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STUDY ON FEASIBILITY OF THE NORTHERN SEA ROUTE FROM RECENT VOYAGES

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ABSTRACT
This paper presents the results of an investigation on the feasibility of shipping via the Northern Sea Route (NSR). Recent commercial voyage records in the NSR show that the shipping season starts in late June and continues through late November. Although sea ice concentration varies spatially and temporally, average ship speed transiting the route is relatively constant at about 10 knots through the season in recent year's voyages, except for the very beginning of the season. Shipping costs were evaluated for three types of cargoes of iron ore, LNG and frozen fish. Data from recent NSR shipping of these cargoes were included in the cost evaluation. Russian regulations were considered in calculating icebreaker escort fee. Shipping costs via conventional shipping route such as the Suez Canal route were also evaluated for comparison.

INTRODUCTION
The Northern Sea Route (herein after referred to as "NSR") is known as the shortest sea route between Northern Europe and East Asia along the Arctic coast of Russia. Through the NSR, the distance can be shortened by about 30% compared to the Suez Canal route. Due to the recent sea ice retreat in the Arctic, NSR transit commercial voyages are increasing year by year. Shipped cargoes are mainly natural resources from Russian Arctic to China. In 2012, 46 voyages were carried out including the first LNG shipping from Snohvit in Norway to Tobata in Japan. Gradually, type of cargo, and departure and destination ports are diversified. Against the background above, it would be noteworthy to consider the feasibility of NSR shipping between Europe and East Asia under the recent actual conditions.
The International Northern Sea Route Programme INSROP was the first-ever full scale study project on the NSR. The project covered wide areas of shipping, ship building, international laws, social and political system, and arctic environment. Ship and Ocean Foundation sponsored the INSROP and related domestic project JANSROP(SOF, 2000). And both projects provided 167 study papers namely INSROP Working Papers. For example, Isakov et al. (1999) studied on economic feasibility of NSR commercial shipping of the natural resources produced in the Arctic.
Arpiainen et al. (2006) studied ice class container ship design and feasibility of the NSR container transport between Europe and Alaska. Schoyen and Brathen (2011) examined economic feasibility of nitrogen fertilizer and iron ore shipping from the Arctic to the East Asia. Omre (2012) examined technical and economic feasibility of container shipping between Yokohama and Rotterdam via the NSR. Erikstad and Ehlers(2012) studied cost saving for different ice class vessels to transit the NSR taking into account for uncertain parameters such as length of navigable season which depends on the ice conditions, round trip times, additional expenditures and fuel price. These studies indicate some advantages and uncertainties related to the NSR. This paper aims to investigate whether the NSR shipping

cost saving based upon shortened distance and time could overtake cost increase caused by harsh ice condition, vessel cost, icebreaker support fee and others.

RECENT NSR ACTIVITIES

In 2010, four transit voyages were conducted through the NSR and 111,000 tons of cargoes consisted of 70,000 tons of gas condensate from Murmansk (Russia) and 41,000 tons of iron ore from Kirkenes (Norway) were shipped to China.

In 2011, 34 transit voyages were conducted and 820 thousand tons of cargos were shipped to and from Asian countries such as China, Korea and Thailand. 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 NSR. In August, the first ever Suez-max tanker, “Vladimir Tikhonov” sailed the Northern Sea Route in only 7.5 days(14.4kn) 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. According to the news release, the ice conditions during her passage were significantly milder than its first voyage in the same year.

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

Table 1 shows the volume and types of the NSR transit cargoes from 2010 to 2012. The table summarizes data obtained from a Russian company ROSATOMFLOT who is in charge of nuclear icebreaker operation. Figure 1 shows origin and destination of NSR transit commercial voyages from 2009 to 2012 and type of cargoes (Otsuka et al., 2013). Dominant cargo is gas condensate, which is loaded at Murmansk and mainly shipped to China and Korea. Iron ore makes up the second largest cargo which is also shipped to China. These natural resources are mainly shipped eastbound standing on expanding Asian demands. On the contrary, westbound shipping is mainly ballast voyage or repositioning. Up to now, westbound cargoes were jet fuel shipped from Korea to Europe, frozen fish from Kamchatka to western Russia and coal from Alaska to Germany.

All ships that transited NSR from 2010 had ice class of IA equivalent or higher. They were escorted by Russian nuclear ice breakers except for the two voyages in 2012 by DASs (double-acting ships) of Norilsk Nickel’s with ice class Arc-7.

Table 1. Shipped Cargoes from 2010 to 21012

Cargo Type	2010	2011	2012
Number of Voyage	(4)	(34)	(46)
Liquid Bulk ton	70,000	604,652(9)	894,079(26)
Iron Ore ton	41,000	110,339(4)	359,201(6)
Frozen Fish ton		24,673(4)	8,265(1)
Ballast/ Repositioning			(6)/ (7)
Total ton	111,000	820,789	1,261,545

Source: Prepared by authors based on the data from the ROSATOMFLOT, 2012.

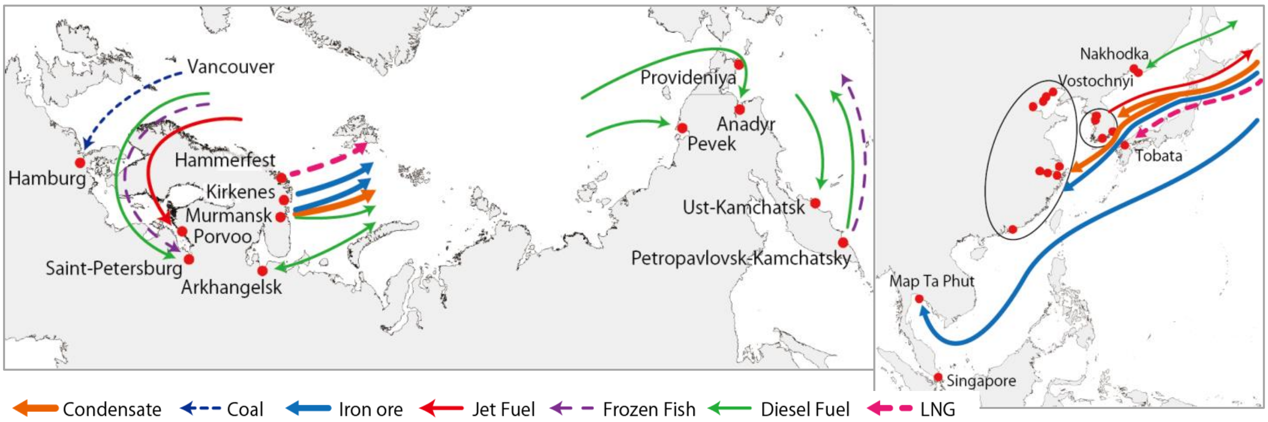

Figure 1. Origin and destination of the NSR voyage from 2009 to 2012 (Otsuka et al., 2013)

SAILING CONDITION OF THE NSR

In general, at the beginning of the summer navigation season, sea ice still remains in the NSR route requiring longer days for ships to transit through the NSR. However, in September, according to the satellite data and reports from ships, there is little ice left in the NSR even in the East Siberian Sea. Figure 2 shows seven days average sea ice concentration along the route from 2006 to 2011 (Otsuka et al., 2013). The sea ice concentration data were retrieved from L3-product of Aqua/AMSR-E (JAXA-a, 2013). Sea ice concentration of NSR is high in the areas from 90E to 105E (eastern part of the Kara Sea to the 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 the Virkitskiy Strait in late September.

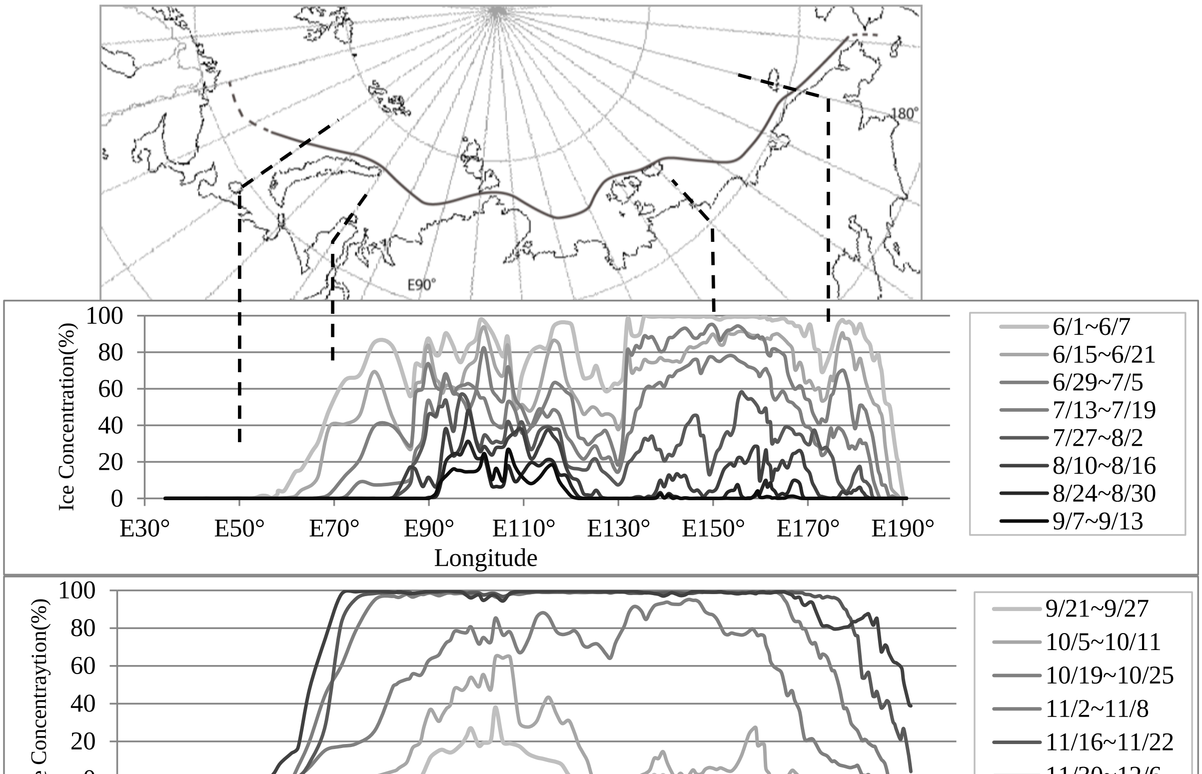

Figure 2. Seven days average sea ice concentration along the NSR, 2009-2011 (Otsuka et al., 2013)

Table 2. Average 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	

Table 2 shows the monthly average sailing speed calculated from the NSR transit voyage records of 2011 and 2012. Except for June, the average sailing speed was about 10 to 11 knot and it took about 8 to 12 days to sail through the NSR.

Late November in 2012, the first LNG NSR shipping was carried out by ice class LNG tanker "Ob' River". Figure 3 shows the ice coverage on November 15th in 2012 (JAXA-b, 2013). Ob' River's track is superimposed on the map. It is reported that the most of the ship's track was covered by sea ice of about 0.4m thick and she sailed through the NSR in 9.5 days at an average sailing speed of about 12 knots. In this voyage, navigation speed of LNG carrier under two icebreakers assistance strongly depends on that of icebreakers to cut an open channel in ice ahead. These case examples indicate that under icebreaker assistance ahead of the cargo vessel in the recent summer and fall condition, the sea ice condition would not affect the sailing speed.

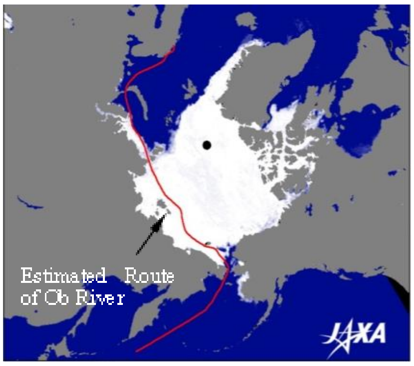

Figure 3. Sea ice concentration in mid-November 2012

SHIPPING COST ESTIMATION MODEL

Based on the actual NSR shipping cases of iron ore, LNG and frozen fish, shipping cost was examined. Following elements are taking into account; depreciation cost, NSR fee and NSR pilot fee, Suez Canal fee and Panama canal fee, crew cost, maintenance cost(supply cost for ship, lubricant cost, dry docking cost, maintenance and spare parts cost), insurance cost(H&M insurance, P&I insurance), fuel & oil cost and port dues.

Study Cases

At present, gas condensate accounts for the largest volume in the NSR transit cargoes. However, the gas condensate production base in Vitino (located in the north western end of the White Sea) is going to be moved to the Baltic Sea coast and cargo volume of it is considered to decrease in the future. In contrast, Russia is making strong effort for LNG exploitation in the Arctic such as the Yamal Peninsula and Shtokman field. It is expected that LNG would be a dominant cargo of the NSR in the near future. In this study, LNG shipping which carried out in 2012 from Hammerfest to Tobata is analysed together with the comparative shipping route using the Suez Canal.

Iron ore accounts for the second largest volume in the NSR transit cargoes. Most of the iron ore shipped via the NSR is loaded in Murmansk and transported to ports in the northeast China such as Rizhao. Thus, the NSR shipping route for cost analysis is set from Murmansk

to Rizhao. However, although it possesses a large potentiality, iron ore production in the Russian Arctic is still minor in the world iron mining today. Therefore, present iron ore importing route to the East Asia is considered to be compared with the NSR. Australia and Brazil are two major iron ore exporters in the world. In this study, iron ore shipping from Itaqui (Brazil) through the Panama Canal is evaluated as a comparative shipping case.
Frozen fish is also a transit cargo of the NSR which is shipped from Petropavlovsk-Kamchatsky to Saint-Petersburg. In the analysis, we take Tomakomai (Japan) as the loading port. This is to examine possibility of Asian ports to connect to European ports in terms of fishery products trade.
Figure 4 shows the case study routes. Table 3 summarises the list of cargo vessels that shipped iron ore, LNG and frozen fish via the NSR from 2010 to 2012. In the cost estimation of the NSR, sailing season is assumed from June 15th and ends on November 30th in all cargo cases. And the summer sailing speed is applied for each cases.

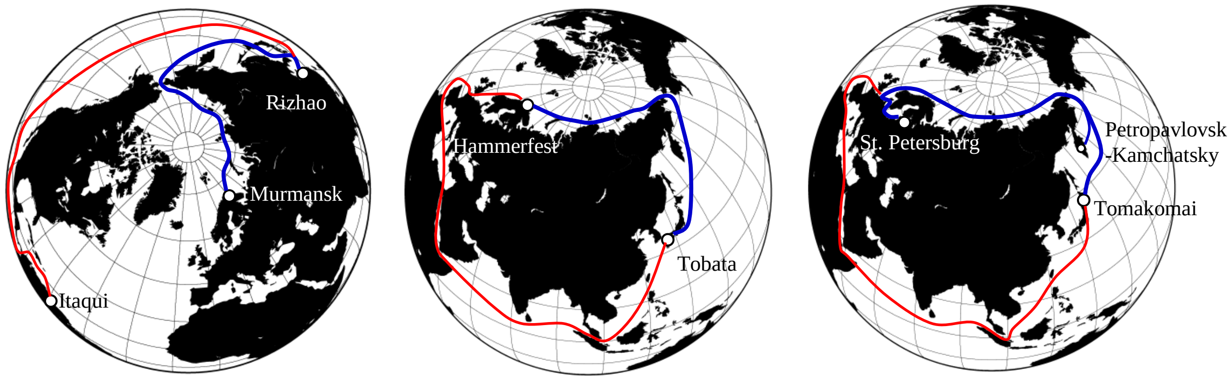

Figure 4. Iron ore, LNG and frozen fish shipping route via NSR

Table 3. Cargo vessels transited NSR in 2010-2012

Ship Name	Flag	Built year	Ice class		GT(t)	DWT(t)
Bulk carrier (iron ore)						
NORDIC ODYSSEY	Panama	2010	DNV	ICE-1A	40,142	75,603
NORDIC BARENTS	Hong Kong	1995	GL	Ice Class IA	27,078	43,732
NORDIC ORION	Panama	2011	DNV	ICE-1A	40,142	75,603
Refrigerated cargo ship (frozen fish)						
KOMMUNARY NIKOLAYEVA	Russia	1989	RS	L1	6,998	7,912
KAPITAN PRYAKHA	Russia	1990	RS	L1	6,998	7,912
RAINFROST	Panama	1985	RS	L1	12,383	13,536
BEREG NADEZHDY	Russia	1982	RS	L1	12,717	13,879
SKYFROST	Panama	1985	BV	Ice Class IA	12,383	9360
LNG Carrier						
OB RIVER	Marshall Islands	2007	BV	Ice Class IA	100,244	84,682

Depreciation cost of vessel

Generally, the depreciation cost of a vessel could be calculated by two methods of the straight-line depreciation and declining balance. Of the two, the straight-line method is used by many vessel owners because of its simplicity. The economic lifetime for depreciation differs by country. For example, it is 8 years in France, 10 years in Germany and 15 years in Japan. In this paper, the depreciation cost of vessel is calculated by the straight-line method with 10 years of the economic lifetime. The yearly depreciation is set to 10.0% of the capital based on building price of the new ship.
New building price of vessel is strongly influenced by market pressures based on the demand of vessel supply and maritime transport. New building price is volatile and fluctuates in short periods. New building prices of various types of vessels from 2003-2010 are reported by RMT2011 (UNCTAD, 2013). Also, the Maritime Press Japan reported actual transactions in

2012 (Maritime Press Japan, 2012). Figure 5 shows these new building prices of dry bulker. Based on the RMT2011, new building price of LNG carrier from 2006 to 2010 varies from 208 to 237 million USD with an average of 222 million USD. New building price of a refrigerator ship is assumed to be higher than a bulker by 30%.

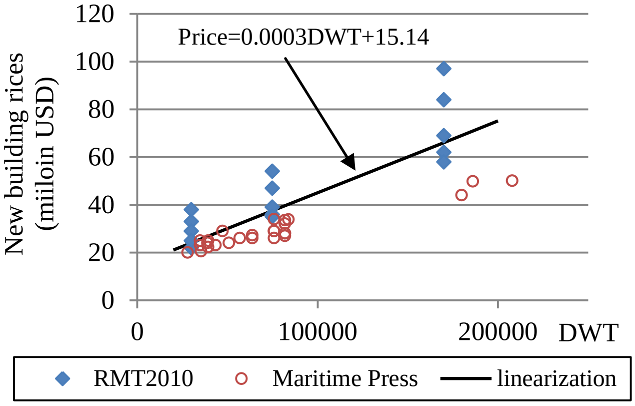

Figure 5. New building price of dry bulker

Table 4. Ice class vessel price

Type	Normal class new building price (million USD)	Ice class premium
Dry bulker ~76,000DWT	0.0003DWT+15.14	1.1
LNG carrier 160,000m^3	222.0	1.1
Refrigerated cargo ship (7,000~ 14,000DWT)	1.3* (0.0003DWT+15.14)	1.1

The present analysis assumed ships of ice class IA to be used for NSR shipping. Ice-classed ships require extra construction cost for additional ice-strengthening. It was assumed in the analysis that new building price for the three ships are all higher by 10% than those of ordinary non ice-strengthened ships of the same type.

For the bulk carrier, construction cost was calculated based on price-DWT relationship from the Figure 5. Thus, the new building price of each vessel is calculated by Table 4.

Tariffs navigating in the NSR

The authors surveyed tariffs for recent NSR shipping. In the case of LNG carrier Ob' River, a fee of 5.0 USD per displacement tonnage was charged for icebreaker escort. For general bulk cargoes, a fee of 5.0 USD/GT is applied except for metals and marine products for which higher rates are set. It was found that NSR tariffs in general are set to be equivalent to or lower than those for the Suez Canal. These tariff settings would be followed under the new NSR law that came into force in January 2013. Based on survey results, icebreaker escort fees for iron ore and frozen fish in this analysis were set to 5.0 USD/GT and 7.5 USD/GT respectively.

Under the Russian NSR law, captain of the vessel to navigate in the NSR is required to have certain time period of navigation experience. If the captain lacks this experience, the vessel must have an ice pilot on board while navigating in the NSR area. The NSR pilot fee is determined in accordance with the Russian legislation based on vessel size, ice class, pilotage distance and the navigation period. In the former NSR law, ice pilot fee was 336USD/day for 12 hours operation and 672USD/day was needed for 24 hour navigation between Kara Gate and Bering straits (Yakovlev et al., 1999).

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

Crew cost

Generally, crew size of a dry bulker, full container ship and PCC is practically 23-25 crews per ship, regardless of ship size. According to the Japan Ship-owners Association (2012), an average annual crew cost is estimated approximately 1.0 million USD/ship/year, with non-

Japanese crews. On the other hand, crew size of a LNG ship is approximately twice as large as the above ships.

Maintenance cost
Maintenance cost includes supply cost, lubricant cost, dry docking cost, and maintenance and spare parts cost. According to an example of annual balance of 55,000DWT bulker owner, which was reported by Hino, the maintenance cost was accounted for 383 thousand USD/year (Hino, 2011). In this study, applying this example to proportional to the new building price, the maintenance cost is set to 1.095%/year of new building price for all types of vessel in this cost estimation.

Insurance cost
In general, insurance cost for vessel is not easy to estimate because actual transaction information is not usually disclosed in the market. In this study, we used a value reported by Hino of 120 thousand USD/year including both P&I and H&M (Hino, 2011). In this study, applying this example to proportional to the new building price, the maintenance cost is set to 0.343%/year for all types of vessel in this cost estimation.

Fuel cost
Fuel consumption is estimated by total used energy which is calculated by operational time including sailing time and break time. Fuel consumption ratio is assumed to be 185gr/KW/h. Here, the fuel consumption is compensated inverse proportion to the ratio between actual sailing speed and nominal sailing speed when sailing at a slower speed in the NSR. The fuel price is assumed to be 650USD/ton based on the recent price of Singapore bunker market.

Port dues
Port dues generally consist of port entry due, berthing due and line-handling charge. In this study, 0.092 USD/GT/call for port entry due and berthing due respectively, and 0.244 USD/GT/call for line-handling charge, are accounted. Thus, total port dues are estimated 0.428 USD/GT/call for each port call. In the shipping cost estimation, port dues are accounted only for both ends of the voyage.

SHIPPING COST ESTIMATION

Iron ore shipping cost
Distance between Murmansk and Rizao is 6,566 NM, while it is 12,956 NM between Itaqui and Rizao. The Arctic route is shorter than the Panama route by about 49%. In the actual iron ore shipping via the NSR, 76,000DWT class panamax bulkers with ice class IA are used. In this study model, panamax bulker of 75,000DWT(40,537GT), which is loading 90% of its capacity as 67,500ton of iron ore, is used for both the Panama route and the Arctic route. The ship sails at a constant cruise speed of 15 knots in open water, while it varies in the NSR. Table 5 summarizes ship speed and sailing season in the cost estimation obtained from recent voyage records. Ship speed varies with area and season. The present analysis was made for the “summer” condition. A voyage via the NSR takes 470 hours (19.6 days), while it is 888 hours (41 days) via the Panama Canal. Other parameters required for the analysis were set as follows; capacity occupancy is 0.9, fuel consumption rate in the loading and unloading at port is 0.1 % of that at sea, and oil consumption rate is 1.0% of that of fuel.
Table 6 shows estimated costs for iron ore shipping. In the shipping via the NSR, fuel and icebreaker/ice pilot fee account for about 48 % and 20 % of the total cost respectively, while fuel takes up about 61% in the Panama shipping. Total cost per a voyage is lower for the NSR than the Panama by about 466 thousand USD.

Table 5. Seasonal sailing speed in the NSR for iron ore bulker

Route	Distance (NM)	Spring 6/15-7/15	**Summer 7/16-10/15**	Autumn 10/16-11/15	Winter 11/16~11/30
Murmansk-Nobaya Zemrya	782	15	**15**	15	15
Nobaya Zemrya-Vilkitsky	489	6	**12**	12	6
Vilkitsky-Dmitri Laptev	592	6	**12**	11	6
Dmitri Laptev-Long	861	6	**12**	12	10
Long-Bering	350	6	**15**	13	10
NSR Total/Average	3,074	8.3	13.1	12.7	9.9

Table 6. Iron ore shipping cost estimation via the NSR and the Panama Canal

Item	Murmansk-NSR-Rizhao	Itaqui-Panama-Rizhao	Remarks
Total navigation hours	470	888	hours/voyage
Total loading/unloading time	156	168	hours/voyage
Engine power	12,000	10,000	kW
Fuel consumption	914	1,599	Ton
Total fuel cost (incl. oil)	**600(48%)**	**1,049(61%)**	*1,000USD/voyage
Icebreaker/ice pilot fee	210		*1,000USD/voyage
Panama Canal fee		29	*1,000USD/voyage
Port due	35	52	*1,000USD/voyage
Overhead expense	**249(20%)**	**81(5%)**	*1,000USD/voyage
Insurance	389	354	USD/day
Crew cost	2,740	2,740	USD/day
Maintenance cost	1,242	1,118	USD/day
Total voyage days	26	41	Day
Operational cost	**114(9%)**	**173(10%)**	*1,000USD/voyage
Depreciation cost	**296(24%)**	**423(25%)**	*1,000USD/voyage
Total cost	**1,259**	**1,725**	*1,000USD/voyage

LNG shipping cost

Cost estimation was made of the LNG shipping by Ob' River (100,244 GT and 147,500 m^3) in November, 2012. In this voyage, a 66,342 tonnes (134,739 m^3) of LNG was shipped. Cost estimation was also made of a shipping via the Suez Canal for comparison. Distances from Hammerfest to Tobata are 6,522 NM and 11,712 NM via the NSR and Suez Canal respectively. The NSR saves distance by about 44 %.

Table 7 summarizes estimated costs for the two routes. Icebreaker escort fee in the NSR is 331,710 USD (5.0 USD per a cargo tonne), while the Suez Canal tariff is 412,453 USD. Shorter distance and lower sailing speed via the NSR results in lower fuel cost. In total, the NSR saves 1,653 thousand USD per a voyage compared with the Suez Canal.

Table 7. LNG shipping cost estimation via the NSR and the Suez Canal

Item	Hammerfest-NSR-Tobata	Hammerfest-Suez-Tobata	Remarks
Total navigation hours	423	616	hours/year
Engine power	29,000	29,000	kW
Total fuel cost (incl. oil)	**1,032(31%)**	**2,170(44%)**	*1000USD/voyage
Suez Canal fee		412,453	USD/voyage
Ice breaker & ice pilot fee	478,206		USD/voyage
Overhead expense	**339(10%)**	**413(8%)**	*1000USD/voyage
Insurance	2,295	2,086	USD/day
Crew cost	5,479	5,479	USD/day
Maintenance cost	7,326	6,660	USD/day
Total voyage days	24	32	Day
Operational cost	**357(11%)**	**451(9%)**	*1000USD/voyage
Depreciation cost	**1,580(48%)**	**1,927(39%)**	*1000USD/voyage
Total cost	**3,307**	**4,960**	*1000USD/voyage

Frozen fish shipping cost

Cost estimation was made for a case of frozen fish shipping from Tomakomai, Japan to Saint Petersburg, Russia. Ship data of *Rainfrost* (12,383GT, 7,600kW, loading 7,000ton of cargoes, Table 3.) are used for the calculation. *Rainfrost* is a refrigerated cargo ship and shipped frozen fish from Petropavlovsk-Kamchatsky to Saint Petersburg in 2011. Costs via the NSR and Suez Canal were compared.

Distances are 7,847 NM and 12,993 NM via the NSR and Suez Canal respectively. The NSR saves distance by about 40 %. The sailing speed is set as 12.0 knots continuously for each voyage.

Table 8 shows the result of cost estimation. The NSR saves about 400 thousand USD of fuel per a voyage since fuel costs are 603 thousand USD and 999 thousand USD for the NSR and the Suez Canal respectively. To calculate the Suez Canal tariff, the General Cargo fee was applied and the tariff is accounted for 119,825 USD per a passage. For icebreaker fee in the NSR, a value of 7.5 USD/GT was assumed for a refrigerated cargo ship. This is higher than that for a bulker by 50 %. The fee is 92,873 USD. In total the NSR saves 578 thousand USD per a voyage.

Table 8. Frozen fish shipping cost estimation via the NSR and the Suez Canal

Item	Tomakomai-NSR-St .Petersburg	Tomakomai-Suez-St .Petersburg	Remarks
Total navigation hours	654	1,083	hours/year
Engine power	7,600	7,600	kW
Total fuel cost (incl. oil)	**603(56%)**	**999(60%)**	*1000USD/voyage
Suez Canal fee		119,825	USD/voyage
Ice breaker & ice pilot fee	100,253		USD/voyage
Port due	5.3	5.3	
Overhead expense	**106(10%)**	**125(8%)**	*1000USD/voyage
Insurance	258	235	USD/day
Crew cost	2,740	2,740	USD/day
Maintenance cost	824	749	USD/day
Total voyage days	33	51	Day
Operational cost	**127(12%)**	**190(11%)**	*1000USD/voyage
Depreciation cost	**250(23%)**	**350(21%)**	*1000USD/voyage
Total cost	**1,086**	**1,664**	*1000USD/voyage

CONCLUSION

Sailing speed of cargo ship in recent NSR transit voyages under icebreaker assistance is almost equal to that of icebreaker and is almost constant during the navigation season excluding early summer. Sea ice almost disappears from the route every year in late summer and it makes cargo ship to sail through the NSR at a speed of 14 knots. Furthermore, if this summer sea ice retreat continues, navigation condition might become calmer and it enables lower ice class ships to navigate into the NSR. The new Russian NSR law refers to the criterion for lower ice class ships that navigate the NSR.

Recent actual icebreaker assistance fee for bulker and LNG carrier accounted for 5.0USD/GT and 5.0USD/cargo-tonnage respectively, which is equivalent to or less than the Suez Canal fee in recent years. Based on the actual NSR shipping cases of iron ore, LNG and frozen fish, sipping cost are analysed. In the NSR shipping, shortened distance and sailing time reduce fuel cost, operational costs and overhead expenses. At the same time, icebreaker fee and ice pilot fee do not largely exceed Suez Canal fee so that the shortened distance could directly affect to the shipping cost reduction. Furthermore, the sailing speed in the NSR is slower than normal waters and it cuts down fuel consumption rate greatly.

In the INSROP studies, it was reported that icebreaker operation could be profitable only if one million ton of cargoes per icebreaker was handled at 5.0USD/cargo-ton (Yakovlev, 1999).

In this study, icebreaker fee was accounted for 3.0USD/ton(iron ore), 5.0USD/ton(LNG) and 13.3USD/ton(frozen fish). All of these cases are profitable for NSR users. On the contrary, under these conditions, icebreaker operator needs to increase NSR cargo flow, otherwise it might lose profitability.

The NSR shipping would be used gradually at first in bulk cargo shipping between Russian Arctic and East Asia. However, there still lays uncertainty such as; capability of icebreaker escort service since current nuclear icebreakers are all aged, whether icebreaker escort fee remains the same level in the future, if summer sea ice condition continues in the future, if maritime transport market would enjoy the NSR advantages, and limited number of ice-classed cargo ships.

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REFERENCES

Arpiainen, M., Kiili, R., Niini, M., 2006. Arctic Shuttle Container Link from Alaska, US to Europe, Aker Arctic Technology Inc. Report K-63

Erikstad, S.O. and Ehlers, S. 2012. Decision support framework for exploiting northern sea route transport opportunities, Ship Technology Research, Volume 59, Issue 2, pp. 34-42.

Hino, M., 2011. Progress of Maritime Shipping Industry and Current Situation, Financial Department of Ehime Bank (in Japanese), pp.14

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 Aerospace Exploration Agency (JAXA-a), 2013. The GCOM-W1 Data Providing Service, retrieved on Jan. 2013, https://gcom-w1.jaxa.jp/

Japan Aerospace Exploration Agency (JAXA-b), 2013. Earth Observation Research Center, Arctic Sea Ice Monitor, retrieved on Jan. 2013, http://www.ijis.iarc.uaf.edu/cgi-bin/seaice-monitor.cgi?lang=j

Japan Ship-owners Association (JSA), 2012, Shipping Fact 2012, (in Japanese)

Maritime Press Japan, 2012. Transactions of newly built merchant fleet in 2012, (in Japanese).

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.

Otsuka, N., Izumiyama, K. Furuichi, M and Kobayashi, W., 2013. Study on Feasibility of Northern Sea Route Shipping, International Symposium on Okhotsk Sea & Sea Ice

SOF(Ship and Ocean Foundation), 2000. The Northern Sea Route, the shortest sea route linking East Asia and Europe

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.

UNCTAD(United Nations Conference on Trade and Development), 2013. Review of Maritime Transport, Table 3.1, pp.64

Yakovlev, A., Semanov, G., Ivanov, Y., Ushakov, A., Zubarev, S., Gavrilo, M., Khlebovitch, V., Moe, K.A., Thomassen, J. and Brude O.W., 1999. Legal and Environmental Evaluation of the Routes Selected for the INSROP Simulation Study, INSROP Working Paper No.128, pp.15