.8 Former icebreaker tariff of the NSR

Ice class	Registered gross tonnage(GT)		Icebreaker tariff (US$/GT)		
			Summer		Winter
	Above	Below	Entire NSR	Part of NSR	
Icebreaker	5,001 10,001 19,001	6,000 11,000 20,001	7.26 6.58 5.49	4.36 3.95 3.29	6.53 5.92 4.94
ULA	5,001 10,001 19,001	6,000 11,000 20,000	9.98 9.04 7.54	6.49 5.88 4.90	9.73 8.82 7.36
UL	5,001 10,001 19,001	6,000 11,000 20,000	18.15 16.44 13.72	11.80 10.68 8.92	17.70 16.03 13.37
L1	5,001 10,001 19,001	6,000 11,000 20,000	22.69 20.55 17.15	15.88 14.38 12.00	23.82 21.58 18.00

These operational system and rules may not fit international maritime market. Issues to be resolved include, the fare system and terms of navigation to be updated to gain

[16] The Northern Sea Route ~The shortest sea route linking East Asia and Europe, Ship and Ocean Foundation, pp.98 and WP-128, 2000.3

transparency, aging ice breakers to be renewed, search and rescue structure to be established, bathymetric information to be updated and prevention of ocean pollution to be strengthened.

b) Updated Russian Regulations for Ships Navigating on the NSR

Against the background above, Russian government has long been preparing for the amending regulation for the NSR navigation. A new NSR law had finally passed the duma and entered in force in January 2013. Updated law includes; shortened term for navigation application, new rules for icebreaker escort and ice pilotage, criterion of navigation fee in proportion to ice class of vessel, navigation season and other factors.

c) Application Procedure

Vessels (naval vessels are not included) that navigate on the NSR must have a permission issued by the Administration of the Northern Sea Route (ANSR). The ANSR was established as a Federal State owned institution, whose offices are located in Murmansk and Arkhangelsk. The Murmansk office mandates application for permission.

The navigation permission is issued based on the application from a ship-owner, a representative of the ship-owner or a captain of the ship by the ANSR, after its review. The application must contain 45 issues such as data about the applicant, information of the vessel and crew etc. An application shall be written in English or Russian and send to the ANSR by pdf file attached to an email. The email address and contact information will be provided on the official website of the ANSR.

The application document should be sent not earlier than 120 calendar days and no later than 15 working days before the estimated arrival date to the NSR. The application shall be received for review on the day of arrival, or, the first working day of its arrival. The ANSR shall release the receipt on the official website within two working days after the receipt. The application shall be reviewed by the ANSR within 10 calendar days of its receipt. If the ANSR decides to issue permission, it is published on the official website no later than two working days of the decision.

d) Rules of Navigation in the NSR Waters

The ANSR shall indicate the need for icebreaker assistance in the permission in relation to the estimated ice condition, navigating season and area. If the icebreaker assistance is needed, the ship-owner, representative of the ship-owner or captain of the ship shall make a contract with icebreaker operating organization. At this moment, the state owned company ROSATOMFLOT is the only organization to provide icebreaker service that capable for transit voyage of the NSR. The icebreaker assistance fee is quoted in proportion to the ship size, ice-class, the distance of icebreaker support and the navigation period. Here, icebreaker assistance is performed by icebreakers that authorized to navigate under the state flag of the Russian Federation. If the captain of the ship does not have required expertise on ice navigation, vessel must navigate under assistance of the ice pilot who is dispatched by the organization providing ice pilotage services in the NSR.

Table 3.9 to Table 3.11 show the criterion of NSR navigation in relation to ice class of the vessel navigates. In the new regulation, vessels with ICE-1 to ICE-3 are allowed to enter the NSR under easy ice condition in summer. In the old regulation, only vessels with ice class of Arc-4 or higher are allowed to enter the NSR. And Arc-4 vessels, which were only allowed to enter the NSR with icebreaker escort in the old regulation, are allowed to navigate independently in easy to moderate ice conditions.

Table 3.9 Criterion of NSR navigation for ice class of ICE1 ~ ICE3 from July to October

Ice Class	Ice Navigation（СП;independent, ПЛ;ice breaker escorted）	The Kara Sea				The Laptev Sea				The East Siberian Sea				The Chukchi Sea			
		Э	Т	С	Л	Э	Т	С	Л	Э	Т	С	Л	Э	Т	С	Л
None	СП	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	ПЛ	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
Ice1	СП	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	ПЛ	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
Ice2	СП	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	ПЛ	-	-	+	+	-	-	-	+	-	-	-	+	-	-	-	+
Ice3	СП	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	ПЛ	-	+	+	+	-	-	-	+	-	-	-	+	-	-	+	+

Table 3.10 Criterion of NSR navigation for ice class of ARC4 ~ ARC9 from July to October

Ice Class	Ice Navigation（СП;independent, ПЛ;ice breaker escorted）	The Kara Sea				The Laptev Sea				The East Siberian Sea				The Chukchi Sea			
		Э	Т	С	Л	Э	Т	С	Л	Э	Т	С	Л	Э	Т	С	Л
Arc4	СП	-	-	+	+	-	-	-	+	-	-	-	+	-	-	+	+
	ПЛ	-	+	+	+	-	-	+	+	-	-	+	+	-	-	+	+
Arc5	СП	-	+	+	+	-	-	+	+	-	-	+	+	-	-	+	+
	ПЛ	-	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+
Arc6	СП	+	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+
	ПЛ	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Arc7	СП	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	ПЛ	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Arc8	СП	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	ПЛ	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Arc9	СП	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	ПЛ	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 3.11 Criterion of NSR navigation for ice class of ARC4 ~ ARC9 from November to December and from January to June

Ice Class	Ice Navigation （СП;independent, ПЛ;ice breaker escorted）	The Kara Sea				The Laptev Sea				The East Siberian Sea				The Chukchi Sea			
		Э	Т	С	Л	Э	Т	С	Л	Э	Т	С	Л	Э	Т	С	Л
Arc4	СП	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ПЛ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arc5	СП	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	ПЛ	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
Arc6	СП	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	ПЛ	-	-	+	+	-	-	-	+	-	-	-	+	-	-	+	+
Arc7	СП	-	-	+	+	-	-	-	+	-	-	-	+	-	-	+	+
	ПЛ	+	+	+	+	-	+	+	+		+	+	+	-	+	+	+
Arc8	СП	+	+	+	+	-	-	+	+	-	-	+	+	-	+	+	+
	ПЛ	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Arc9	СП	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	ПЛ	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

1: Vessels without ice class and vessels with ice class Ice1~Ice3 are not allowed to navigate the NSR from November to December and from January to June.

2: Vessels without ice class are allowed to navigate the NSR independently only on open water area.

Notation:
Э- extreme ice conditions according to the Rosgidromet official information;
Т- severe ice conditions according to the Rosgidromet official information;
С- moderate ice conditions according to the Rosgidromet official information;
Л- easy ice conditions according to the Rosgidromet official information;
＋navigation allowed, - navigation is not allowed

The details of the icebreaker fees have not become clear yet. However, based on the interview to the relevant people in Russia, icebreaker fees will be implemented by taking into account the Suez Canal fees, and it will be discounted under the convoy operations.

3.2.2. Commercial Arctic Shipping via the NSR

a) Sea Ports in the Arctic

There are a limited number of ports along the Arctic coast. They are mainly located along the Russian coast and mouth of large rivers shown in Figure 3.10. These ports are summarized in Table 3.12. On the contrary, there is no commercial port along the NWP.

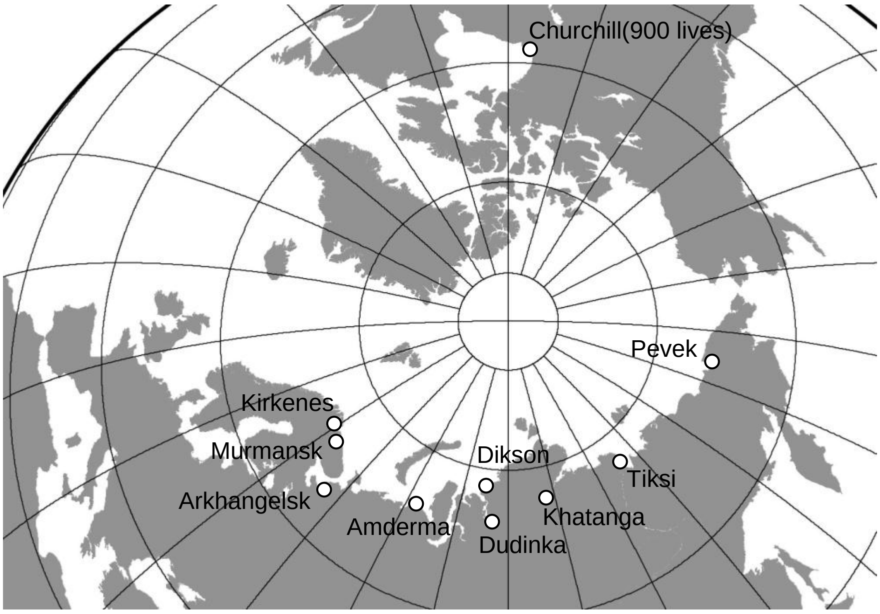


Figure 3.10 Sea ports in the Arctic

Table 3.12 Summary of the Arctic ports

Port	Facilities	Notes
Pevek	Berths;200m×2×4.9~6.1m, Water Basin;11~12.2m, crane×7	NSR supporting port in the East Siberian Sea.
Tiksi	Berths;200m×6.4~7.6m, Water Basin;6.4~7.6m, crane ; max25t	Mouth of the Lena River. Main port of the Sakha Republic, handling timber and petroleum/fuel. NSR supporting port in the Laptev Sea.
Khatanga	Water basin ; 3.5~8m,	Downstream region of the Khatanga River.
Dikson	Berths;150m×9.4m, Water Basin;6.4m, crane ;8t×3	Mouth of the Yenisei River, NSR supporting port in the Kara Sea.
Dudinka	Berths6.4~7.6m, Water Basin;7.1~9.1m,	Cargo turn over; 4.5mln ton, locating downstream region of the Yenisei River. Logistic base for Norilsk Nickel mine. Operating year round via NSR.
Amderma	Berths; 3m	Base port for the development of the Pechora Sea, nominated for search and rescue base of the NSR.
Arkhangelsk	Berths;175-190m×~9.2m, crane; 5~40t×50	Cargo turn over; 1.5mln ton(2007), pulp/paper, container, metals, timber, coal.
Murmansk Commercial Port	13Berths(-6.0~-12.5m), gauntly crane ×52 (max40t), ship loader ; 1000t/hr	Ice free, the largest port in the Russian Arctic. Cargo turn over; 15mln ton(2009), coal(12.2mln ton). Gas condensate and iron ore are loaded and shipped via NSR.
Kirkenes	Berths ; 4.9～6.1m, Oil terminal ; 9.4~10.0m	Northernmost port in Norway. Russian fishing vessel 600/year. Iron ore, gas condensate, project cargoes.

b) Commercial Shipping via NSR

With background of the Arctic sea ice deterioration, oil price appreciation and realization of natural resource production in the Russian Arctic, international commercial shipping via the Northern Sea Route is attracting a great deal. In 2009, the Beluga Shipping, a German shipping company, carried two project cargoes for GE power plants, from Korea to the Ob' river estuary via the Northern Sea Route. It became a new opening of the Northern Sea Route.

In 2010, five voyages were conducted through the Northern Sea Route. Iron ore from Kirkenes (Norway) and gas condensate from Murmansk (Russia) were shipped to China. In these voyages, Russian nuclear icebreakers escorted the ice class bulk carriers. A double acting ship, a ship designed to sail ahead in open water and astern in ice, "Monchegorsk", owned by Norilsk-Nickel, became the first ship to transit the Northern Sea Route without icebreaker assistance.

In 2011, commercial shipping through the Northern Sea Route reached 34 voyages and 820 thousand tons of cargos were shipped to and from Asian countries such as China, Korea and Thailand[17].

Table 3.14 shows a summary of the Northern Sea Route activities in 2011. In this year, sailing season started in late June and the last voyage was completed in late November, which means the longest navigational period of transit ever. During these five months, nine large tankers with a total of 480,000 tons of gas condensate had sailed the Northern Sea Route. In August, the first ever Suez-max tanker, "Vladimir Tikhonov" sailed the Northern Sea Route in only 7.5 days which is the fastest record. In general, water depth of the Northern Sea Route along the coast, where sea ice condition is mild, is not deep enough for Suez-max class vessels. However, in 2011, it was reported that the waters north of the North Siberian Islands became ice-free and enabled Suez-max class vessels to sail through the NSR in a short period. The last tanker voyage was completed within only 10 days with an average speed reaching 13 knots ("*Perseverance*"). According to the news release, the ice conditions during her passage were significantly milder than its first voyage in the same year[18].

In 2012, number of transit voyages reached 46 vessels and 1.26 million tons of cargoes were transported via the NSR(Table 3.15). Type of cargo was the same as 2011. Topic of this year was the first LNG shipping by ice class LNG carrier "Ob' River". She sailed westward the NSR in ballast in October, and then sailed eastward from Hammerfest (Norway) to Tobata (Japan) via the NSR again in mid-November with 135thousand m^3 of LNG. In this year, first convoy voyage, a voyage by a group of vessels escorted by icebreakers, was also conducted two times. This showed a possibility to expand the NSR cargo capacity under the limited number of icebreakers.

[17] "Флот пошел по Севморпути", ООО "ПортНьюс", retrieved on Jan. 2012 from http://rus-shipping.ru/ru/stats/?id=53
[18] "Second Arctic voyage a success, 21-Sep. 2011", http://www.transpetrol.com/news/, retrieved on 30 Nov. 2011.

Table 3.13 NSR commercial shipping in 2010

Cargo Type	Number of Vessels	Volume(t)	Displacement (t)	Eastbound Cargo Volume (t)	Westbound Cargo Volume(t)
Liquid	1	70,000		70,000	
Bulk	1	41,000		41,000	
Ballast	2				
Total:	4	111,000			

Table 3.14 NSR commercial shipping in 2011

Cargo Type	Number of Vessels	Volume(t)	Displacement (t)	Eastbound Cargo Volume (t)	Westbound Cargo Volume(t)
Liquid	9	604,652		540,254	64,400
Bulk	4	110,339		109,794	
Frozen Fish	4	24,673			24,673
Ballast					
Repositioning					
Total:	34	739,664			

Table 3.15 NSR commercial shipping in 2012

Cargo Type	Number of Vessels	Volume(t)	Displacement (t)	Eastbound Cargo Volume (t)	Westbound Cargo Volume (t)
Liquid	26	894,079		661,326	232,753
Bulk	6	359,201		262,263	96,938
Frozen Fish	1	8,265			8,265
Ballast	6		472,075		
Repositioning	7		78,351		
Total:	46	1,261,545	550,426	923,589	337,956

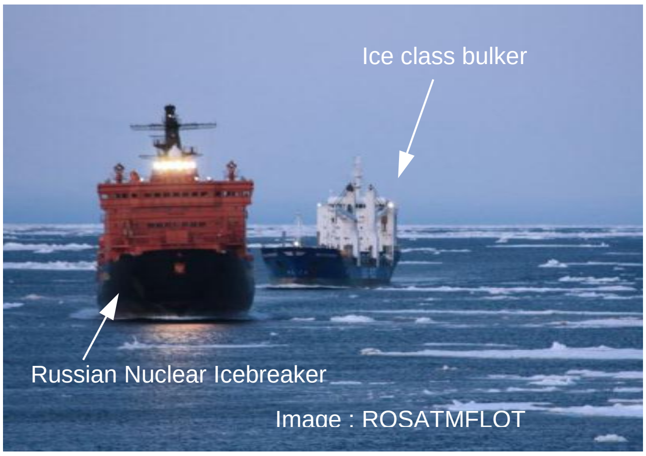


Figure 3.11 NSR navigation in recent years[19]

[19] ROSATOMFLOT and TSCHUDI Shipping

Figure 3.12 shows origin and destination of NSR transit voyages from 2009 to 2012 and type of cargoes. Dominant cargo is gas condensate, which is loaded at Murmansk and mainly shipped to China. Iron ore makes up the second largest cargo and also shipped to China. So far, mainly natural resources were shipped eastbound reflecting Asian demands for natural resources. On the contrary, westbound shipping is mainly ballast voyage or repositioning. So far, westbound cargoes were jet fuel shipped from Korea to Europe, frozen fish from Kamchatka to western Russia and coal from Alaska to Germany.

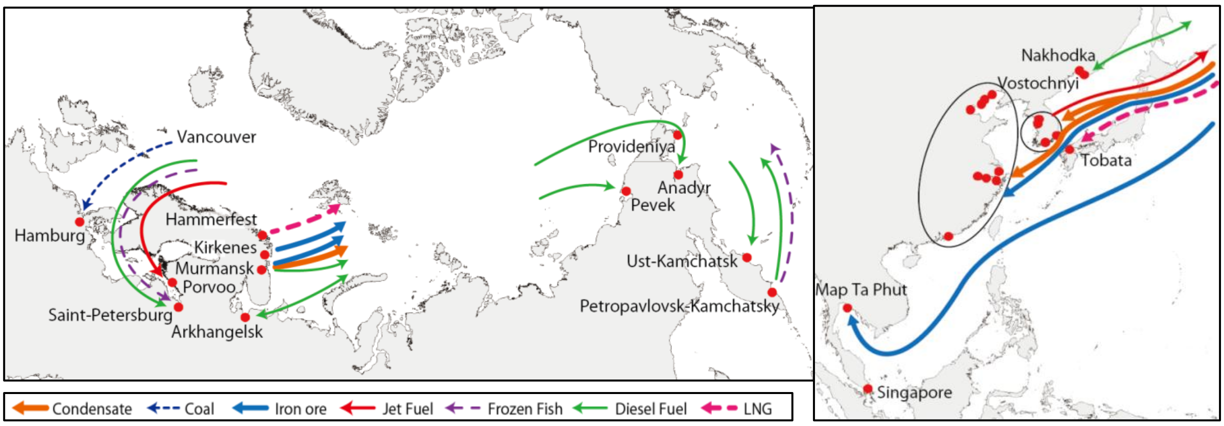


Figure 3.12 Origin and destination of the NSR voyage from 2009 to 2012

3.2.3 Navigability of the NSR

a) Ice Condition and Navigable Season

At the beginning of the summer navigation season, sea ice still remains in the NSR route requiring to ships longer days to transit the whole NSR. However, in August and September, there were little ice in the NSR even in the East Siberian Sea according to the satellite data and reports from ships. Figure 3.13 shows seven days average sea ice concentration from 2006 to 2011 along the route. In the Figure, sea ice concentration was retrieved from the satellite data of L3-product of Aqua/AMSR-E[20]. Sea ice concentration is high from 90E to 105E (eastern part of the Kara Sea to Virkitskiy Strait), and from 130E to 170E (eastern part of the Laptev Sea to western part of the East Siberian Sea). However, sea ice disappears from most of the NSR route except for the area around Virkitskiy Strait on late September. As a result, the NSR is navigable from late June to late November in these years.

[20] Data had retrieved from "The GCOM-W1 Data Providing Service (https://gcom-w1.jaxa.jp/)" by JAXA

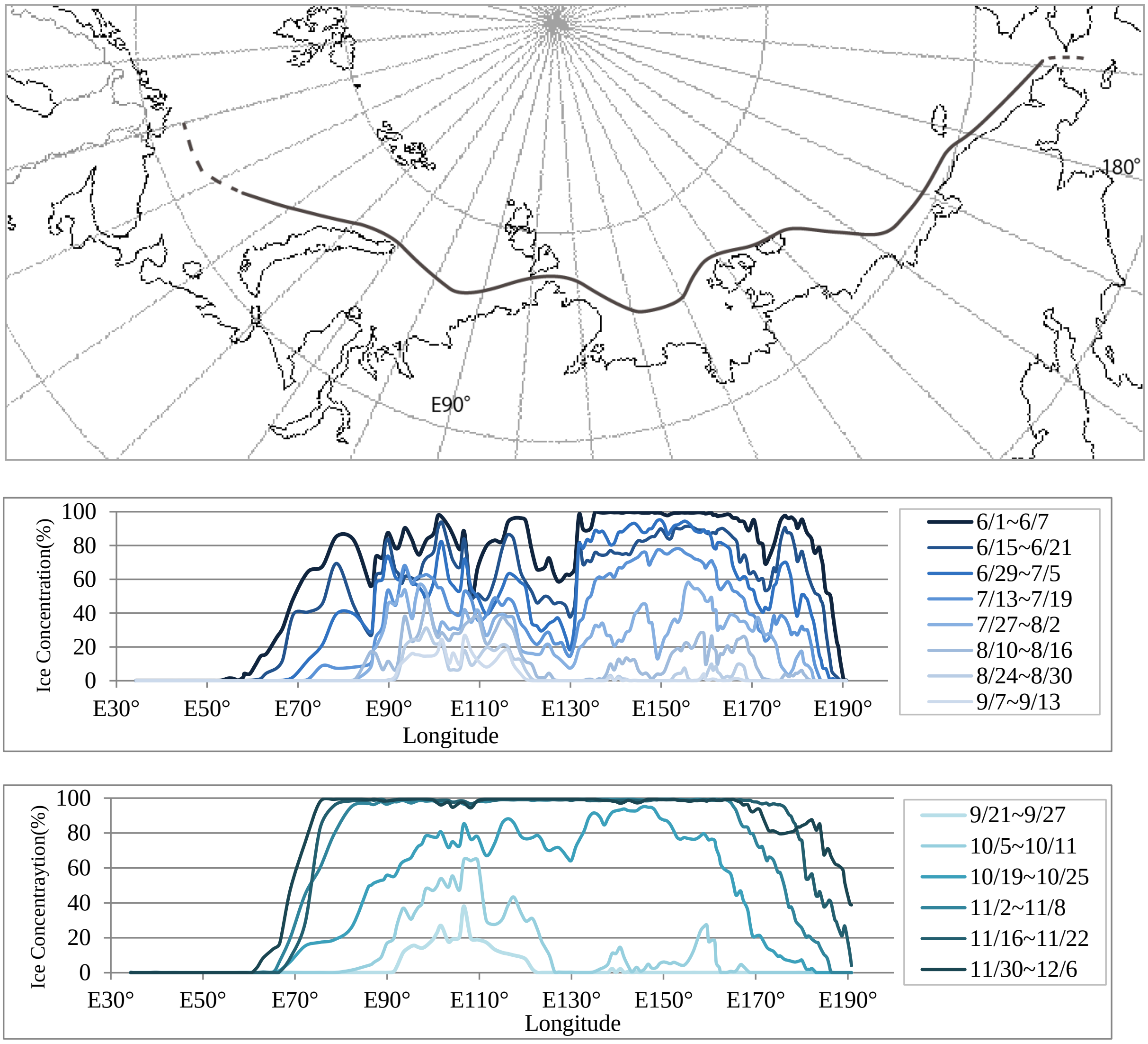


Figure 3.13 Seven days average sea ice concentration along the NSR, 2009-2011

b) Icebreaker Escorted Navigation

According to the Russian NSR regulations, in the NSR navigation with icebreaker assistance, icebreakers cut an open channel in ice and cargo vessels follow. Icebreakers are also in charge of sounding ice conditions on the route and instructing cargo vessels for safe navigation through the radio communication with the 16 channel of VHF-band. Cargo vessels are obliged to follow the instruction. Convoy navigation is arranged by the icebreaker service organization (ROSATOMFLOT). If a captain does not have required experience navigating in the NSR, cargo vessels sailing in the NSR should have an ice pilot onboard. The ice pilot provides assistance to the vessel's captain regarding navigation conditions and steering of the vessel.

Figure 3.14 Icebreaker-supported navigation in the NSR[21]

NSR transit voyage records of 2011 and 2012 shows that it took about 8 to 12 days to sail through the route. Monthly average sailing speed is shown in Table 3.16. According to the report from ROSATOMFLOT, it took longer days in June to sail through the NSR due to difficult ice conditions. In July sea ice melted rapidly and sailing speed increased to 10-11 knots. Under the icebreaker assistance, navigation speed of cargo vessels depends totally on that of icebreaker to cut an open channel in ice ahead. And the ice condition does not affect the sailing speed in the ordinary summer and fall.

On late November in 2012, the first LNG shipping was carried out by an ice-classed LNG carrier “Ob’ River” from Hammerfest (Norway) to Tobata (Japan). Figure 3.15 and Figure 3.16 shows ice coverage in the Arctic on November 15th 2012. It is reported that the vessel encountered sea ice of about 0.4m thick. However, “Ob River” had sailed through the NSR in 9.5 days on average speed of about 12 knots.

Table 3.16 Average sailing speed of NSR transit voyage in 2011 and 2012 (unit: kn)

Month / Year	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Number of Voyage
2011		10.3	10.2	9.5			34
2012	5.9	9.9	11.2	11.2	11.2	11.0	46
Average	5.9	10.0	10.8	10.7	11.2	11.0	

[21] ROSATOMFLOT, The Navigation on the Northern Sea Route Today & in the Future, 2012.

Figure 3.15 NSR voyage of Ob River[22]

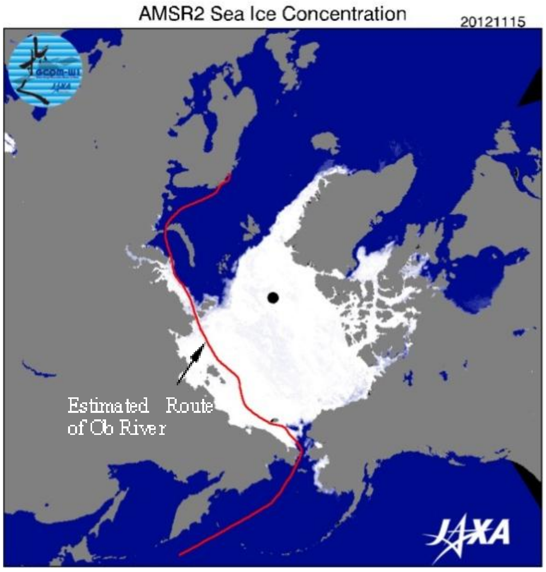


Figure 3.16 Sea ice concentration in mid-November 2012[23]

c) Ice Class Vessels

Ice class cargo vessels are not very common in maritime transport in the world. However, there are certain numbers of ice-classed merchant ships operating in icy waters including the Russian Arctic, Baltic Sea, the Sea of Okhotsk and North American waters. In the Baltic Sea, which is covered by sea ice in winter, many ice-classed vessels are used to transport cargoes and icebreakers support their operation. The Great Lakes and the Saint Lawrence River are also covered by ice in winter in most of the area and ice-classed cargo vessels operate there. However, most of these vessels are built to lower ice classes, such as IB and IC. There are limited number of ice-classed vessels of IA and higher. Figures 3.17 through 3.20 show DWT and the year of construction for ice-classed vessels of IA and higher by ship types.

[22] CNIIMF (Central Marine Research & Design Institute, Ltd.), Russia, 2012.
[23] Modified by authors based on the image of Japan Aerospace Exploration Agency, Earth Observation Research Center (JAXA), Arctic Sea Ice Monitor, Retrieved on Jan. 2013, http://www.ijis.iarc.uaf.edu/cgi-bin/seaice-monitor.cgi?lang=j

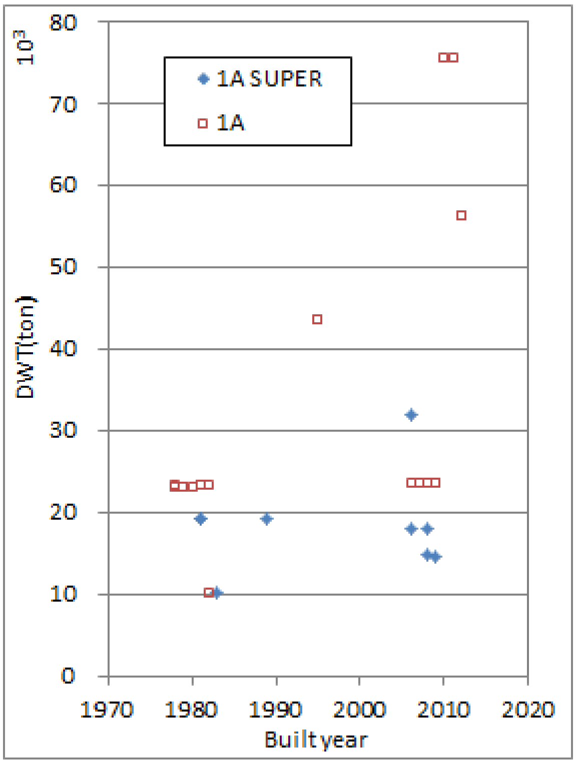


Figure 3.17 Ice class bulk carrier with IA or higher

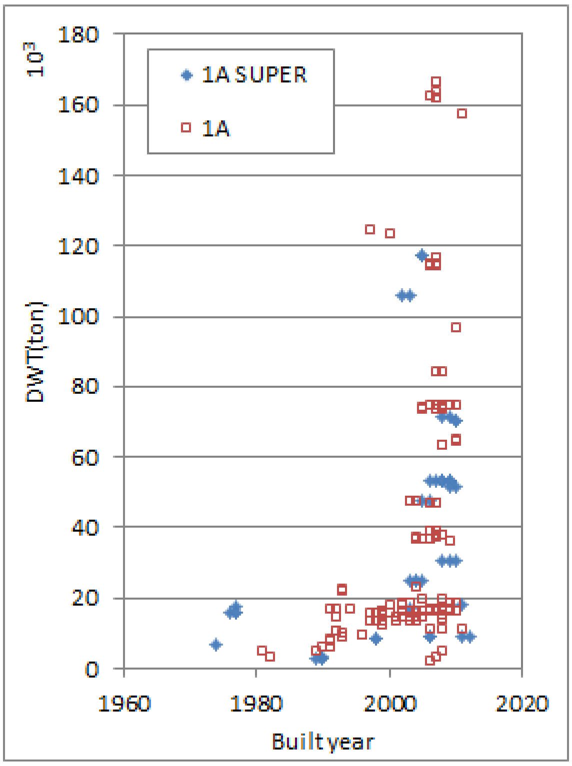


Figure 3.18 Ice class tanker with IA or higher

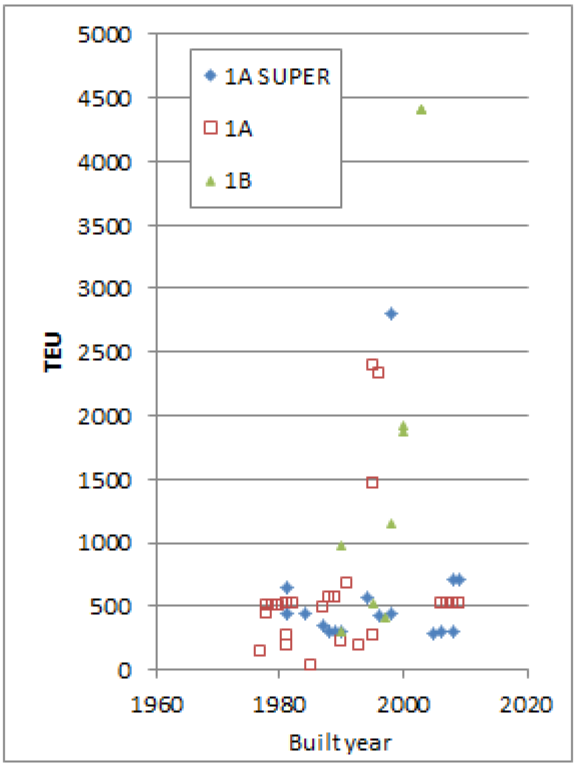


Figure 3.19 Ice class container ship

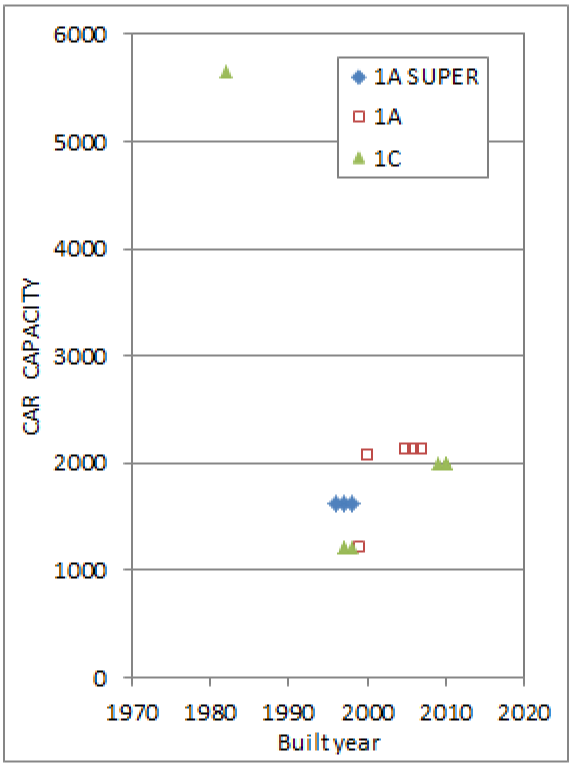


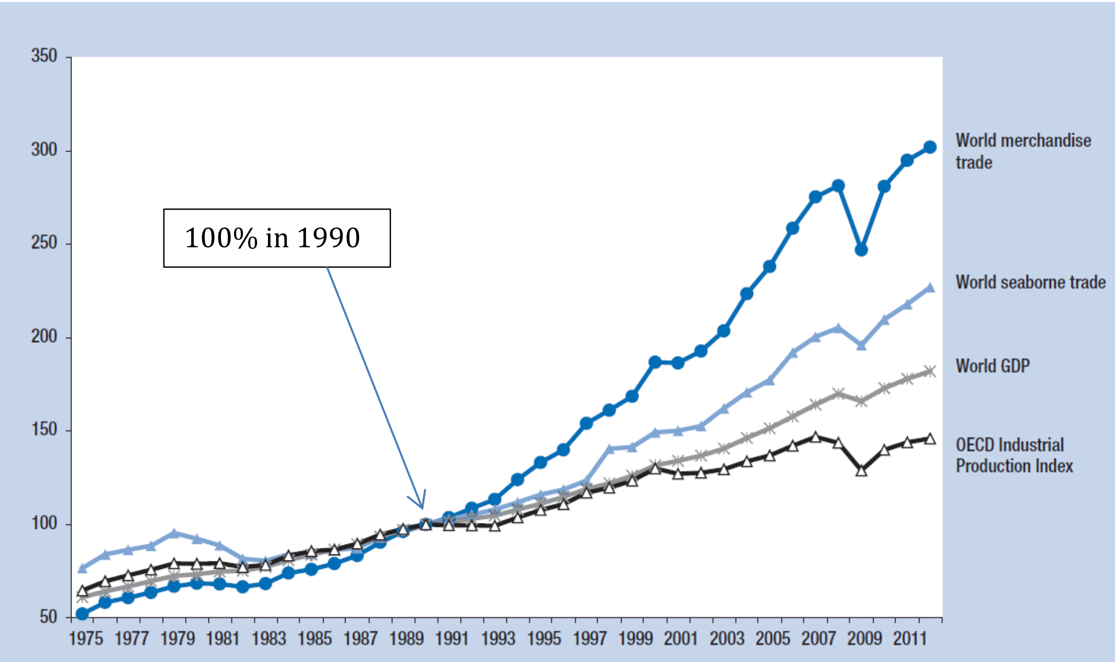
Figure 3.20 Ice class PCC

3.3. World's Interests in the Arctic Sea Routes

3.3.1. World Seaborne Trade

a) Overview of World Seaborne Trade

In 2010, the world economy started to climb out of the crisis, which broke out in late 2008. In 2011, the world economy has been continuously developed at a slower rate than in 2010. In tandem with this growth, world seaborne trade grew by 4% on the back of strong growth in container and dry bulk trades in 2011. At the same time, the world GDP developed by a modest 2.1%, with 4.9 % growth of developing economies and 1.1% in the developed economies. It is clear that this economic development was driven mainly by developing economies and economies in transition, in particular China (7.9 %) and India (6.0 %).



UNCTAD secretariat, on the basis of OECD Main Economic Indicators, May 2012; UNCTAD, *The Trade and Development Report 2012*; UNCTAD *Review of Maritime Transport*, various issues; WTO, Table A1a;the WTO press release 658, Apr.2012, "*World trade 2011, Prospects for 2012*."; The 2012 index for seaborne trade is calculated on the basis of the growth rate forecast by Clarkson Research Services in Shipping Review & Outlook, spring 2012..

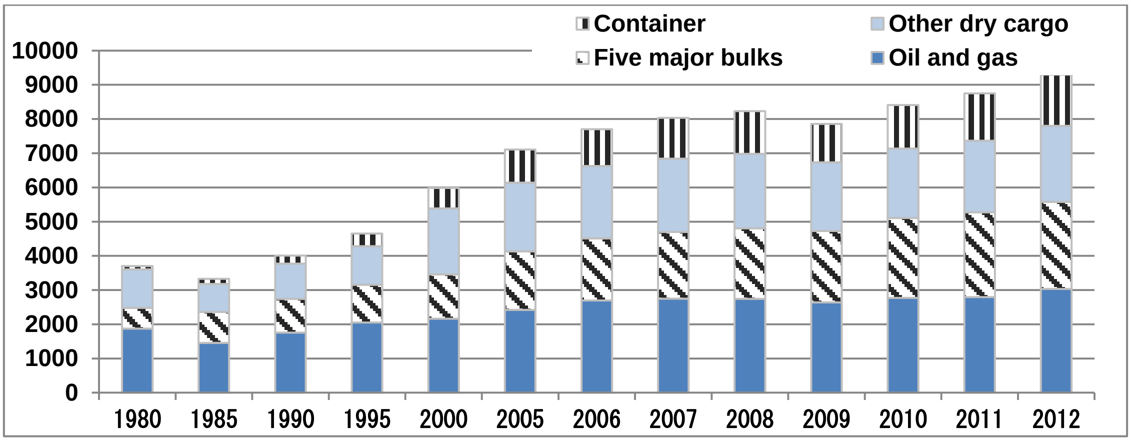
Figure 3.21 World merchandised trade, world seaborne trade and GDP[24]

The world seaborne trade has been clearly reflected upon the world economic situation characterized by GDP as shown in Figure.3.21. In 2011, total volume of world seaborne trade reached a record 8,748 million tons. In 2012, it might reach 9,297 million tons with growth of 6.3% according to the forecast by Clarkson Research in *Shipping Review and Outlook (Spring 2012).* This development was driven by the expansion of dry cargo based on container and major dry bulks, which grew by 8.6% and 6.1%, respectively. At the

[24] Review of Maritime Transport 2012(herein after RMT 2012), UNCTAD, Figure 1.1, pp.2

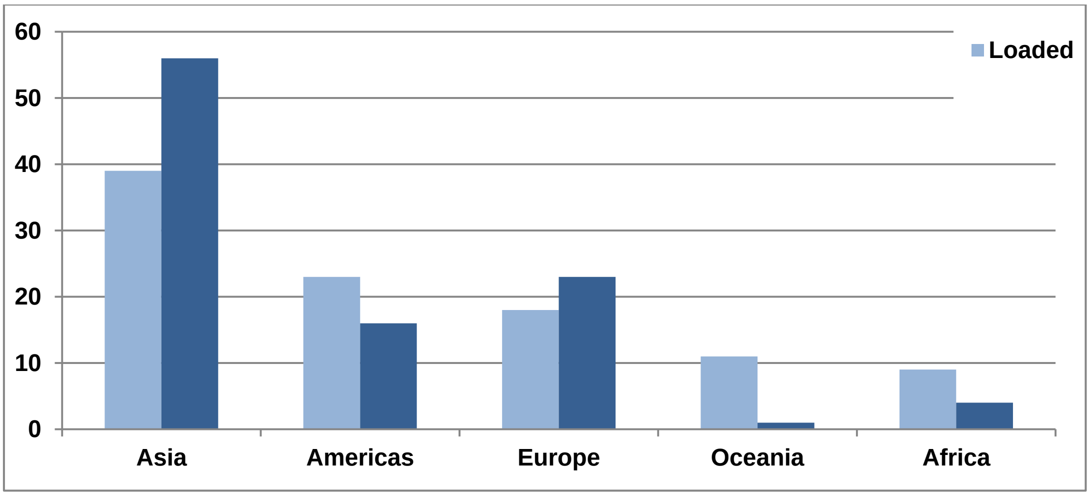
same time, oil and gas trade volume, which was almost stable from 2007 to 2010, slightly expanded to reach record high of 2,796 million tons.

The RMT 2012 indicates that the developing countries contribute increasingly larger shares and growth to both world GDP and world seaborne trade in recent years. In 2011, a total of 60% of the world seaborne trade volume was originated from developing countries and a total of 57% was destined to their territories. And today, Asia has become the largest loading and unloading area making up 39% of total goods loaded and 56% of goods unloaded.



Source: UNCTAD Review of Maritime Transport, various issues. For 2006.2012, the breakdown by type of dry cargo is based on Clarkson Research Services' Shipping Review & Outlook, various issues. Data for 2012 are based on a forecast by Clarkson Research Services in Shipping Review & Outlook, spring 2012.

Figure 3.22 International seaborne trade by type of cargo (million tons)[25]



Source: Compiled by the UNCTAD secretariat on the basis of data supplied by reporting countries, and data obtained from the relevant government, port industry and other specialist websites and sources. Figures are estimated based on preliminary data or on the last year for which data were available.

Figure 3.23 World seaborne trade by area (2011)[26]

[25] RMT 2012, Figure 1.2, pp.9.
[26] RMT 2012, Figure 1.3(c), pp.10.

b) Bulk Cargo

In 2011, volumes of dry bulk cargo remained continuous growth with strong import demand for raw materials in developing economies in particular China and India. Within the five major bulks, which accounted for about 42% of total dry cargo, iron ore accounted for the largest share (42.5%), followed by coal (38.1%). In 2011, seaborne trade of iron ore expanded by 6%, driven by strong demand of China, which accounts for about 2/3 of world iron ore trade volume.

In 2011, the volume of coal shipments including both thermal coal and coking coal expanded by 5.1% compared with 2010. The largest coal importers are Japan (18%) and Europe (18%) followed by China, India and Republic Korea with 13% of share by each countries.

From 2000, crude oil shipment volume has been expanding at a relatively slower rate than other cargoes at an annual rate of less than 1%. However, in 2011, crude oil shipment was declined by 1.4% based on the decline of consumption in developed economies. The largest loading areas were Western Asia followed by Africa, developing America and transition economies such as Russia. And major importing areas were Japan, North America, Europe and developing Asia.

Shipment of liquefied natural gas (LNG) showed strong growth by 10.3% in 2011. This expansion was backed by increasing demand by United Kingdom (35.3%), Japan (12.6%) and the Republic of Korea (11.0%). Here, Asia accounted for 62.7% of global LNG imports with Japan as world largest importer.

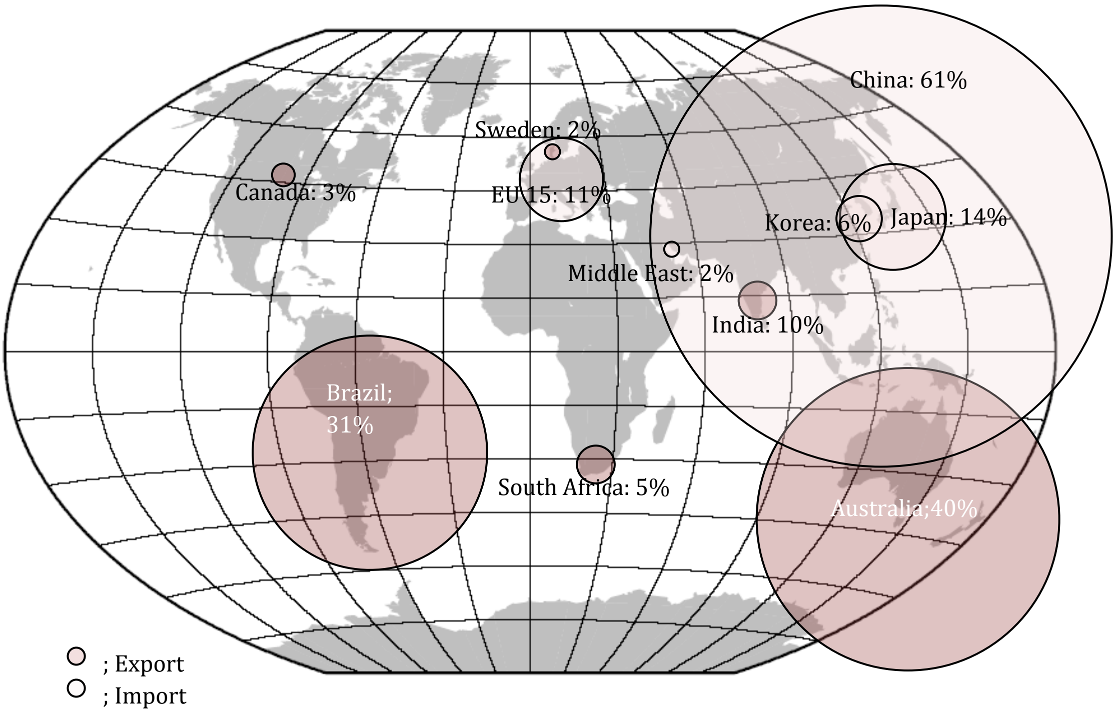


Figure 3.24 Iron ore exporter and importer

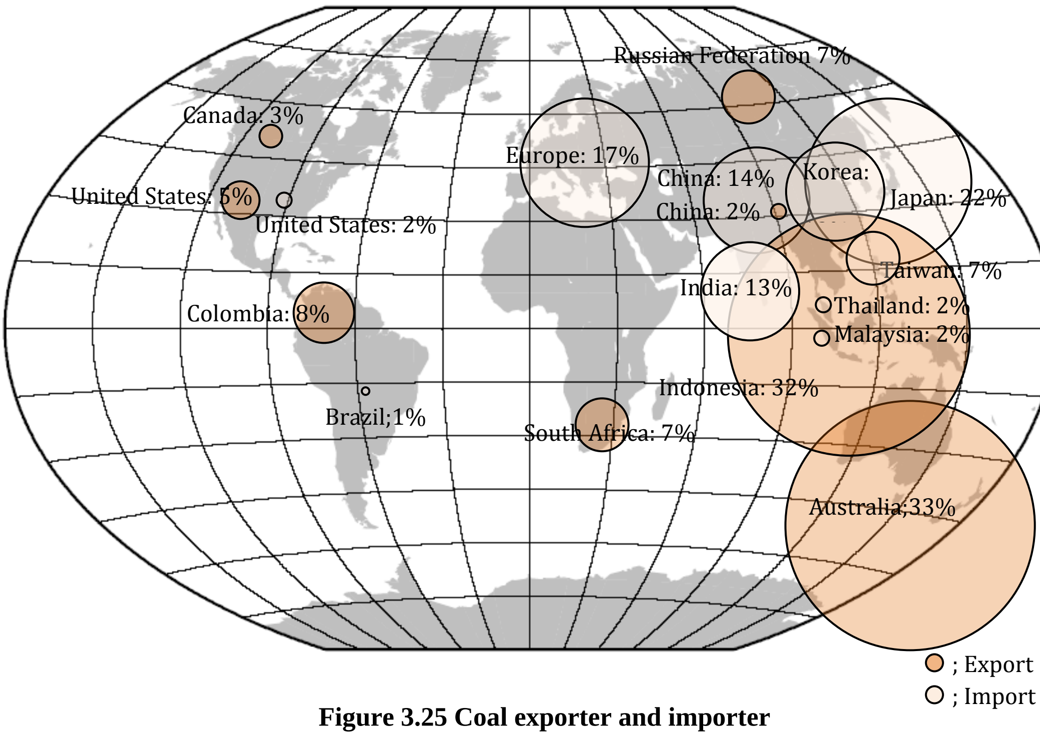


Figure 3.25 Coal exporter and importer

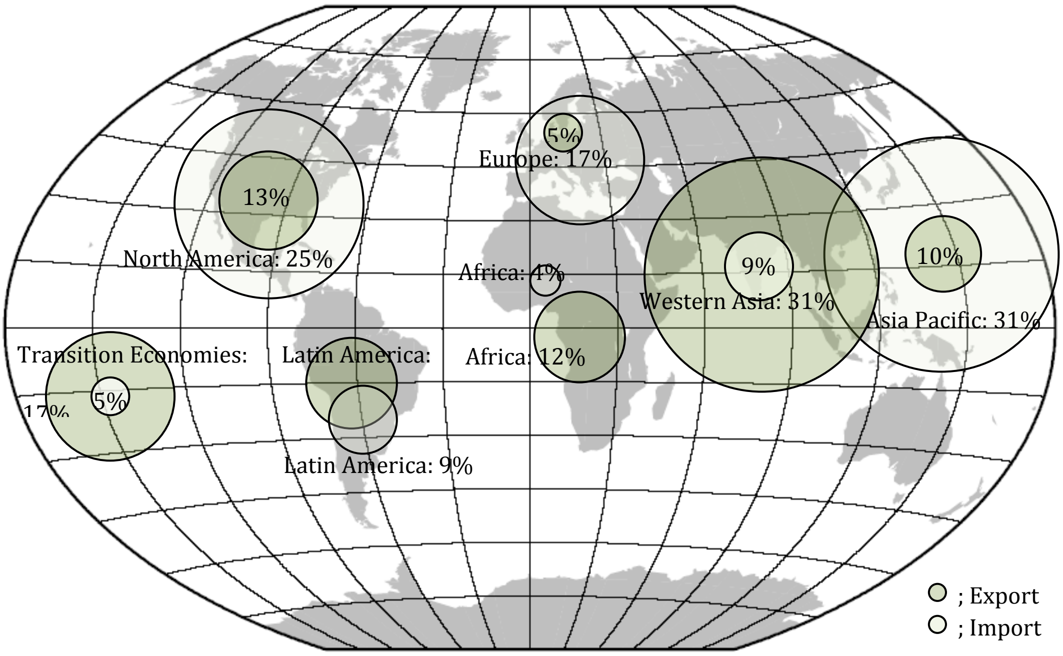


Figure 3.26 Crude oil exporter and importer

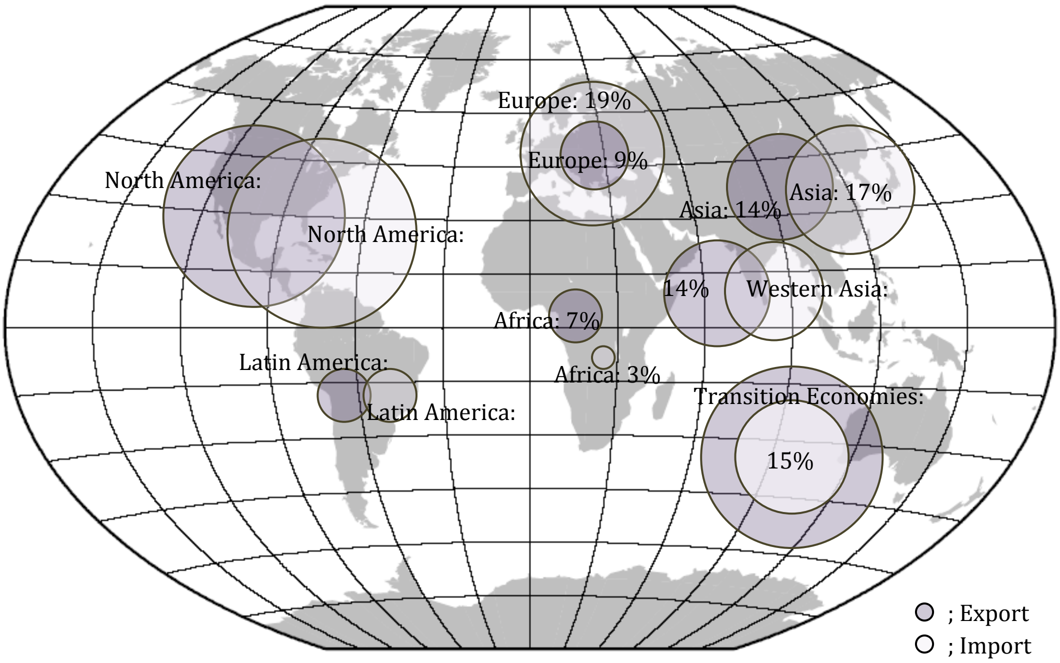


Figure 3.27 Natural gas exporter and importer

c) Container

The container trade is the fastest growing cargo sector at an average growing rate of 8.2% since 1990 until 2010. In 2011, total container shipment volume reached 151 million TEU with 7.1% of growth. Here, container volumes of trans-Pacific route declined by 0.5%, while Asia- Europe route and trans-Atlantic route enjoyed 6.3% and 5.7% of growth respectively[27]. *RMT 2012* indicated that these growth were sustained by non-main lane East-West, North-South and intraregional trades.

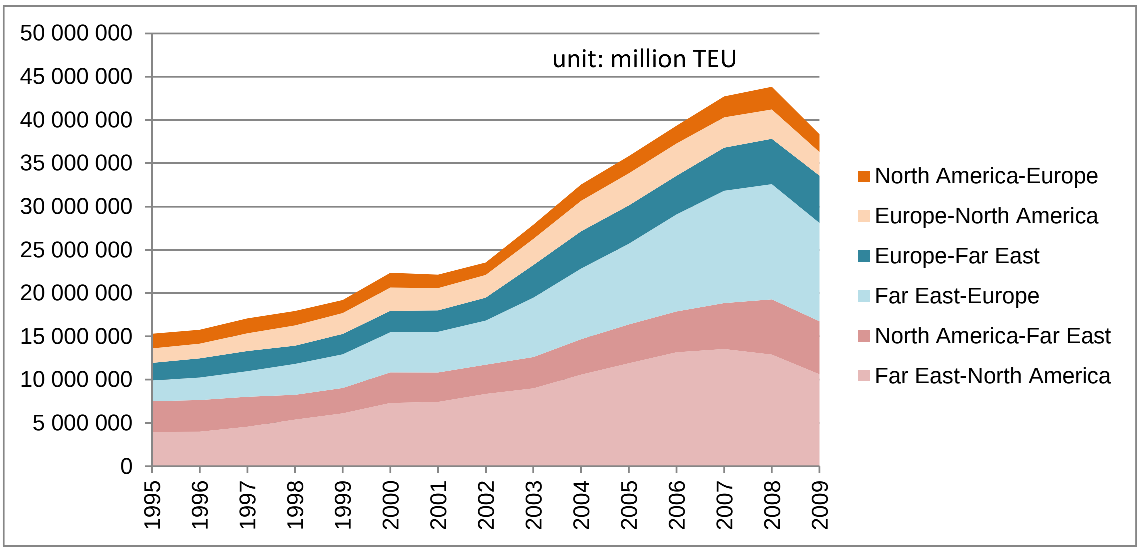
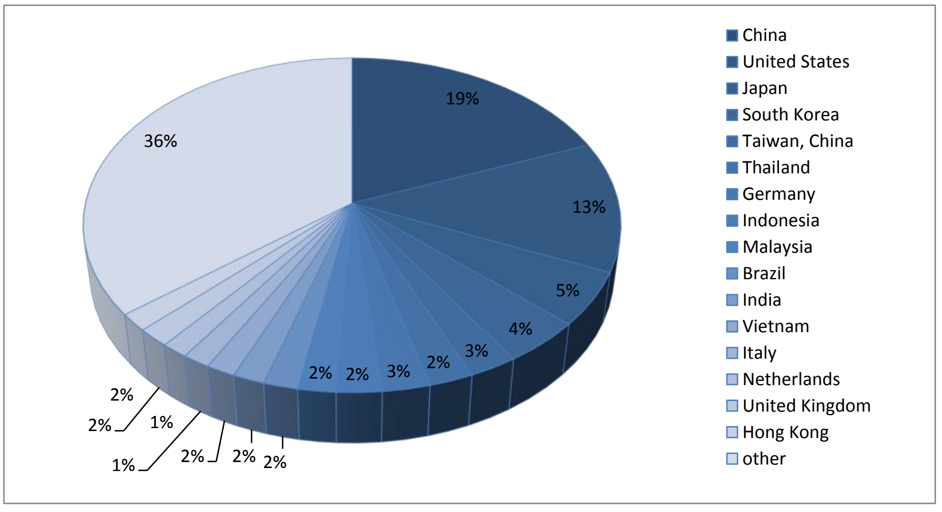


Figure 3.28 Estimated cargo flows on major east–west container trade routes[28]



Unit: %

Figure 3.29 World share of containerized cargo in 2010[29]

[27] RMT 2012 , pp.19

[28] FACILITATION OF TRANSPORT AND TRADE IN LATIN AMERICA AND THE CARIBBEAN, International maritime transport in Latin America and the Caribbean in 2009 and projections for 2010

[29] Compiled by authors on the basis of data from World Shipping Council, Sources from IHS Global Insight World Trade Service, viewed on May 2012, http://www.worldshipping.org/about-the-industry/global-trade/trade-statistics

3.3.2. Potential of Natural Resource Exploitation

Against the background of recovery from economic crisis of the world, the world primary energy consumption in 2010 rebounded by 5.6% compared to the previous year. Here, consumption in Non-OECD countries experienced strong growth by 7.5%. Among them, China surpassed the US and became the world's largest energy consumer sharing 20.3% of world's energy. And in 2011, China alone accounted for 71% of global energy consumption growth since OECD consumption decreased led by Japan's decline. In order to bear this increasing demand, it is required to develop new deposit and new energy resources. In this context, while previous developments were mainly carried out in the areas which are technically and economically favorable, recent project sites are shifting to the area of harsh and difficult conditions such as the Arctic Ocean and offshore deep-water areas. In 2008, U.S. Geological Survey (USGS) had completed an assessment of undiscovered conventional oil and gas resources in the north of the Arctic Circle. They estimated that the total mean undiscovered conventional oil and gas resources of the Arctic are approximately 13% and 30% of those of world total respectively. With the deterioration of arctic sea ice in summer, the energy resources in the Arctic arouse world interest in many ways.

Currently, oil and gas fields in the Arctic can be found in ; north of Timan-Pechora and off the coast(Russia), Yamal Peninsula(Russia), Mackenzie Valley and the Queen Elizabeth Islands in Canada, and Prudhoe Bay in Alaska.

Due to the nuclear power plant disaster in Fukushima, Japan occurred in 2011 and an international expectation for GHG reduction, LNG demand is increasing over the world today. Meanwhile, sea ice deterioration in the Arctic Ocean and appreciating energy price may encourage energy resource developments and commercial shipping in the Arctic Ocean.

Being the world's largest crude oil producer, Russian oil production from existing oil fields is showing a sign of leveling off. Thus Russia is emphasizing to develop new oil and gas fields in the Arctic, and has achieved commercial production in the coastal areas of the Arctic Ocean such as the Yamal peninsula and Varandei terminal in recent years.

For these energy resource developments in the Arctic, potential market is not only western coast of North America and Europe but also the East Asian countries. The East Asian countries, which have been importing energy resources mainly from the Middle East, are facing a task to diversify their energy resource procurement, since the piracy off the Samaria coast and resource price appreciation are growing into serious problems. The Arctic Sea Route draws an international attention as a new sea route with no piracy.

Thus, increased accessibility based upon the decrease in the Arctic sea ice extent, extending navigable summer season and shorter shipping route to Asia is becoming a driver to push these exploitations.

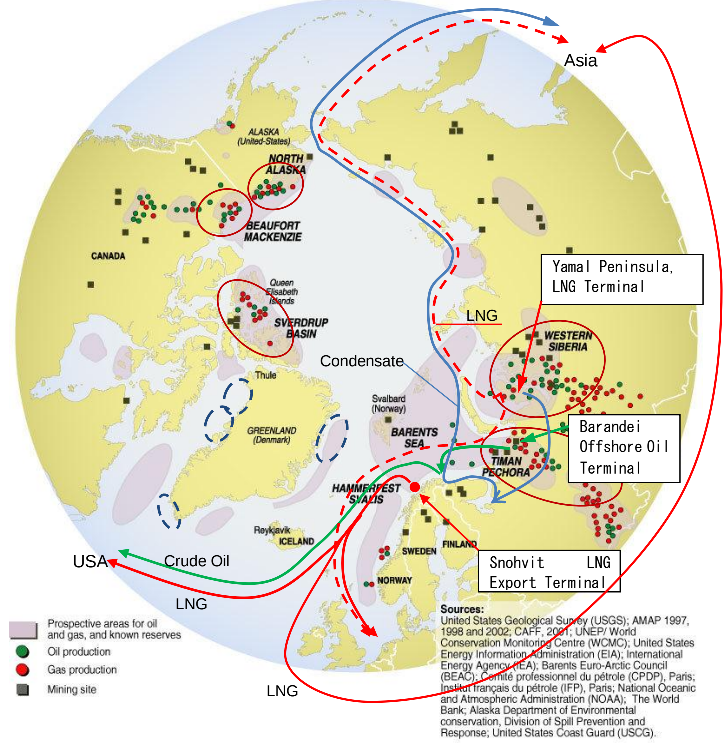


Figure 3.30 Natural resource exploitation field in the Arctic Ocean[30]

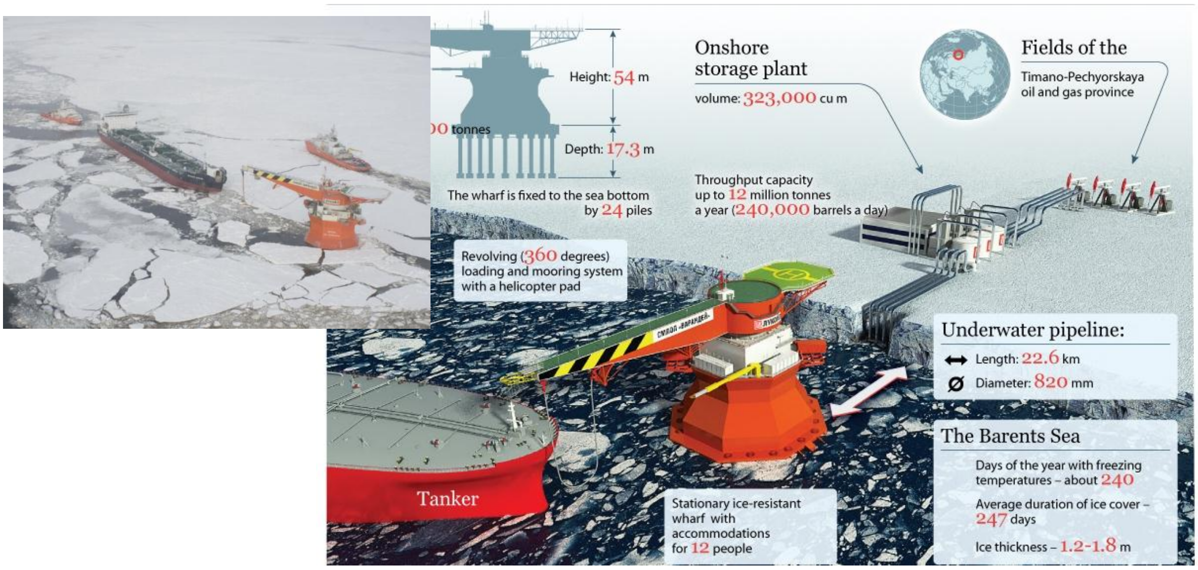


Figure 3.30 Varandei Offshore Oil Terminal[31]

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30 Modified by authors based on the image created by Philippe Rekacewicz & Hugo Ahlenius, UNEP/GRID-Arendal, http://www.grida.no/graphicslib/detail/fossil-fuel-resources-and-oil-and-gas-production-in-the-arctic_a9ca

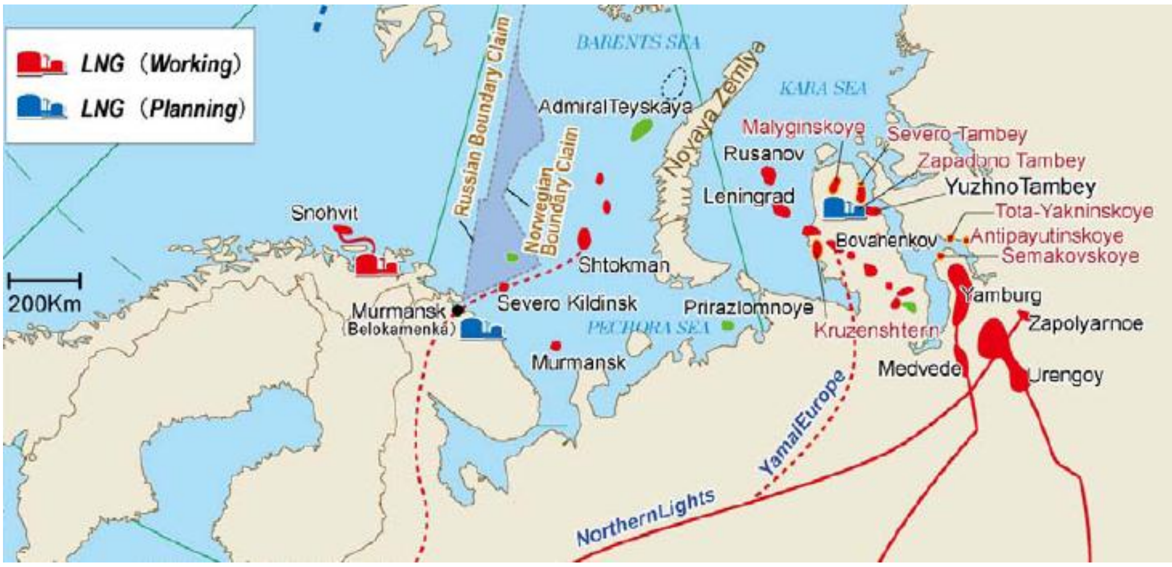

Figure 3.31 Arctic oil and gas exploitation field[32]

3.3.3. Potential of Arctic Sea Routes

a) Natural resource demand and transportation via the NSR

Today, East Asia is the largest importer of iron ore and natural gas. This strong demand for natural resources in East Asia would continue in accordance with the economic growth in these areas. Today, these areas are facing appreciation of resource price and needs for diversification of production area for stable procurement. In this regard, natural resource exploitation in the Arctic draws their attention in recent years. China and Japan have already started to participate in some development projects in the Arctic.

As a result of sea ice retreat, natural condition of the Arctic natural resource exploitation is becoming milder. At the same time, due to a sign of leveling off in the existing Russian oil fields, Russia encourages new oil and gas field developments in the Arctic, such as the Yamal peninsula and Varandei oil terminal in recent years. In these resource exploitations, Asia is no doubt an important market. Here, products would be transported via the NSR in summer season and the Suez Canal route in winter.

The NSR has been already used for bulk cargoes mainly for gas condensate and iron ore. Most of these cargoes were shipped to China. Recently, it becomes apparent that the current gas condensate storage base in the Arctic is going to be removed to the Baltic coast, so that the cargo volume of gas condensate might decrease in the future. Nevertheless, ROSATOMFLOT, which runs nuclear icebreaker in the NSR, expects LNG shipping for

[31] RIA NOBOSTI, retrieved from http://arctic.ru/expert-opinions/timano-pechyorsky-oil-and-gas-province
[32] Motomura, M., "Russia: Clouds over natural gas export (in Japanese)", Briefing of Oil and Gas Business Environmental Research, JOGMEC, 2009.

future dominant cargo of the NSR. The Yamal LNG project plans to produce first LNG in 2017 by 5 million ton per year. And then, 15 million tons annually in full operation. At the same time, Russian government expressed that the existing gas pipeline in Siberia will be expanded to the Yamal Peninsula site, and gas will delivered to European market. Thus, the LNG will be shipped to another market such as the Asian countries. The Snohvit, which is an existing world northernmost gas field in Norway, will also be targeting the Asian market. And, the LNG shipping, which was carried out in 2012 by "*Ob' River*", was a steppingstone for upcoming LNG transport via the NSR.

b) Cost effectiveness

In the recent NSR voyages, the icebreaker fee, which was charged by ROSATOMFLOT, was reported to be almost the same as or not that much exceed that of the Suez Canal fee for the same vessel. In general, the fuel cost accounts for the largest portion of total shipping cost. And building cost of ice class vessel would be about 10%~20% higher than that of normal vessel without ice-strengthening. So, the shortening of shipping distance could directly affect the shipping cost. Thus, the NSR shipping cost remained advantage against the Suez Canal route. The cost analysis is carried out later chapter in this report.

c) Container and other dry cargo shipping

Recently, Asian auto industry and consumer electronics industry are becoming very sensitive for shipping cost of their production. In the transportation between Asia and Europe, some cargoes, which formerly used Trans-Siberian Railway, come to have a tendency to change their transportation route to maritime transport via the Suez Canal. This climate can be a motivation for the NSR shipping.

The conventional shipping lane between Asia and Europe has many ports to call. On the contrary, the NSR does not have destination port along the Arctic Sea coast. Thus, the NSR shipping service is limited its origin and destination to two areas as East Asia and Northern Europe.

Today, container shipping is provided by regular service at short intervals from daily to weekly in general. In the case of the NSR, limited number of ice class vessels, limited cargo volumes and limited capacity of icebreaker service would make it difficult to ensure such short and regular interval service. If we put four ice class vessels into the NSR Shipping service with 28 days of single voyage, interval of service will be 14 days.

At present, the NSR voyage is available for about five months from late June to late November. And the Suez Canal is used in other months if the NSR service for container cargo becomes a reality. This would be another point for the realization of the NSR shipping whether the demand of users and shipping company can accept this condition.

d) Ice class vessel

At present, several ice class bulkers, which have necessary ice class to navigate the NSR, have already operated in the transit voyage of the whole NSR route. However, there is not enough number of ice class bulkers if the cargo volume will increase. On the contrary, there are fairly a good number of ice class tankers that can navigate the NSR. And there is very limited number of ice class LNG carrier in the world. It is reported that new building contracts are currently underway for the Yamal LNG project. Ice class container carrier is also scarce. There are only some ice class container carriers, which have ice class of IA or higher, operating in the Saint Lawrence River areas.

e) Capability of the NSR shipping

According to the interview to ROSATOMFLOT, they are capable to assist the NSR voyage up to 15 million tons of cargo volume under the current nuclear icebreaker fleet. Since there are four nuclear icebreakers and will become three within the year of 2013, most of the NSR navigation should be conducted by convoy voyage to achieve cargo volume. However, current nuclear icebreakers have already come to its age, and refitted life extension reinforcement. So renewal of these nuclear icebreakers has long been an important issue in Russian maritime parties. It is reported that the first new icebreaker building was started in 2012 and expected to launch in 2017. The second and third icebreakers are expected to be launched in 2018 and 2020. Building cost of a nuclear icebreaker is reported as about 37 billion Rub (about 900 million EUR) and this huge budget is not confirmed in the Russian Federation completely. So there is still a risk of the delay of launch and advance in price of icebreaker assistance. It is indicated that if the icebreaker assistance fee is fairly advanced, the users of NSR will built higher ice class vessel which can sail without icebreaker assistance and operate independently in the NSR. Recent sea ice retreat could make independent navigation possible for higher ice class cargo vessel.

4. Cost Analysis of the Northern Sea Route (NSR) and the Conventional Route Shipping

4.1. Literature review

Isakov, N., et al (1999) carried out the first pioneering study on economic feasibility of the NSR commercial shipping of the natural resources produced in the Arctic region, i.e. crude oil, LNG and timbers to be exported. Ship and Ocean Foundation [SOF] (2000) is the mile-stone full-scale study on technical and economic feasibility of the NSR commercial shipping between Yokohama and Hamburg, by assuming ice-breaking bulk/container ship of 40,000 DWT. This study proposed the NSR-SCR-combined shipping by the ice-breaking bulk/container ship, which is compared to the SCR shipping by the ordinary bulk/container ship on a yearly operation basis. The unit cost of the NSR-SCR-combined shipping of general cargo was estimated at 18 (USD/ton), which is approximately equal to that of the SCR shipping by the ordinary ship of the same size. Consequently, no significant comparative advantage of the NSR-SCR-combined shipping was identified.

Arpiainen, M. and Killi, R. (2006) made a systematic cost analysis of container transport between Alaska and Iceland, by assuming double-acting container ships of 750 TEU and 5,000 TEU, which can sail astern-ward with ice-breaking function in the icy waters. Since this ice-breaking container ship is able to navigate the NSR without escort by the Russian ice-breakers, NSR fee was not applied to the cost analysis while the Russian regulation requires the ice-breakers' escort for all the vessels sailing via the NSR. Shipping unit costs of container were estimated 345-526 (USD/TEU) for the 5,000 TEU-ship and 1,244-1,887 (USD/TEU) for the 750 TEU-ship, which were equivalent to the container shipping tariffs between Japan and Europe. In this context, the NSR commercial shipping was evaluated presumably feasible, while no cost analysis was made between East Asia and Europe.

Verny, J. and Grigentin, C. (2009) made a cost analysis of container transport between Shanghai and Hamburg, by assuming the ice-class 4,000 TEU-ship, which was compared among the potential alternative routes: the SCR, Siberia Land Bridge (SLB) route and Sea & Air route. Shipping unit costs of container were estimated 2,500-2,800 (USD/TEU) for the NSR shipping, which are twice as much as those of the SCR shipping (1,400-1,800 (USD/TEU)). Consequently, the NSR shipping was figured out infeasible, because building cost of a new ice-class 4,000 TEU-ship was assumed USD 180 million which is four times as much as the average building cost (USD 47 million) of a new ordinary 4,000 TEU-ship in 2012.

Liu, M. and Kronbak, J. (2010) made a comprehensive analysis of container shipping cost between Yokohama and Rotterdam, by assuming the ice-class 4,300 TEU-ship. This analysis was based on the NSR-SCR-combined shipping on a yearly operation basis. Three factors most influencing on the total cost of the NSR shipping, i) NSR service-period of the year, ii) NSR fee, and iii) fuel cost, were analysed when estimating the shipping unit cost by setting several scenarios at various levels of the factors. Levels of the factors were set 90 days, 180 days and 270 days for the NSR service-period, 50%-off, 80%-off and 100%-off for NSR fees, and 350 (USD/ton), 700 (USD/ton) and 900 (USD/ton) for fuel cost. The NSR-SCR-combined shipping was evaluated infeasible for most of the scenarios, because the extremely high level of NSR fee (979USD/TEU) was assumed in the analysis. However, the NSR-SCR-combined shipping could be feasible, only if NSR fee were free (100%-off) and the fuel cost were at a higher level of between 700 and 900 (USD/ton).

Schoyen, H. and Brathen, S. (2011) examined economic feasibility of bulk cargo (tramp) shipping of nitrogen fertilizer and iron ore produced in the Arctic region to be exported to East Asia, taking uncertainty of schedule reliability of the NSR shipping into account. Shipping unit cost of nitrogen fertilizer was estimated 42.6 (USD/ton) for the NSR shipping compared to 43.3 (USD/ton) for the SCR shipping. Similarly, shipping unit cost of iron ore was estimated 37 (USD/ton) for the NSR shipping, which is compared to 39 (USD/ton) for the SCR shipping. Furthermore, the NSR shipping is twice as energy efficient as the SCR shipping in view of fuel consumption, taking slow operational sailing speed in the ice waters into account. The authors concluded that comparative advantage of the NSR shipping is doubling of the fuel efficiency, while shipping unit costs of raw materials are estimated nearly the same between the NSR and the SCR shipping.

Omre A. (2012) examined technical and economic feasibility of container shipping between Yokohama and Rotterdam, by assuming ice-class container ship of 3,800 TEU. This analysis was based on the NSR-SCR-combined shipping on a yearly operation basis. Two factors of the NSR service-period and the fuel cost, which are most influencing on the total cost of the NSR shipping, were also analysed when estimating the shipping unit cost by setting several scenarios. The NSR service-periods were set 70 days, 100 days and 120 days, and similarly the fuel costs were set 400 (USD/ton), 550 (USD/ton) and 700 (USD/ton). Remarkable feature of the study is that the cost estimation was made by applying the relationship that fuel consumption per distance unit is proportional to the square of sailing speed and assuming NSR fee is at a reasonable level of 5.0 (USD/GT) in the analysis. Consequently, the NSR-SCR-combined shipping was evaluated realistically feasible in any scenarios.

In conclusion, the NSR shipping (including the NSR-SCR-combined shipping) has been recently evaluated feasible by accumulating experiences and know-how in many studies, while having been evaluated realistically infeasible in the early studies. Extended NSR service-period of the year and the fuel price appreciation in recent years are the most critical factors, which make the NSR shipping realistically more feasible than ever.

4.2. Cost components of maritime shipping

Maritime shipping cost components can be clarified in many ways such as operator's viewpoint, ship-owner's viewpoint, etc. (Ship and Ocean Foundation [SOF] (2000) and Hino M. (2011)). Typical examples of the clarification are presented in Table 4.1.

Table 4.1 Maritime shipping cost components (examples)

Operator's view	Ship-owner's view	
Capital cost	Depreciation cost	---
NSR fee	NSR fee	---
Ice pilot fee	Ice pilot fee	---
Suez Canal fee	Suez Canal fee	---
Crew cost	Crew cost	---
Maintenance cost	Maintenance cost	Supply cost of ship
		Lubricant cost
		Dock cost
		Maintenance and spare part cost
Insurance cost	Insurance cost	H&M insurance
		P&I insurance
Fuel cost	Fuel cost	---
Port dues	Port dues	---
---	Miscellaneous cost	---
---	Administration cost	---
---	Interest fee	---

4.2.1. Capital cost and depreciation cost

Both capital cost and depreciation cost are the cost to be applied to a yearly repayment and a yearly depreciation of the capital, based on building cost of the new ship. In Ship and Ocean Foundation (2000), the concept of the capital cost was introduced as a yearly repayment (i.e. equivalent to a repayment of 10.9% of the capital cost for 15 years) of the new ship as defined by the condition (an interest rate of 7% and a return period of 15 years), from the project finance viewpoint.

On the other hand, in Hino, M. (2011), depreciation cost was introduced as a yearly depreciation of the capital for the economic lifetime of 15 years in Japan, which is equivalent to a repayment of 6.7% of the capital cost for 15 years when applying straight-line method. Appropriate lifetime should be assumed for the analysis, taking a range of economic lifetime of 8 years in France, 10 years in Germany and 15 years in Japan into account.

Building costs of various types of the new ships applied to the analysis should be based on the sales transactions in recent years, because ship building costs easily fluctuate to a certain extent shortly. Typical examples of the building costs of various types of the ordinary new ships based on actual transactions in 2012 are presented in Table 4.2 (Maritime Press Japan, (2012), UNCTAD, (2011)).

Table 4.2 Building costs of various types of the ordinary new ships based on actual transactions in 2012

Ship type	Applicable routes	Ship size	Ship building cost (million USD)
Container ship	NSR/SCR	4,000 TEU	47.0
	SCR	6,000 TEU	67.4
	SCR	8,000 TEU	87.9
	SCR	15,000 TEU	159.4
LNG ship	NSR/SCR	150,000 m3	200.0
PCC ship	NSR/SCR	6,500 CEU	68.3
Dry bulk ship	NSR/SCR	75,000 DWT	33.5
	SCR/Cape Route/PCR	170,000 DWT	58.2

Related studies (Liu, M. and Kronbak, J. (2010) and Omre A. (2012)) pointed out that a special attention should be drawn to the additional cost of 10-30% of the ordinary ship, which is necessary for building a new ice-class ship of the same type and the same size.

4.2.2. NSR fee

NSR fee is required when hiring the Russian NSR ice-breakers, because escort is compulsorily requested by the Administration of the Northern Sea Route of the Russian Government. NSR fee may change due to the market transactions reflecting a balance of demand and supply, while the official NSR tariff was established by the Russian Government. As reported by the operator of the NSR commercial shipping in recent years, the actual NSR fee revealed 5.0 (USD/GT) (Falck, H. (2012)). Therefore, Omre, A. (2012) adapted NSR fee of 5.0 (USD/GT) in the study, due to the recently accumulated NSR fee transactions.

4.2.3. Ice pilot fee

The ship master (captain) on a bridge watch must possess the minimum level of knowledge of navigation in the ice waters: experience of steering ships under ice conditions along the NSR for not less than 15 days. In the absence of such experience, the presence of an ice pilot aboard the ship is compulsory (Ship and Ocean Foundation [SOF] (2000)). Ice pilot fee was stipulated as 673 (USD/day) for the NSR navigation between Kara and Bering straits.

4.2.4. Suez Canal fee and Panama Canal fee

Suez Canal fee is determined for each ship type based on Suez Canal Net Tonnage (SCNT) which can be approximated by gross tonnage (GT) of the ship (Suez Canal Authority

Website (2012)). Table 4.3 presents the Suez Canal fee as of December, 2012. However, careful attention should be drawn to a wide variety of discounts for specific ship types.

Table 4.3 Suez Canal fee as of December, 2012

	Vessel Type	SC Net Tonnage												(Unit: SDR / SCNT)	
		First 5000		Next 5000		Next 10000		Next 20000		Next 30000		Next 50000		Rest	
		Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast
1	Tankers of Crude Oil	7.88	6.70	5.58	4.74	4.22	3.59	1.84	1.56	1.63	1.39	1.51	1.28	1.41	1.20
2	Tankers of Petroleum Products	7.88	6.70	5.58	4.74	4.22	3.59	2.54	1.56	2.49	1.39	2.38	1.28	2.27	1.20
3	Dry Bulk Carriers	7.88	6.70	6.02	5.12	4.76	4.05	1.51	1.28	1.41	1.20	1.35	1.15	1.30	1.11
4	LPG Carriers	7.88	6.70	5.70	4.85	4.22	3.59	3.02	2.57	2.81	2.39	2.71	2.30	2.71	2.30
5	LNG Carriers	7.88	6.70	6.13	5.21	5.30	4.51	3.68	3.13	3.57	3.03	3.47	2.95	3.35	2.85
6	Chemical Carriers & Other Liquid bulk Carriers (*)	8.24	7.00	6.37	5.41	5.08	4.32	3.24	2.75	3.14	2.67	3.02	2.57	3.02	2.57
7	Containerships	7.88	6.70	5.41	4.60	4.20	3.57	2.94	2.50	2.73	2.32	2.15	1.83	2.05	1.74
8	General Cargo Ships	7.88	6.70	6.08	5.17	4.24	3.60	3.18	2.70	3.08	2.62	3.03	2.58	2.97	2.52
9	Ro/Ro Ships	7.88	6.70	5.86	4.98	4.56	3.88	3.29	2.80	3.08	2.62	2.97	2.52	2.86	2.43
10	Vehicle Carriers	7.88	6.70	5.41	4.60	4.05	3.44	2.89	2.46	2.73	2.32	2.15	1.83	2.05	1.74
11	Passenger Ships	7.88	6.70	5.54	4.71	4.56	3.88	3.23	2.75	3.18	2.70	3.08	2.62	2.97	2.52
12	Special Floating Units	8.55	-	5.66	-	5.09	-	3.61	-	3.40	-	3.08	-	2.97	-
13	Other Vessels	8.24	7.00	5.55	4.72	4.67	3.97	3.40	2.89	3.29	2.80	3.08	2.62	2.97	2.52

Table 4.4 Panama Canal fee as of December, 2012

(Unit: USD/PC UMS)

Vessel type	Conditions	Panama Canal fee		
Container	Laden	72.0 USD/TEU		
	Balast	57.6 USD/TEU		
Vessel type / PCUMS	PC UMS (ton)	0-10,000	10,000-20,000	20,000+
General Cargo	Laden	4.74	4.64	4.57
	Balast	3.79	3.72	3.66
Dry Bulk	Laden	4.71	4.55	4,47
	Balast	3.76	3.63	3.58
Tanker	Laden	4.68	4.61	4.53
	Balast	3.75	3.69	3.62
Chemical Tanker	Laden	4.82	4.74	4.65
	Balast	3.86	3.79	3.73
LPG	Laden	4.75	4.68	4.59
	Balast	3.84	3.77	3.71
Vehicle Carriers / RoRo	Laden	4.40	4.31	4.24
	Balast	3.52	3.45	3.40
Others	Laden	4.96	4.86	4.78
	Balast	3.97	3.89	3.83

Panama Canal fee is similarly determined for each ship type by SDR (Special Drawing Right) unit based on Panama Canal Universal Measurement System (PC UMS) which can be also approximated by gross tonnage (GT) of the ship size (Panama Canal Authority Website (2012)). Table 4.4 presents the Panama Canal fee as of December, 2012.

4.2.5. Crew cost

Crew sizes of container ship, PCC and dry bulk ship, are practically 23-25 per ship, whatever the ship size is large or small. Japan Ship-owners Association [JSA] (2012) revealed that an average annual crew cost is estimated approximately 1.0 million (USD/ship/year), unless all the crew members are Japanese. On the other hand, crew size of LNG ship is approximately 45 per ship twice as large as the above-mentioned ships. Consequently, an average annual crew cost is similarly estimated 2.0 million (USD/ship/year) for LNG ship, based on the same conditions.

4.2.6. Maintenance cost

Maintenance cost is comprised of supply cost of ship, lubricant cost, dock cost and spare parts cost. Since Hino, M. (2011) estimated an annual maintenance cost of dry bulk ship of 55,000 DWT as 383 thousand (USD/year), of which ship building cost is 35 million (USD/ship) in the study, an annual maintenance cost can be determined proportional (1.095% /year) to the ship building cost, whatever the ship types vary.

4.2.7. Insurance cost

The ocean-going ship is generally required to purchase both H&M and P&I insurance. However, insurance cost estimation is one of the most difficult task to achieve, because insurance market transactions are not usually disclosed to the public due to the nature of the insurance business. Hino, M. (2011) estimated the annual insurance premium of both H&M and P&I insurance as 120 thousand (USD/year) in total for the dry bulk ship of 55,000 DWT, of which ship building cost is 35 million (USD/ship). Annual insurance premium of both H&M and P&I insurance in total can be determined proportional (0.343%/year) to the ship building cost, whatever the ship types vary.

On the other hand, Ship and Ocean Foundation [SOF] (2000) suggested that annual insurance premium of 10 (USD/GT/year) in total for both H&M and P&I additional insurance is compulsory for the NSR shipping. The NSR shipping may need to bear a certain disadvantage of the insurance premium for uncertain and risky sailing in the ice waters.

Apart from the ordinary insurance cost, Aden Emergency Charge (40USD/TEU) is applied to the shippers of container cargo via the SCR as a kind of insurance premium for piracy off Somalia (MOL, (2012)). The SCR shipping may need to bear a significant disadvantage of piracy risk off Somalia.

4.2.8. Fuel cost

Fuel cost may dominantly account for the shipping cost, reflecting the fuel prices which have been increasing at a consistent pace for the last ten years. The relationship that fuel consumption per distance unit is proportional to the square of sailing speed is recommended to apply for calculation, when operational sailing speed is slower in the ice waters for the NSR shipping.

4.2.9. Port dues

Port dues usually consist of port entry due, berthing due and line-handling charge. Assuming 0.092 (USD/GT/call) for port entry due and berthing due respectively, and 0.244 (USD/GT/call) for line-handling charge, total port due is estimated 0.428 (USD/GT/call) for each port entry.

Port entry of bulk cargo ship is twice at the both ends of the voyage, because bulk cargo ships usually call only loading port and discharging port for a single voyage, whichever the NSR or the SCR shipping are applied. On the other hand, typical container ship operation via the SCR between East Asia and Northwest Europe pragmatically requires 10 port calls, visiting major in-between ports as well as both end ports so as to accommodate abundant demand. Therefore, 10 port calls are assumed for a single voyage of the SCR container shipping in this study.

Container handling charge of 100 (USD/TEU) is assumed to add to the port dues for loading and discharging respectively at the both end ports, so as to easily compare the estimated shipping unit cost with the container shipping tariff on CIF basis.

4.3. Practical NSR shipping scenarios

So as to set the practical scenarios for the NSR shipping as well as the alternative route shipping, various factors are to be taken into account, i.e. the NSR service-period, maximum ship-size for the NSR sailing, ice-class ship building cost, nominal sailing speed in the ordinary waters, and operational sailing speed in the icy waters and the ordinary waters. Furthermore, special attentions are to be drawn to the cargo demand distribution along the NSR, the SCR and other alternative routes, when assuming the shipping scenarios of container, bulk cargo, LNG and vehicle transport.

Only a limited number of the studies have been accumulated concerning the NSR shipping for bulk cargo, while the commercial shipping of natural resources i.e. gas condensate, LNG and iron ore produced in the Arctic region, in fact, have been realized by the NSR shipping.

When focusing on container transport, the NSR shipping may take an advantage of shorter transport time due to reduced sailing distance and avoiding major risks of the SCR shipping, i.e. piracy risk off Somalia and chalk-point such as the Malacca Strait. Container ship operators are able to consolidate abundant cargo demand to and from major hub ports along the SCR, while no population and container demand are expected along the NSR.

4.3.1. NSR service-period and sailing speed

Many previous studies were conducted on container shipping via the NSR, taking a significant advantage of reduced sailing distance compared to the SCR shipping between East Asia and Northwest Europe. Since container shipping may require fixed schedule operation as liner shipping, disadvantage of limited NSR service-period is crucial, which are only 4 to 6 months of the year.

Table 4.5 NSR service-period and operational sailing speed in icy waters for recommended scenario

(unit: days)

NSR Service-period	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Operational Sailing Speed (knot)	12.8 Knot (Ice waters)			14.1 Knot (Ice waters)			12.8 Knot (Ice waters)	
	20.0 Knot (Ordinary waters)							
105 days	---	---	---	30	30	30	15	---
135 days	---	---	15	30	30	30	30	---
165 days	---	15	30	30	30	30	30	---
195 days	---	30	30	30	30	30	30	15
225 days	15	30	30	30	30	30	30	30

When setting the scenarios for the NSR shipping, a range of the NSR service-period of 105 days to 225 days is pragmatically recommended to assume, taking the recent records of the NSR commercial shipping into account. Since the operational sailing speed in the icy waters is relatively slow compared to that in the ordinary waters, the operational sailing speed is recommended to set at 12 to 15 knot as indicated in Table 4.5.

4.3.2. Maximum ship-size for NSR shipping

The ordinary NSR has a draft restriction of 13.0 m at the Sannikov Strait, and breadth restriction of 33-49 m, determined by the breadth of ice breakers to follow (Figure 4.1). Maximum ship-size is determined by the ship-type as an approximately 50,000 DWT-class, taking the above-mentioned restrictions into account. Principal items should be appropriately determined for container ship, LNG ship, PCC and dry bulk ship respectively, which satisfy at least the draft restriction of 13.0 m for the NSR shipping.

Figure 4.1 Representative NSR and its draft restriction at the Sannikov Strait

4.3.3. Ice-class ship building cost

Ships sailing through the NSR are required to satisfy ice-class PC7(equivalent to NK IA, LR 1A, RS Arc4) or higher, which may bear 10-30% additional cost to build (Liu, M. and Kronbak, J. (2010), Omre A. (2012)). When setting the scenarios, the percentage of the additional cost should be appropriately assumed, taking the ship-type into account (10% for container ship).

4.3.4. Operational sailing speed and fuel consumption

Fuel consumption of the sailing ship is computed by multiplying SFOC (Specific Fuel Oil Consumption) (g/KWh), engine power (KW) and sailing hours (h). Since ice-class ship may consume more fuel than the ordinary ship, mainly due to the additional weight of reinforced thick steel hull, premium for SFOC of ice-class ship should be assumed at a reasonable level (10%).

SFOC is fixed at a level of 185 (g/KWh), whatever the ship type is applied, which may decrease proportionally to the square of operational sailing speed. Therefore, reduction effect of fuel consumption increases to a large extent, when the operational sailing speed is slower than the nominal sailing speed (Omre A. (2012)).

4.3.5. NSR shipping scenarios for container transport

When setting the scenarios for container transport between i.e. Yokohama and Hamburg via the NSR, 4,000 TEU ice-class container ship may be recommended to select for the scenarios. Economy of scale effect can be generated to a certain extent by this ship size, satisfying the draft restriction of 13.0 m at the Sannikov Strait. On the other hand, medium, large and ultra-large container ships of the 4,000 TEU, 6,000 TEU, 8,000 TEU and 15,000 TEU-classes are to be selected for the alternative route shipping via the SCR (see Table

4.6). Load factor of the container ship should be assumed 70% for eastward and westward sailing respectively, taking liner shipping characteristics into account.

Table 4.6 Principal items of container ship for NSR shipping scenario

Ship-size	Route	Crew	LOA (m)	Beam (m)	Draft (m)	GT (ton)	DWT (ton)	Speed (Knot)	Engine Power (KW)
4,000TEU	NSR/SCR	23	296	32	13.0	40,000	50,000	25	40,000
6,000TEU	SCR	23	296	40	14.0	75,000	80,000	25	57,000
8,000TEU	SCR	23	323	43	14.5	89,000	82,000	25	68,000
15,000TEU	SCR	23	397	56	15.5	155,000	155,000	25	80,000

4.3.6. NSR shipping scenario for LNG transport

Since 150,000 m3 ice-class LNG ship “Ob River” carrying LNG succeeded in sailing from Hammerfest (Norway) to Tobata (Japan) via NSR in November and December 2012, ice-class LNG ship of the same size may be recommended to select for the scenarios for LNG shipping between i.e. Hammerfest and Yokohama via NSR (see Table 4.7). The same LNG ship should be selected for potential alternative route shipping via SCR.

Load factor of LNG ship should be assumed 90% for eastward sailing, taking the one-way traffic characteristics of LNG from Europe to East Asia into account.

Table 4.7 Principal items of LNG ship for NSR shipping scenario

Ship-size	Route	Crew	LOA (m)	Beam (m)	Draft (m)	GT (ton)	DWT (ton)	Speed (Knot)	Engine Power (KW)
150,000m3	NSR/SCR	46	290	49	11.9	120,000	77,000	20	27,000

4.3.7. NSR shipping scenario for vehicle transport

Vehicle transport between East Asia and Europe may have significant potential demand not only for westward shipping from Japan and Korea to Europe but also eastward shipping from Europe to Japan, Korea and China, while PCC ship had not succeeded in NSR commercial shipping before. When setting up the scenarios for vehicle shipping between i.e. Yokohama and Bremerhaven, 6,500 CEU ice-class PCC ship may be recommended to select, which may take economy of scale advantage by satisfying the draft restriction of 13.0 m (see Table 4.8).

Load factor of PCC ship should be assumed 90% for westward sailing for export from Japan and Korea to Europe, while assuming eastward shipping load factor from Europe to Japan, Korea and China as 50% and 0%.

Table 4.8 Principal items of PCC ship for NSR shipping scenario

Ship-size	Route	Crew	LOA (m)	Beam (m)	Draft (m)	GT (ton)	DWT (ton)	Speed (Knot)	Engine Power (KW)
6,500 CEU	NSR/SCR	25	200	32	10.3	62,500	21,500	20	15,500

4.3.8. NSR shipping scenario for dry bulk transport

Since 75,000 DWT Panamax ice-class dry bulk ship "Sanko Odyssey" carrying iron ore succeeded in sailing from Murmansk (Russia) to China via NSR in September 2012, ice-class dry bulk ship of the same size is recommended to select for the scenario for dry bulk shipping between i.e. Kirkenes (Norway) and Dalian (China) via NSR (see Table 4.9).

170,000DWT Suez-max ice-class dry bulk ship carrying iron ore should be selected for potential alternative route shipping between i.e. Itaqui (Brazil) and Dalian via SCR or Cape route as well as expanded Panama Canal Route (PCR), taking the sailing distance and iron ore production potential in the northern Brazil into account.

Table 4.9 Principal items of dry bulk ship for NSR shipping scenario

Ship-size	Route	Crew	LOA (m)	Beam (m)	Draft (m)	GT (ton)	DWT (ton)	Speed (Knot)	Engine Power (KW)
75,000 DWT	NSR/SCR	25	225	32	14.0	40,000	75,000	14.5	9,000
170,000 DWT	SCR/ Cape route/ Expanded PCR	25	290	45	17.9	90,000	170,000	14.5	16,000

4.3.9. Various aspects of the NSR shipping evaluation

Maritime shipping industry is a capital-intensive industry which by nature aims at maximizing profit on a yearly operation basis of a fleet of ships. The NSR shipping may achieve more voyages than the SCR shipping between i.e. East Asia and Northwest Europe by taking advantage of reduced sailing distance. Consequently, the more annual shipment from one place to the other on a yearly operation basis is expected for the NSR-SCR-combined shipping, so that the maritime shipping industry is able to make more profit than the simple SCR shipping operation. Therefore, the annual shipment capacity of the NSR-SCR-combined shipping may become a beneficial index from the financial viewpoint.

Secondly, speedy transport of valuable cargo via the NSR due to reduced sailing distance compared to the SCR shipping may bring a significant competitive advantage. Reduced transport time is of greater importance to the valuable cargo shippers and consignees.

Thirdly, the NSR shipping may reduce fuel consumption, because of reduced sailing distance and higher energy efficiency gained by reduced sailing speed in the icy waters. Assuming that carbon dioxide be produced 3.19 ton by burning 1.0 ton of bunker fuel, reduction effect of CO^2 emission by unit cargo between the same origin and destination pair may become a beneficial index from the greener shipping viewpoint (IMO (2009)).

4.4 Empirical analysis of NSR shipping

Empirical analysis is achieved for the case study on container transport between East Asia and Northwest Europe, on which a lot of the previous studies focused, assuming a practical level of the dominant factor variables, i) NSR service-period, ii) NSR fee, and iii) fuel cost.

Cost estimation is made on a yearly operation basis, assuming the NSR-SCR-combined shipping which combines the NSR shipping for the summer time and the SCR shipping for the rest of the year. This brings a fair platform to compare the NSR-SCR-combined shipping with the SCR shipping on the same operation basis, which is practically important from the financial viewpoint.

4.4.1. Scenarios

a) Origin and destination pair

Scenarios of container transport between Yokohama (East Asia) and Hamburg (Northwest Europe) are selected for the empirical analysis.

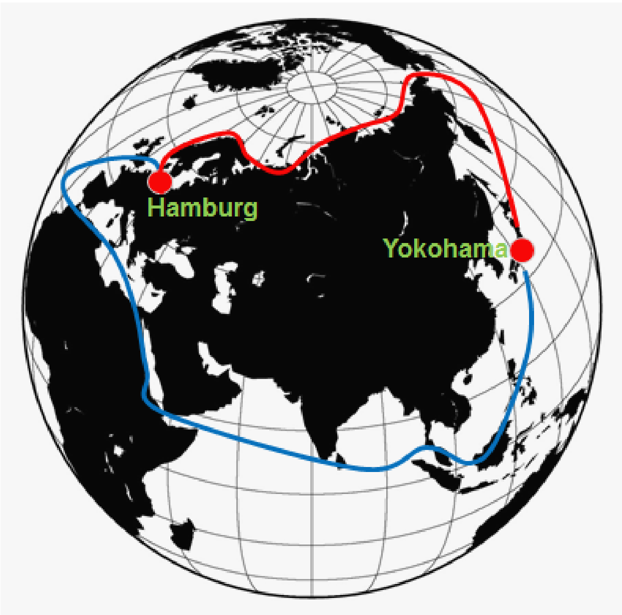

Figure 4.2 Comparative routes for SNR and SCR shipping in the scenarios

b) Assumed container ship-size for comparative routes

The ice-class 4,000 TEU container ship is assumed for the NSR-SCR-combined shipping, while the ordinary container ship of the same size (4,000 TEU), the ordinary large container ships of 6,000 TEU and 8,000 TEU, and the ordinary ultra-large container ship of 15,000 TEU are assumed for the SCR shipping.

c) NSR service-period and operational sailing speed

NSR service-period is assumed 105 days, 135 days, 165 day, 195 days and 225 days as indicated in Table 5, taking the recent NSR commercial shipping records into account. Similarly, operational sailing speed is also assumed 14.1 knot for the summer time (August, September and October), 12.8 knot for the spring and autumn season (May, June, July, November and December) as indicated in Table 4.5.

d) Operational sailing speed and fuel consumption

SFOC is fixed at a level of 185 (g/KWh), whatever the ship-size is applied, which is assumed to decrease proportional to the square of operational sailing speed. Since an ice-class ship may consume more fuel than the ordinary ship, mainly because of the additional weight of reinforced thick steel hull, 10% premium is assumed for SFOC of the ice-class ship.

4.4.2. Level of cost component

Level of the following nine (9) cost components is assumed as discussed in 4.3.

a) Capital cost and depreciation cost

Depreciation cost is applied with the economic lifetime of 10 years and straight-line method.

b) NSR fee

NSR fee is assumed 5.0 (USD/GT), as NSR fee transaction was reported at a level of 5.0 (USD/GT) (Falck, H. (2012)).

c) Ice pilot fee

Ice pilot fee is assumed 673 (USD/day) for the NSR navigation between Kara and Bering straits, as stipulated by the Russian regulation.

d) Suez Canal fee

Suez Canal fee is assumed as defined on the website of Suez Canal Authority as of December 2012.

e) Crew cost

Crew cost is assumed 1.0 million (USD/ship/year), as reported by Japan Ship-owners Association [JSA] (2012).

f) Maintenance cost

An annual maintenance cost is proportionally assumed 1.095 (%/year) of the ship building cost, as reported by Hino, M. (2011).

g) Insurance cost

Annual insurance premium of both H&M and P&I insurance in total is proportionally assumed 0.343 (%/year) of the ship building cost, as reported by Hino, M. (2011).

Annual insurance premium of 10 (USD/GT/year) in total is assumed as additional H&M and P&I insurance premium for the NSR shipping, as reported by Ship & Ocean Foundation [SOF], (2000) .

Apart from the ordinary insurance cost, Aden Emergency Charge (40USD/TEU) is assumed for the SCR shipping as a kind of insurance premium for piracy off Somalia, as stipulated by MOL, (2012).

h) Fuel cost

Fuel cost is assumed 300 (USD/ton), 650(USD/ton), and 900 (USD/ton), taking the recent transactions in Singapore into account.

i) Port dues

Port dues are assumed 0.428 (USD/GT/call) in total for each port entry, including port entry due, berthing due and line-handling charge. Additionally, Container handling charge of 100 (USD/TEU) is assumed for loading and discharging respectively at the both end ports, so as to easily compare the estimated shipping unit cost with the container shipping tariff on CIF basis.

4.4.3. Shipping unit cost comparison per TEU

a) Cost component breakdown

Shipping unit costs per TEU are computed, and their cost components are also presented by the ship-size for the NSR-SCR-combined shipping and the SCR shipping, assuming the scenario (NSR service-period of 105 days and fuel cost of 650 (USD/ton)). Shipping unit cost is computed 1,211 (USD/TEU) for the NSR-SCR-combined shipping by the ice-class 4,000 TEU-ship, which is compared to 1,355 (USD/TEU) for the SCR shipping by the ordinary container ship of the same size.

Shipping unit costs of 1,320 (USD/TEU) and 1,211 (USD/TEU) are computed for the SCR shipping by the ordinary large container ships of 6,000 TEU and 8,000 TEU respectively, which are less competitive than the NSR-SCR-combined shipping by the ice-class 4,000 TEU-ship. However, computed shipping unit cost of 944 (USD/TEU) for the SCR shipping by the ordinary ultra-large container ship of 15,000 TEU, is much more competitive than the NSR-SCR-combined shipping (4,000 TEU), by gaining economy of scale effect of the ultra-large container ship.

When looking at detailed cost components, fuel cost accounts for approximately 50% of the total shipping unit cost for all the ship-sizes. Following the fuel cost, port dues occupy approximately 20%, and depreciation cost and the NSR-SCR-combined fees including Aden emergency charge occupy approximately 10% respectively.

Table 4.10 Cost component breakdown by ship-size

Unit (Upper: '000 USD/year, Lower: %)

Ship-size/ NSR service-period	4,000 TEU NSR 105days SCR 260days	4,000 TEU NSR 0 day SCR 365days	6,000 TEU NSR 0 day SCR 365days	8,000 TEU NSR 0 day SCR 365days	15,000 TEU NSR 0 day SCR 365days
Annual container throughput	36,400 (TEU/year)	33,600 (TEU/year)	50,400 (TEU/year)	67,200 (TEU/year)	126,000 (TEU/year)
Shipping unit cost per TEU	1,211 (USD/TEU)	1,355 (USD/TEU)	1,320 (USD/TEU)	1,211 (USD/TEU)	944 (USD/TEU)
Annual voyages	NSR: 5 SCR: 8	SCR: 12	SCR: 12	SCR: 12	SCR: 12
Depreciation cost	4,925 (11.2 %)	4,688 (10.3%)	6,728 (10.1%)	8,769 (10.8%)	15,909 (13.4%)
NSR fee, Ice pilot fee, NSR insurance premium	1,433 (3.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Suez Canal fee, Suez insurance premium, Aden emergency charge	3,115 (7.1%)	4,572 (10.0%)	7,099 (10.7%)	8,387 (10.3%)	14,208 (11.9%)
Crew cost	954 (2.2%)	997 (2.2%)	997 (2.2%)	997 (2.2%)	997 (2.2%)
Maintenance cost	491 (1.1%)	513 (1.1%)	736 (1.1%)	997 (1.2%)	1,741 (1.5%)
Insurance cost	154 (0.3%)	161 (0.4%)	231 (0.3%)	301 (0.4%)	545 (0.5%)
Fuel cost	24,196 (54.9%)	25,815 (56.7%)	36,787 (55.3%)	43,787 (53.9%)	51,631 (43.4%)
Port dues, container handling charge	8,822 (20.0%)	8,772 (19.3%)	13,932 (20.9%)	18,011 (22.1%)	33,931 (28.5%)
Grand total	44,086 (100%)	45,522 (100%)	66,511 (100%)	81,011 (100%)	118,965 (100%)

This cost analysis shows that the NSR-SCR-combined shipping by ice-lass 4,000 TEU-ship may become competitive against the same-size (4,000 TEU) and the ordinary large container ships (between 6,000 TEU and 8,000 TEU), similar to the study by Omre (2012). Only the exception is the ordinary ultra-large container ship (15,000 TEU) which takes far greater economy of scale advantage for the SCR shipping.

b) Effect of NSR Service-period

The longer the NSR service-period is assumed, the lower the shipping unit costs are expected as naturally understood. Shipping unit cost is computed 1,211 (USD/TEU) for the NSR-SCR-combined shipping by the ice-class 4,000 TEU-ship (the NSR service-period of 105 days), followed by 1,186 (USD/TEU), 1,090 (USD/TEU), 1,074 (USD/TEU) and 984 (USD/TEU) respectively for the NSR service-periods of 135 days, 165 days, 195 days and 225 days.

However, computed shipping unit cost of 944 (USD/TEU) for the SCR shipping by the ordinary 15,000 TEU-ship via the SCR, which may gain a significant economy of scale effect of ultra-large container ship, is much more competitive than the NSR-SCR-combined shipping (984USD/TEU) for the longest NSR service-period of 225 days by the ice-class 4,000 TEU-ship.

Table 4.11 Shipping unit cost, annual voyage numbers and NSR service-period by ship-size

Container ship-size NSR service-period/SCR service-period	Upper: Shipping unit cost Lower: Annual voyages
Ice-class 4,000 TEU/NSR: 105days Ice-class 4,000 TEU/SCR: 260days	1,211 USD/TEU 13 (NSR:5+SCR:8)
Ice-class 4,000 TEU /NSR: 135days Ice-class 4,000 TEU/SCR: 230days	1,186 USD/TEU 14 (NSR:6+SCR:8)
Ice-class 4,000 TEU/NSR: 165days Ice-class 4,000 TEU/SCR: 200days	1,090 USD/TEU 14 (NSR:8+SCR:6)
Ice-class 4,000 TEU/NSR: 195days Ice-class 4,000 TEU/SCR: 170days	1,074 USD/TEU 15 (NSR:9+SCR:6)
Ice-class 4,000 TEU/NSR: 225days Ice-class 4,000 TEU/SCR: 140days	984 USD/TEU 15 (NSR:11+SCR:4)
Ordinary 4,000 TEU/SCR: 365days	1,355 USD/TEU 12 (SCR:12)
Ordinary 6,000 TEU/SCR: 365days	1,320 USD/TEU 12 (SCR:12)
Ordinary 8,000 TEU/SCR: 365days	1,211 USD/TEU 12 (SCR:12)
Ordinary 15,000 TEU/SCR: 365days	944 USD/TEU 12 (SCR:12)

c) Effect of NSR fee

Scenario that NSR fee is assumed 5.0 (USD/GT), is compared to the scenario that NSR fee is assumed 674 (U SD/TEU) referring to the previous studies, by computing their cost components presented in table 9. For the base scenario (the NSR service-period is 105 days), the NSR-SCR-combined shipping unit cost is computed 1,858 (USD/TEU) when NSR fee is assumed 674 (USD/TEU), which is higher by 53% than 1,211 (USD/TEU) when NSR fee is assumed 5.0 (USD/GT). Extremely high NSR fee setting of 674 (USD/TEU) undoubtedly makes the NSR commercial shipping infeasible, as indicated by the previous studies.

This clearly suggests that the recent NSR fee transactions of 5.0 (USD/GT) can be understood as practically competitive level against the Suez Canal fee to a maximum extent (Falck, H. (2012)).

Table 4.12 Cost component breakdown by NSR fee for basic scenario

Ship-size / 4,000 TEU NSR service-period	NSR fee: 5.0 (USD/GT) NSR 105 days SCR 260 days	NSR fee: 674 (USD/TEU) NSR 105 days SCR 260 days
Annual container throughput	36,400 (TEU/year)	33,600 (TEU/year)
Shipping unit cost per TEU	1,211 (USD/TEU)	1,858 (USD/TEU)
Annual voyages	NSR: 5 / SCR: 8	NSR: 5 / SCR: 8
Depreciation cost	4,925 (11.2 %)	4,925 (7.3%)
NSR fee, NSR pilot fee, NSR insurance premium	1,433 (3.3%)	24,967 (36.9%)
Suez Canal fee, Suez insurance premium, Aden emergency charge	3,115 (7.1%)	3,115 (4.6%)
Crew cost	954 (2.2%)	954 (1.4%)
Maintenance cost	491 (1.1%)	491 (0.7%)
Insurance cost	154 (0.3%)	154 (0.3%)
Fuel cost	24,196 (54.9%)	24,196 (35.8%)
Port dues including container handling charge	8,822 (20.0%)	8,822 (13.0%)
Grand total	44,086 (100%)	67,624 (100%)

d) Effect of fuel costs

Shipping unit costs of the NSR-SCR-combined shipping by the ice-class 4,000 TEU-ship are computed 856 (USD/TEU), 1,211 (USD/TEU) and 1,464 (USD/TEU) respectively when assuming fuel costs of 300 (USD/ton), 650 (USD/ton) and 900 (USD/ton), which become competitive against the SCR shipping by the medium-size container ship (4,000 TEU) and the large container ship (6,000 TEU-8,000 TEU) respectively.

Table 4.13 Shipping unit cost by ship-size with fuel prices of 300USD/ton, 650USD/ton and 900USD/ton

(Unit: USD/TEU)

Ship-size/ NSR service-period	4,000 TEU NSR 105days SCR 260days	4,000 TEU NSR 0 day SCR 365days	6,000 TEU NSR 0 day SCR 365days	8,000 TEU NSR 0 day SCR 365days	15,000 TEU NSR 0 day SCR 365days
Annual container throughput	36,400 (TEU/year)	33,600 (TEU/year)	50,400 (TEU/year)	67,200 (TEU/year)	126,000 (TEU/year)
Annual voyages	NSR: 5 SCR: 8	SCR: 12	SCR: 12	SCR: 12	SCR: 12
Fuel cost: 300USD/ton	856 (USD/TEU)	945 (USD/TEU)	930 (USD/TEU)	862 (USD/TEU)	726 (USD/TEU)
Fuel cost: 650USD/ton	1,211 (USD/TEU)	1,355 (USD/TEU)	1,320 (USD/TEU)	1,211 (USD/TEU)	944 (USD/TEU)
Fuel cost: 900USD/ton	1,464 (USD/TEU)	1,648 (USD/TEU)	1,598 (USD/TEU)	1,459 (USD/TEU)	1,110 (USD/TEU)

However, computed shipping unit costs of 726 (USD/TEU), 944 (USD/TEU) and 1,110 (USD/TEU) for the SCR shipping by the ultra-large container ship (15,000TEU) when assuming fuel costs of 300 (USD/ton), 650 (USD/ton) and 900 (USD/ton) are far more competitive than the NSR-SCR-combined shipping (865 (USD/ton), 1,211 (USD/ton) and 1,464 (USD/ton)) by the ice-class 4,000 TEU-ship.

4.4.4. Comparison of annual container shipment capacity

The NSR-SCR-combined shipping enables 13 to 15 voyages per year depending on the NSR service-period (105days-225days), while the number of annual voyages is 12 for the SCR shipping, achieving annual container shipment of 33,600 (TEU/year) by the 4,000 TEU-ship. As the number of annual voyages increases, the NSR-SCR-combined shipping by the 4,000 TEU-ship may achieve annual container shipment of 36,400 (TEU/year) [108.3%], 39,200 (TEU/year) [116.7%] and 42,000 (TEU/year) [125.0%] respectively for the annual voyages of 13, 14 and 15.

Additional annual shipment of 25% may seem attractive enough to the operators and/or ship-owners from the financial viewpoint. Since the large container ships of 6,000 TEU and 8,000 TEU, and the ultra-large container ship of 15,000 TEU for the SCR shipping may achieve 50,400 (TEU/year), 67,200 (TEU/year) and 126,000 (TEU/year) respectively, however, the ice-class 4,000TEU-ship may become less competitive than the large and ultra-large container ship from the viewpoint of the annual container shipment.

4.4.5. Comparison of container transport time

Transport time via the NSR is estimated 19.3 days, 35.4% faster than that (30.4 days) via the SCR, while the NSR service-period is limited to the period of 105 days to 225 days for the time being. In fact, the reduced transport time by the NSR-SCR-combined shipping is a significant advantage against the SCR shipping especially for the highly valuable cargoes.

4.4.6. Comparison of reduction effect of CO^2 emission

Reduction effect of CO^2 emission due to reduced sailing distance via the NSR is computed within a range of 13% and 35% for the NSR service-period of 105 days to 225 days (see table 11). This may attract the operators and/or ship-owners from the greener shipping viewpoint rather than the financial viewpoint.

Table 4.14 Unit CO^2 emission per TEU by ship-size and NSR service-period

(Unit: CO2 ton/TEU)

<table>
<tr><th>Ship-size/
NSR service-period</th><th>4,000 TEU
NSR 105days
SCR 260days</th><th>4,000 TEU
NSR 0 day
SCR 365days</th><th>6,000 TEU
NSR 0 day
SCR 365days</th><th>8,000 TEU
NSR 0 day
SCR 365days</th><th>15,000 TEU
NSR 0 day
SCR 365days</th></tr>
<tr><td>NSR 105days
SCR 260days</td><td>1.023
(ton/TEU)</td><td rowspan="5">1.182
(ton/TEU)</td><td rowspan="5">0.733
(ton/TEU)</td><td rowspan="5">0.656
(ton/TEU)</td><td rowspan="5">0.412
(ton/TEU)</td></tr>
<tr><td>NSR 135days
SCR 230days</td><td>0.992
(ton/TEU)</td></tr>
<tr><td>NSR 165days
SCR 200days</td><td>0.889
(ton/TEU)</td></tr>
<tr><td>NSR 195days
SCR 170days</td><td>0.868
(ton/TEU)</td></tr>
<tr><td>NSR 225days
SCR 140days</td><td>0.772
(ton/TEU)</td></tr>
</table>

4.5. Concluding summary

The Northern Sea Route (NSR) shipping has recently gained a momentum for maritime trade between East Asia and Northwest Europe, taking the direct effect of reduced sailing distance of approximately 40% compared to the SCR into account, as the Arctic sea-ice retreats due to the global warming. Particularly in 2012, the NSR shipping marked record-high volume of 1.26 million tons for the last ten years, by accumulating 46 voyages of natural resource shipping (e.g. gas condensate, LNG and iron ore). Accordingly, many related studies have been accomplished concerning comparative analysis of estimated shipping cost via the NSR and the alternative conventional routes.

Since the assumption of the cost estimation varies among the studies, however, there remain some difficulties when comparing the estimated shipping costs in the studies. This study aims at establishing the common platform of a wide range of cost estimation assumptions through clarifying and analysing cost components referring to the literatures as well as the most recent interviews of the NSR shipping professionals. Empirical analysis was accomplished and revealed container shipping cost between East Asia and Northwest Europe.

Based on the scenario by the ice-class 4,000 TEU-ship assuming the NSR service-period of 105 days and fuel cost of 650 (USD/ton) as a base scenario, the NSR-SCR-combined shipping cost was computed 1,211 (USD/TEU), which may show significantly competitive against the SCR shipping (1,355 (USD/TEU), 1,320 (USD/TEU) and 1,211 (USD/TEU) respectively by the 4,000 TEU, the 6,000 TEU and the 8,000 TEU ordinary container ships). Being understood naturally, the longer the NSR service-period is assumed, the lower the shipping unit costs are expected. However, a special attention should be drawn to the recent trends that container ships operated via the SCR between East Asia and Northwest Europe have been shifting to the large (6,000 TEU - 8,000 TEU) and/or ultra-large (15,000 TEU) ships rapidly, which significantly affects the competitive advantages of the NSR-SCR-combined shipping by the ice-class 4,000 TEU-ship.

As the number of annual voyages increases, the NSR-SCR-combined shipping by the 4,000 TEU-ship may achieve annual container shipment of 36,400 (TEU/year) [108.3%], 39,200 (TEU/year) [116.7%] and 42,000 (TEU/year) [125.0%] respectively for the annual voyages of 13, 14 and 15. Additional annual shipment of 25%, compared to the annual shipment of 33,600 TEU by the SCR shipping (12 voyages), may seem attractive enough to the operators and/or ship-owners from the financial viewpoint.

Transport time via the NSR is estimated 19.3 days, 35.4% faster than that (30.4 days) via the SCR, of which reduced transport time is a significant advantage against the SCR shipping especially for the highly valuable cargoes.

Reduction effect of CO^2 emission due to reduced sailing distance via the NSR is computed within a range of 13% and 35%. This may attract the operators and/or ship-owners from the greener shipping viewpoint rather than the financial viewpoint.

Cost analysis of the NSR-SCR-combined shipping for the various scenarios may provide valuable insights to the researcher as well as practitioners. Similar studies are quite challenging and valuable on especially LNG, iron ore and vehicle transport. Based on the common platform provided by this research, a large number of the related researches are recommended to be accumulated.

5. Future Challenges

5.1. Maritime Transport

5.1.1 Emerging competitiveness of NSR shipping

NSR fee may change due to the market transactions reflecting a balance of demand and supply, while the official NSR fee tariff was established by the Russian Government. Reported by the operator of NSR commercial shipping in recent years, actual NSR fee transaction revealed 5.0 (USD/GT) (Falck, H. (2012)). Consequently, NSR-SCR-combined shipping was evaluated realistically feasible compared to the existing conventional route (SCR), if ice-class 4,000TEU-ships are available with the NSR fee level of 5.0 (USD/GT), as reported in Chapter 4.

5.1.2 Flexible port call patterns

As G6 alliance has emerged recently, container vessels of major alliances may seasonally change their port call patterns, taking seasonally fluctuating container demand among ports. A NSR-SCR-combined shipping scenario of NSR for summer time and SCR for the rest of the year, which are revealed in Chapter 4, may become realistic, because some ports had already experienced such seasonally flexible port calls. Both container shipping companies and customers may maximize their benefits by introducing seasonally flexible port call patterns, when NSR shipping becomes economically and technically available. Accordingly, port authorities need to deeply understand such trends of ship operators.

5.1.3 Availability of large-size ice-class container vessels for NSR shipping

Ice-class container vessels of ICE 1B or lower are under operation in some seasonally ice-covered waters, e.g. the Baltic Sea. Container vessels of ICE 1A or higher are under operation in the waters of more severe ice condition. For example, the OTTAWA EXPRESS (DNV ICE 1A, 2,808TEU) has been navigating in the ice-covered waters such as the Saint-Lawrence River. Smaller size container vessels of ICE 1A are also under operation in Russian Arctic waters. Taking the huge potential demand of NSR container shipping into account, more and more larger-size (4,000 TEU) container vessels of ICE 1A or higher are expected to be in services as indicated in Chapter 4.

5.1.4 Quality of NSR container shipping

Taking container shipping potential demand through the Arctic Ocean into account, which has not experienced NSR shipping before, shipping quality of NSR container transport needs to be carefully examined. For example, extreme low temperature, dew drop and vibration caused by icebreaking may cause some damages to precision parts, electronic devices and other sensitive instruments.

However, the Arctic Ocean is in fact warmer than the Arctic land area where Trans-Siberian Railway (TSR) has been long in service because of the huge heat capacity of ocean. Air temperature in summer time is also mild so that it cannot cause any problems to sensitive cargoes. In the general way of icebreaker-escorted navigation in NSR, cargo vessel may not be affected by the sea ice because open waterway is secured by icebreakers. According to the interviews to the Russian experts, the vibration is very small in the usual NSR navigation in summer time. In this regard, trial NSR shipping to gather technical information may be beneficial to persuade the potential customers.

5.1.5 Potential cargo for NSR shipping

Extended summer ice retreat in the Arctic Ocean may enable vessels of lower ice-class to enter NSR, while all the vessels transiting the NSR should have higher ice-class than IA in the past. For the past two years of commercial NSR transit voyage achieved between 2011 and 2012, two third of transit cargoes were gas condensate, and the rest were iron ore, fuels and frozen fish. According to the interviews to the experts of the NSR shipping, shipped volume of gas condensate would diminish and be replaced by LNG to be produced from the Russian Arctic coast in 2016. The produced LNG is highly expected to be transport to the Asian market. Similarly, the Snohvit LNG, which is the current world northernmost LNG production field, is expected for the Asian market as well. Since we have experienced so far only one voyage of LNG transport through the Arctic, however, the LNG transport through the Arctic Ocean remains a challenging task so that more and more information and experience should be accumulated.

5.2. Port Facilities

5.2.1 Berthing facilities, channels and basins

Since ice-strengthened vessel is designed almost the same body shape of the ordinary vessel, neither special berthing facilities nor special considerations for in-harbor navigation are necessary. Consequently, in principle, many ice-class vessels under operation in the Baltic Sea are able to call at the Baltic Sea ports and North European ports without any special loading/unloading facilities.

5.2.2 Fuel supply facilities

Taking the recent regulations on emissions from the ocean-going and berthing-at-port vessels into account, LNG-fueled vessels have been recently drawing a significant attention of port and maritime industry. Consequently, ports are expected to install LNG bunkering facilities especially when receiving NSR shipping vessels as indicated in 5.3.1. LNG trading ports may take competitive advantages, when NSR shipping by LNG-fueled vessels gets more and more popular.

5.3. NSR navigation

5.3.1 Emission issues for NSR shipping

In 2011, IMO adopted a new chapter 9 on "Special requirements for the use or carriage of oils in the Antarctic area" to MARPOL Convention, which prohibits using lower grade fuels[33]. Some scientists pointed out that some kinds of regulations would be needed in the future to restrict the use of heavy fuel oil, otherwise sensitive Arctic Ocean environment could not be protected from the impacts associated with spilled heavy oils from ship accidents. The Arctic ports might be required to supply such high-quality fuel oils with the vessels which originated to and destined to them.

MARPOL Convention sets limits on NOx and SOx emissions from the ships in its Annex VI. Accordingly, ship-owners could have three countermeasures, 1) to change low sulphur fuel, 2) to install an exhaust gas scrubber, or 3) to install LNG fuel-engine. Consequently, LNG-fueled vessels, which have been recently drawing a significant attention of port and maritime industry, would require ports to install LNG bunkering facilities. LNG trading ports may take competitive advantages, when NSR shipping by LNG-fueled vessels gets more and more popular.

5.3.2 Icing of the Vessels

Icing of the vessels in fact occurs in the seasonally ice-covered waters such as in the Baltic Sea and the White Sea. In some cases, rise in temperature intensifies icing of the vessels in the Arctic Ocean. Once icing of the vessels occurs, stability of the vessel could be badly diminished. Thus, de-icing equipment and weather forecast considering icing would be of importance.

[33] Fuels at a density of higher than 900 kg/m^3 at 15°C or a kinematic viscosity of higher than 180 mm^2/s at 50°C are banned.

References

Arpiainen, M. and Killi, R., 2006, Arctic shuttle container link from Alaska US and Europe, AARC K-63, Aker Arctic Technology Inc.

Falck, H., 2012, Shipping in Arctic Waters -The Northern Sea Route-, Mariehamn (April 26th. 2012).

Furuichi, M. and Otsuka, N., 2012, Effects of the Arctic Sea Routes (NSR and NWP) Navigability on Port Industry, May, 21, Jerusalem, Israel, Presentation at Port Planning and Development Committee, International Association of Ports and Harbors (IAPH).

Hino, M., 2011, Progress of maritime shipping industry and current situation, Financial Department of Ehime Bank (in Japanese).

IMO, 2009, Second IMO GHG Study 2009.

Isakov, N. A., et al, 1999, The NSR Simulation Study Package 3: Potential Cargo Flow Analysis and Economic Evaluation for the Simulation Study (Russian Part), INSROP Working Paper No. 139.

Japan Ship-owners Association (JSA), 2012, Shipping Fact 2012 (in Japanese), Date of access: 21/12/2012, http://www.jsanet.or.jp/data/pdf/data1_2012b.pdf.

Liu, M. and Kronbak, J., 2010, The potential economic viability of using the Northern Sea Route (NSR) as an alternative route between Asia and Europe, Journal of Transport Geography, No.18, pp.434-444.

Maritime Press Japan, 2012, “Transactions of newly built merchant fleet in 2012 (1)”, (in Japanese), (December 10, 2012).

Maritime Press Japan, 2012, “Transactions of newly built merchant fleet in 2012 (2)”, (in Japanese), (December 11, 2012).

MOL, 2012, http://www.moljapan.co.jp/service/ex_charge/eur.shtml (Date of access: 21/12/2012).

Omre A., 2012, An economic transport system of the next generation integrating the northern and southern passage, Master Thesis, Norwegian University of Science and Technology.

Panama Canal Authority, 2012, http://www.pancanal.com/eng/maritime/tolls.html (Date of access: 21/12/2012).

Ragner, C. L., 2000, Northern Sea Route Cargo Flows and Infrastructure - Present State and Future Potential, FNI Report 13, Fridtjof Nansen Institute.

Schoyen, H. and Brathen, S., 2011, The Northern Sea Route versus the Suez Canal: cases from bulk shipping, Journal of Transport Geography, No. 19, pp.977-983.

Ship & Ocean Foundation [SOF], 2000, The Northern Sea Route -The Shortest sea route linking East Asia and Europe.

Suez Canal Authority, 2012, http://www.suezcanal.gov.eg/TollCirculars.aspx (Date of access: 21/12/2012)

UNCTAD, 2011, Review of Maritime Transport 2011.

Verny, J., and Grigentin, C., 2009, Container shipping on the Northern Sea Route, International Journal of Production Economics, No.122, pp. 107-117.

Yakovlev, A., et al, 1999, The NSR Simulation Study Package 7: Legal and Environmental Evaluation of the Routes Selected for the INSROP Simulation Study, INSROP Working Paper No. 128.