doi: 10.3724/SP.J.1085.2013.00158
September 2013 Vol. 24 No. 3: 158-166

Scale and scope of maritime cargoes through the Arctic Passages

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Received 22 February 2013；accepted 30 June 2013

Abstract This paper investigates the sources of goods being shipped through the Arctic passages, and trade generated in the Arctic, including oil and gas exploitation. Furthermore, it assesses the present situation for maritime cargo shipped from the Far East to Northwestern Europe and North America. Two main types of cargo are predicted to pass through the Arctic passages in the future. First, about 10 million t of liquefied natural gas will be delivered from Russia and the Nordic Arctic to the Far East by 2030. Second, there will be two-way trade flow of containerized cargo from the Far East to Europe and the United States through the Northeast, Central and Northwest Passages. This will relieve pressure on present routes from the Far East to Northwestern Europe and North America. If Arctic navigation is technically possible in all seasons and shipping costs fall to those of ordinary ships, then assuming an equal share of shipping volume with the traditional canal routes, the maximum container freight passing through the Arctic passages by 2030 will be approximately 17.43 million TEUs (Twenty-foot Equivalent Units) per year, which is 85% of the volume transported on traditional canal routes in 2011. We conclude that there will be large-scale gas transportation through the Northeast Passage in the near future, and transit shipping across the Arctic will focus more on container transportation. The differences in shipping costs between Arctic routes and traditional canal routes are also compared.

Keywords **Arctic shipping routes, canal routes, cargo, container transportation, liquefied natural gas, assessment**

Citation: Zhang X, Shou J M, Zhou H J. Scale and scope of maritime cargoes through the Arctic Passages. Adv Polar Sci, 2013, 24:157-165, doi: 10.3724/SP.J.1085.2013.00157

1 Introduction

Arctic passages are beginning to be used as sea transportation corridors, connecting the manufacturing centers of the Far East with the consumption centers of Northwestern Europe and eastern North America, in response to climate change and current international trade patterns. The passages comprise three main channels (Figure 1): the Northeast Passage (in northern Eurasia), the Northwest Passage (along the northern rim of North America), and the Central Passage (at high latitudes of the Arctic Ocean). The length of each channel is about 3 000 n mile[1].

The extent of sea ice in the Arctic Ocean is reducing with climate change. The area of summer sea ice dropped to 3.41 million km^2(about one-quarter of the area of the Arctic Ocean), another record low[2], on 16 September 2012. Commercial use of the Northeast Passage began from the melting of the ice, with 46 ships passing through the Northeast Passage(compared with 34 ships in 2011). The freight volume rose from 0.83 million t in 2011 to 1.26 million t in 2012[3]. The shipping season has expanded to nearly 5 months per year (from the middle of July to early December). With the increase of cargo volume, the Arctic passages have acted as a main line linking Asia and Europe in an early form.

There has been much research on the Arctic passages at home and abroad. However, there has been little quantitative prediction of Arctic shipping considering changes in the extent of sea ice and the current conditions of operation. Such quantitative prediction is required by nations and companies in deciding when they will take advantage of the Arctic passages. This paper first analyzes the distributions and development plans of Arctic resources. Using statistical

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data of current shipping-line freight volumes, a preliminary forecast analysis is then carried out for types and quantities of cargoes in future commercial navigation in the Arctic passages.

Figure 1 Map of Arctic sea routes and traditional canal routes. Number is the length of the rouce, unit: n mile.

2 Framework and model for predicting Arctic shipping

Decisions made by sea-shipping enterprises are founded on predictions of the future types and quantities of cargoes to be shipped internationally. A number of agencies issue commercial market analyses every year. These reports, using shipping business statistics, predict the development of the future shipping market. Shipping in the Arctic passages at the present time is only tentatively progressing towards a larger scale and more mature service, and therefore, historic statistics cannot be used directly in predictions. According to the Arctic Council[1], the four main types of shipping activity in the Arctic region are community logistics supply, cruises, fishing and bulk-cargo transportation. Current Arctic shipping mainly focuses on activity within the region, while shipping across the Arctic is rare. Oil and gas sourced in the Arctic are mainly transported by pipelines, and the transportation of these resources by Arctic shipping has only just begun. As a result, there are insufficient data for quantitative prediction of Arctic shipping. Arctic shipping is mainly between continents. In intercontinental trade, decisions relating to sea shipping are made according to business scale, which depends on the distribution and quantity of goods. To analyze supply volume, we can roughly draw a structure of the theoretical flow and scale of goods in Arctic shipping; the analysis structure is shown in Figure 2.

According to the analysis, the future of Arctic shipping is mainly aimed at the Arctic (as a destination) and across the Arctic. The Arctic is sparsely populated (approximately 10 million people)[4], but has a vast area(about 8 million km^2). The largest city in this region is Murmansk, which has a population of approximately 300 000 people. Thus, it is difficult for the Arctic to form a large-scale consumer market by itself. However, the Arctic is rich in natural resources, especially natural-gas reserves[5]. The region will become a supplier of raw material in its economic integration. The main type of cargo delivered to the Arctic is the building materials needed for the outputs of the Arctic region and surrounding manufacturing centers. Considering all factors, natural gas will become a large-scale cargo, and potentially the largest-scale cargo, carried in Arctic shipping.

Compared with other global seaways, the routes across the Arctic are more convenient for intercontinental sea trade and they will take a share of the cargo volumes currently transported by traditional seaways. We consider the three main types of shipping: tanker, dry-bulk and container shipping. In terms of tanker shipping, we note that oil and gas resources in the Middle East, Africa, central Asia, southern Canada and southern Russia are mainly transported via traditional sea routes or through pipelines to the rest of the world. Arctic shipping is not expected to be used for such resources unless there are political issues or war.

Iron ore, coal and grains account for a large proportion of the international dry-bulk shipping market. At present, the resources of iron ore, coal and carbon are mainly distributed in southern Brazil, Australia and South Africa. Grains are mainly distributed on the east coast of South

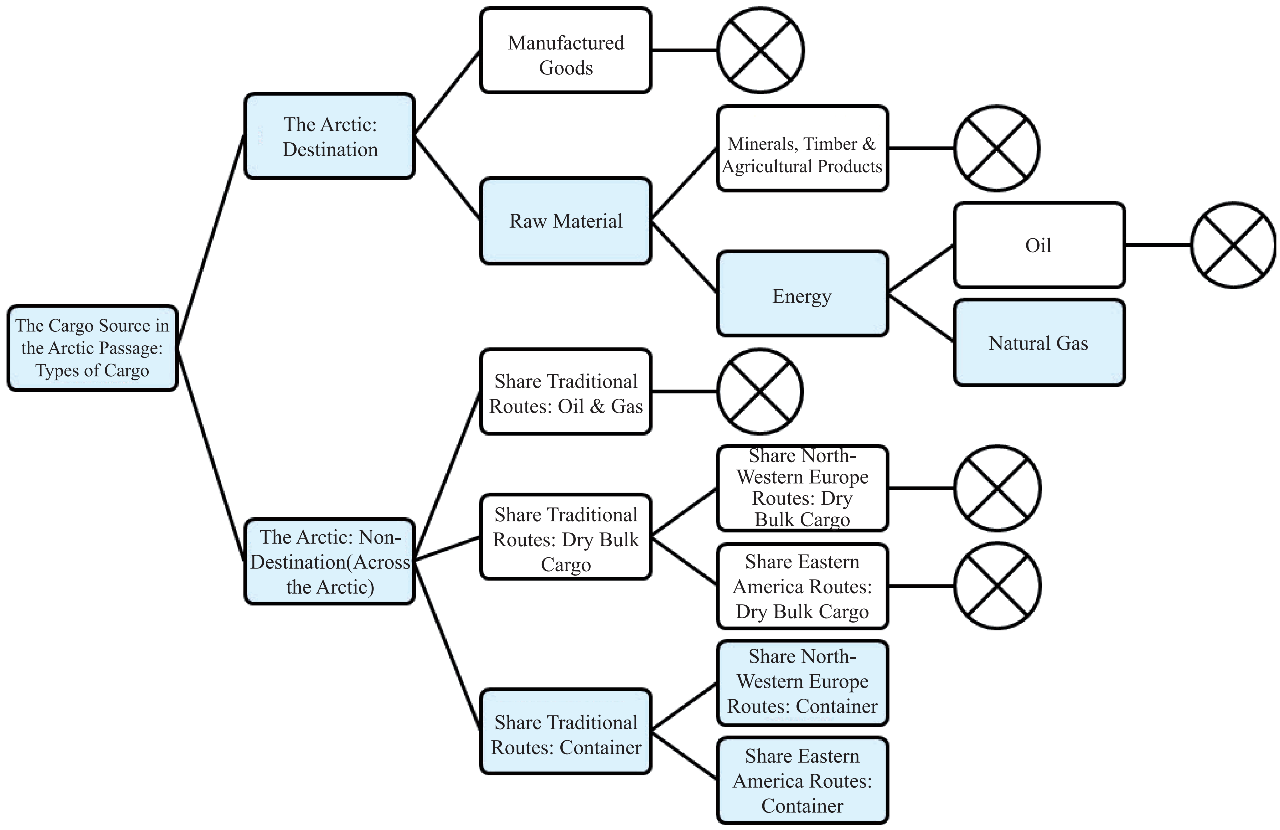

Figure 2 Analysis framework of cargo types in future Arctic shipping.

America, in western America and on the Gulf Coast[6], which are positioned too far south to take advantage of cross-Arctic shipping. However, the Arctic passages can provide transportation routes for other types of bulk cargo. To estimate the cargo volume that could be carried in Arctic shipping, we analyze the bulk cargo volume passing through the Suez Canal. Schøyen and Brathen found that the bulk cargo volume transported on the Northwestern Europe—Far East route through the Suez Canal was at least 10 million t in 2004. They predicted a continuing rise in the volume starting in 2004[7]. However, according to a report released by the Suez Canal Administration, there was a rise and fall in the bulk cargo volume from 2000 to 2012, and the cargo volume in 2012 was less than that in 2000 (Table 1). Over that period of more than a decade, the increase in cargo volume passing through the Suez Canal is attributed to a rise in the container transport of oil and gas, and less so to the transportation volume of dry bulk.

Bulk cargo transportation on the Northwestern Europe—Far East route accounts for a large proportion of the bulk cargo passing through the Suez Canal. We thus use the bulk cargo volume passing through the Suez Canal to estimate the bulk cargo volume on the Northwestern Europe—Far East route. The bulk cargo volume on the Northwest Europe—Far East route is calculated not to exceed 13 million t per year, and may even have peaked in 2007. It is therefore reasonable to infer that the future shipping volume will change periodically, ranging from 7 million t to 13 million t per year. Considering that the transportation of 40 000 t of bulk cargo requires five voyages by a single ship, 65 ships are needed for the total bulk transportation on the route. Assuming that the Arctic passage takes a 50% share of this total bulk transportation, 30 to 49 ships are required to transport 3.5 million t to 6.5 million t of dry bulk each year. Compared with the 3 billion t of bulk transportation worldwide each year[8], this bulk transportation through the Arctic is tiny.

The traditional routes for container shipping are from Asia to Europe and from Asia to North America, connecting the manufacturing centers in Asia to the consumption centers in Europe and North America. These are the largest and most concentrated shipping routes in the world. Because of their water depths and narrow passages, the Panama and Suez Straits have become bottlenecks on these traditional routes, and the time cost of queuing is expected to continue to increase year by year. The volume of container transportation in the Northern Hemisphere has increased at a rapid rate. If the Arctic shipping routes are feasible, they will effectively ease traffic pressure on traditional routes. Indeed, according to data sorted by the United Nations Conference on Trade and Development and Eurostat, the shipping volume between China and eastern North America and Northwestern Europe via the traditional canal routes reached 700 billion United States dollars(USD) in 2011, accounting for one-fifth of the cargo trade. China enjoys six ports which are in the list of the World's Largest Container Ports. So container shipping is the main type of transportation. If China's economic growth remains at 8% per year, then container transportation via the traditional canal routes will increase substantially. If the extent of Arctic sea ice continues to shrink, the transportation time available each year in the Arctic passages will be further extended, and the feasibility of container transportation will increase. Considering this demand, container transportation, especially to China, will be the main type of transportation through the Arctic passages. The scale of this type of transportation will be discussed later in the article.

Table 1 Annual cargo volumes through the Suez Canal in 2000–2012 (unit: t)*

Cargo Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Oil & Gas Volume	52 982	62 267	50 043	69 125	87 193	97 490	114 627	125 627	129 305	104 639	128 132	145 572	175 508
Container Volume	143 819	147 282	165 240	191 014	220 379	247 136	276 899	324 572	343 989	308 919	367 001	397 204	397 958
Dry-bulk Volume	171 180	162 879	153 563	197 743	213 418	226 479	237 109	259 899	249 695	145 687	150 931	149 024	166 448
Total	367 981	372 428	368 846	457 882	520 990	571 105	628 635	710 098	722 989	559 245	646 064	691 800	739 914

*Data from http://www.suezcanal.gov.eg/

3 Analysis of cargo structure, flow direction and scale in the Arctic channel

3.1 One-way trade pattern for liquefied natural gas (LNG)

As mentioned earlier, transportation destined for the Arctic region is primarily to assist the delivery of raw materials outward. From development plans for wood and ore to be transported through the Arctic channels, we know that ore exploitation in the Arctic regions of Canada and Greenland is still under discussion[9]; the Arctic region in Norway has been mined and cargo delivered via the Northeast Passage to the Far East, although reserve will run out within 10 years; there are no exploitation plans for the Arctic regions of Sweden and Finland; Alaska delivers aquatic products, zinc, and copper to Asian markets via its southern ports; and wood and ore sourced in northern Russia are mainly transported by railway and through the Northeast Passage. Another main cargo in the Arctic region is oil and gas, and the region is rich in gas reserves[5].

Natural gas in the Arctic region is mainly distributed in Russia, Alaska and Norway. Oil sands in Canada, mainly distributed in Alberta, are transported through its southern ports after being processed, and not transported through the Northwest Passage. Alaska has rich natural-gas reserves, but transportation of the natural gas in the future will be through pipelines and southern ports. However, because of technical breakthroughs and the rise of output in America's shale gas industry, there is less urgency in developing Alaska's natural-gas reserves. However, the situation is different in Russia and Norway. The shale gas market will probably compete against the natural-gas market, and Russia and Norway have an urgent need to establish a natural-gas development plan for the Arctic. This is evidenced by the freight volume of energy products accounting for more than 70% of the cargoes in the Northeast Passage in recent years. The price of natural gas in the Far East is much higher than that in Europe and North America[10]. The importation of natural gas from Russia to Europe is mainly through pipelines. The natural gas of Russia and Norway is mainly exported to East and Southeast Asia. Therefore, there will be a freight flow of LNG from Russia and Norway to the Far East.

The scale of trade on the route from the Far East to the Arctic is relatively small, and the freight flow is not expected to be large. Table 2 gives the values of trade between China and the Arctic. The value of goods exported from China to the Arctic in 2011 was 340 million USD, which equaled the value of goods exported from Japan and South Korea separately. The total export value from the Far East to the Arctic is 1 billion—2 billion USD.

Table 2 Values of trade between China and the Arctic (unit: million USD)*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Export to Arctic	53	72	75	121	154	274	391	489	512	479	285	342
Import from Arctic	122	117	165	275	416	533	1 001	1 067	1 470	1 033	972	1 552
Total	175	189	240	396	570	807	1 392	1 556	1 982	1 512	1 257	1 894

*Data are quoted from the research report Plan for the Arctic Region and Evaluation of China-Arctic Development, written by the author.

According to the analysis, we can draw a diagram illustrating the pattern of one-way trade flow of LNG from Russia and the Nordic Arctic to East Asia and Southeast Asia (Figure 3).

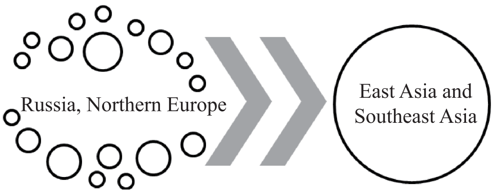

Figure 3 Arctic shipping of LNG from Russia and the Nordic Arctic to East Asia and Southeast Asia.

The scale of this shipping can be estimated from the total reserves of oil and gas in the Arctic and the Arctic LNG development plans of Russia and Norway. According to data on the reserves and distributions of Arctic oil and gas released by the United States Geological Survey, the theoretical scale of future energy transportation on the Arctic routes will reach 37 billion t[10]. The proportions of transportation of oil and gas by ships and pipelines will be different. Generally speaking, the transportation mode will be decided by the size of the reserve and the distance to the market. The bigger the reserves and the longer the distance, the cheaper that transportation by ships will be, relative to transportation by pipelines. The distance for LNG transportation from the Arctic to East Asia and Southeast Asia exceeds 5 000 km, and ship transportation will thus be much cheaper. The oil and gas in the south of the Arctic are transported by pipelines. Considering the effect of reserve distance, the oil and gas in the north, including the offshore areas, will be transported through the Northeast Channel to Europe, North America, East Asia and Southeast Asia. The freight volume, in the case of even shares for shipping and pipelines, will reach 18.5 billion t.

We now turn to the transportation volume of natural gas in early and middle stages. From the development plans of Gazprom (a huge Russian natural-gas extractor) and the Norway National Oil Company(Table 3), we estimate that by 2030, if one-third of the increase in natural gas is transported by sea and only during summer, the shipped volume will reach 1.7 billion to 41.2 billion m^3(2.7 million to 66 million m^3 or 1.35 million to 30 million t after liquefaction). The natural gas in Russia and Norway will thus be mainly exported to East Asia and Southeast Asia. For convenience of calculation, we assume market trisection among North America, Europe and Asia, and the LNG needed to be shipped to East Asia and Southeast Asia will reach 0.5 million to 10 million t. This paper will not analysis the route to the Europe and America because ice-class ships are not needed.

If the shipping season in the Northeast Passage remains constant (from early July to early December), each ship will make five voyages per season, and the number of ice-class ships required for the transportation of LNG (on the basis of the specifications of the Ob River[11]) will increase to 30 by 2030 (Table 4).

Development plans may be adjusted dynamically according to market changes. Iceland and Greenland are exploring oil and gas fields. Many new shelf gas fields are being listed for development at an accelerating rate. The shipping season may be extended through improvements in shipbuilding technology and operation technology. In general, the above demand is a conservative prediction.

Table 3 Planned LNG production on Russia and Norway's Arctic continental shelf

Planned natural gas field in Arctic region	Reserve/ (billion m^3)	Planned output/ (billion $m^3 \cdot a^{-1}$)	Starting year
Snohvit(Norway)	193	5.1	2007
Shtokman(Russia)	3 800	23.7(first stage)	2017
Yamal(Russia)	16 000	95(primary stage)	2016
Total	19 993	123.8	

*Data from Xi N[10] and www.intsok.com

Table 4 Assessment of the number of LNG ships passing through the Northeast Passage by 2030

Year	Deliver demand of the LNG in Arctic region/(million $t \cdot a^{-1}$)	Number of ice class ships*
2012–2030	0.5 to 10	2–30

*Estimated on the basis of the Ob River (made in Singapore in 2007, cargo capacity of 145 700 m^3, gross tonnage of 67 022 t, catamaran hull) and a round trip of 30 d (including laytime).

3.2 Prediction of the two-way trade flow pattern and scale of container cargo

The role of the Arctic Sea route serving to ease traditional routes has been discussed by the shipping community. Ports in the Fast East, Northwest Europe and eastern North America will reduce mileage to other places through the Arctic route[12]. We can therefore make a preliminary judgment that an Arctic northern sea route (possibly including the Central Passage) can ease pressure on traditional routes from the Far East to Northwestern Europe, and the Northwest Passage can ease pressure on routes arriving at ports in the Caribbean and eastern North America (Figure 4).

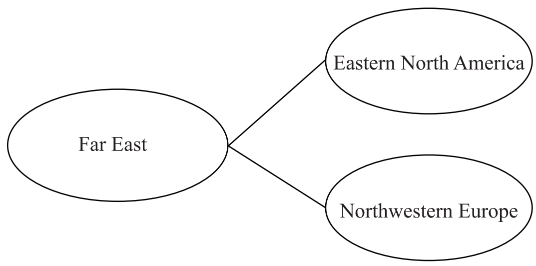

Figure 4 Arctic shipping of containers from the Far East to coastal regions of the North Atlantic.

In recent years, the Arctic ice has been melting at a surprising rate, and the multiyear accumulation of ice in the middle of the Arctic has begun to shrink substantially[13]. It has been reported that a central sea route (the Central Passage) may open earlier than the Northwest Passage in the shipping season[14]. The Fifth Chinese National Arctic Expedition in 2012 took the Northeast Passage on their outward journey[15] and the Central Passage on their return journey, demonstrating the technical feasibility of navigating the latter route.

In analysis of the theoretical scale of Arctic container shipping, it is noted that the freight volume of containers transported from the Far East to Northwestern Europe is 13.35 million 20-foot equivalent units (TEU) in 2011, and the volume on the Pacific routes is 21.59 million TEU per year, comprising 14.24 million TEU per year on the eastern route and 7.34 million TEU per year on the western route[16]. The freight volume on the Pacific routes is mainly concentrated on the route from the Far East to western North America and routes from the Far East to the Caribbean and eastern North America, with the former route not passing through the Arctic channel. According to the 2012 Faith Report[17], the freight volume on the Far East—North America eastern route is about 12.01 million TEU and that on the western route is about 6.135 million TEU. The Far East—North America routes account for more than 85% of the total volume on the eastern and western routes of the Pacific lines, including the volume of Canada. On the Far East—North America eastern route, the volume of exports to eastern North America accounts for about 40% of all exports. It is reasonable to assume that on the western route, the volume of exports on the Far East—North America western route also accounts for about 40%. Approximately 34% (85%×40%) of the volume in TPEB(Trans Pacific Traffic East Bound) and TPWB(Trans Pacific Traffic West Bound) then comes from the Far East to eastern North America.

The estimation of future freight volume usually adopts linear, polynomial and power laws[16]. Using the linear and power formulas of prediction methods given in the literature[16], the present article calculates average results for the freight volumes of the Far East—eastern North American route and the Far East—Northwest Europe Route in 2030, as presented in Table 5. If the Arctic passages ease the total volume on these routes by 50%, then the container freight volume on the Arctic sea route in 2030 will be 17.43 million TEU, which is a theoretical maximum, being 85% of the volumes of the two traditional routes in 2011. Of course, the feasibility of navigating the Arctic routes is considered to be a more fundamental determinant of what will happen. Although the present article only estimates the maximum volume of shipping in the case of feasible navigation, such estimation of demand may be helpful in deciding the capital investment for development of the Arctic sea routes.

4 Discussion of container shipping costs for the Arctic sea routes and traditional Canal routes considering relevant papers

Many research reports have given pessimistic estimates for container shipping in the Arctic and there are few container ships on Arctic routes. There may be two reasons for this: One is the poorer operating environments of the Arctic routes, and the other is the higher shipping costs compared with the costs on traditional routes. The poor environmental conditions can be countered by technical innovations, which will in turn reduce costs.

Table 5 Assessment of maximum volumes of container shipping through the Arctic sea routes by 2030

Sea Route Affected by the Arctic Sea Route	2011		2030	
	Real Gross	Real Share	Predicted Gross	Maximum Share
Far East to Northwest-European	1 335	0	2 360	1 180
Far East-North America East Coast	734	0	1 126	563
Total	2 069	0	3 486	1 743

According to the above analysis, the Arctic routes will ease some of the freight volume on the two traditional routes. The proportion (50%) of Arctic shipping is proposed considering all-year navigability, and competing routes will eventually reach a balance according to their management and service charges. This assumes maximum sharing. However, with current technology, whether the Arctic routes can ease the pressure of container shipping on traditional routes remains an open question. According to the above analysis, there will be great demand for container shipping in the future. However, there are more commercial trails of tankers and bulk freighters than those of container ships. Maritime enterprises will choose the Arctic routes on the basis of cost comparison for the current technology. The fundamental issue is the high cost of transporting on Arctic routes.

Many papers published at home and abroad have compared the operating costs of the Arctic routes with those of traditional routes. Verny and Grigentin[18] and Somanthan et al.[19] conducted comprehensive analyses of container ships. Considering the container ship type and tonnage and the navigation speed and distance as parameters, they compared the required freight rate (RFR) for the routes through the Northeastern Passage, Northwestern Passage, Suez Canal and Panama Canal, under the assumption of year-round navigation in the Arctic. The results are given in Table 6.

According to Table 6, the Northeast Passage has an RFR 80% higher than that of the Suez Canal route and the Northwest Passage has an RFR 16% higher than that of the Panama Canal route. Owing to the different navigation conditions for the two Arctic routes, there is a big difference in the assumptions made in Ref. 18 and Ref. 19. The rental fees of seaworthy ships for the Arctic routes are respectively 128% and 30% higher than rental fees for ships for the traditional routes in the two papers. This accounts for most of the differences in the RFRs for the two Arctic routes and traditional routes.

Table 6 Comparison of freight costs for container shipping on Arctic routes and canal routes according to the literature

	Shanghai To Hamburg*		YOK To NY**	
	Through Suez	Through Northeast Route	Through Panama	Through Northwest Route
Type: Capacity	Sambhar: 4 000	Special Sambhar: 4 000	CAC3: ?	CAC3: ?
Average Speed/knot	24	21	20	20
Single Trip/d	28−30	18−20	24.1	21.4
RFR (Dollar/TEU)	1 400−1 800	2 500−2 800	541	625

* Quoted from Ref. [18]; ** quoted from Ref. [19].

The present article makes a simplified comparison from the perspective of a single ship voyage. Three items are mainly responsible for the high cost of transportation on the Arctic routes: the high rental fee of an ice-class ship, the management and service fees of navigation in ice areas, and the special insurance required for ships navigating ice areas. Compared with transportation on the Arctic routes, transportation on the traditional routes must pay higher voyage fees (shipping fees, fuel charges and environmental emission charges), canal dues and pirate insurance. If the special insurance required for a ship navigating ice areas is equal to the pirate insurance required for a ship on a traditional route, then ignoring environmental emission charges and the optimal design of a container port-of-call link, we only compare three items: the ship rental fee, the management and service fee and the voyage fee.

4.1 Rental fees for ice-class and ordinary ships

Rental fees include ship construction fees and depreciation fees for Arctic routes. The construction fee of an ice-class ship is generally at least twice that of an ordinary ship. Because there is no leasing market for ice-class ships, it is difficult to accurately estimate this fee. If the idle ship capacity is taken into account, the rental fee of an ice-class ship may be more than twice that of an ordinary ship. This article prices the rental fee for an ice-class ship at 73 000 USD a day and that for an ordinary ship at 32 000 USD a day on each line[18].

4.2 Management and service fees of pilotage in canal and ice areas

This item and the canel fee are same in nature. But the fee is still compulsory among North Sea routes now. The charges vary widely according to the type and tonnage of the ship, and there is no clear charging standard. In reference to the fees for Xue Long ship and bulk carrier, the fee of a container may range from 400 000 to 800 000 USD. For the Northwest Passage, the Canada Maritime Management Authority currently implements a reporting system without a specific charge. With regard to the canal fee, 10 000-TEU ships passing through the Suez Canal pay 500 000 USD[20] and 5000-TEU ships pay 300 000 USD. In the case of the Panama Canal, 5000-TEU ships pay approximately 450 000 USD[21].

4.3 Voyage fee

The difference in the voyage fee depends mainly on the difference in the shipping mileage between the Arctic route and the traditional route. The mileage of the traditional route from Shanghai to Hamburg is 10 715 miles and that from Shanghai to New York is 10 567 miles. The mileage of the Arctic route from Shanghai to Hamburg is 7 952 miles and that from Shanghai to New York is 8 632 miles. If the average speed is 20 knots, the time savings achieved by taking the Arctic routes are respectively 6.7 d and 4 d(Table 7). Ships with capacity of 5 000 TEU use 103 t of fuel per day, the fuel charge is 103×700=72 100 USD per day and the crew wages are 3 333 USD per day. This gives a total voyage fee of 3 333+72 100=75 433 USD per day (Table 8).

Table 7 Days saved by choosing an Arctic route over a canal route*

Prime cost	Shanghai to Hamburg		Save	Shanghai to New York		Save
	Passing the Suez Canal	Passing the Northeast Route		Passing the Panama Canal	Passing the Northwest Route	
Shipping mileage	10 715	7 952	2 763	10 567	8 632	1 935
Voyage days	22.3	15.6	6.7	22.0	18.0	4

*At a speed of 20 knots, excluding the berth time.

Table 8 shows that under the condition that a single ship does not wait when passing through the Suez Canal (or waits for a period less than any delay incurred by the ship on the Arctic route), transportation through the Northeast Passage will cost 220 000 USD more than that on the traditional route. The expensive management and service fee charged by Russia may limit the trail shipping of containers through the Northeast Passage. The Canada Maritime

Management Authority has not issued a specific service-charging policy for the Northwest Passage. Its comparative advantage is thus 140 000 USD. However, the Northwest Passage is more difficult to navigate than the Northeast Passage, and it not been opened to cross-border commercial shipping at present.

Table 8 Comparison of costs for container shipping on Arctic routes versus canal routes (Unit: 10 000 USD)

Prime Cost	Shanghai to Hamburg		Cost Variance	Shanghai to New York		Cost Variance
	Passing the Suez Canal	Passing the Northwest Route		Passing the Panama Canal	Passing the Northwest Route	
Ship leasing fee	71.4	113.9	42.5	70.4	131.4	61
Voyage fee	168.2	117.7	−50.5	166	135.8	−30.2
Management and service fee of pilotage in canal and ice areas	30	60	30	45	0	−45
Total	269.6	291.6	22	281.4	267.2	−14.2

5 Discussion and conclusion

There is great potential in the commercial development of Arctic routes in the future and potential competition between the Arctic routes and the Suez and Panama Canal routes. From the above analysis, we discuss the following points.

(1) If the construction fee of an ice-class ship remains unchanged and, at the same time, the service fees for Arctic routes are lowered, there will be an obvious competitive advantage in using the Arctic routes over the traditional routes. As the transportation of freight on traditional routes continues to increase, the delay costs for ships as they pass through the Suez and Panama Canals will further increase. Meanwhile, the Arctic route has an obvious advantage over the route around the Cape of Good Hope. This means that the Suez and Panama Canals will have to adopt a lower pricing policy to compete with the Arctic routes.

(2) If there is a navigation carbon tax in the future[22], a faster boat speed will attract a higher levy of navigation tax because of the increased carbon emission. Low steaming of container shipping on the Arctic routes will then present an obvious advantage, in that it will allow shipping at lower speed over a short distance in the same timeframe compared with shipping on the traditional routes.

(3) The expensive management and service fee for the northern route above Russia is a major constraint of Arctic shipping. On 28 July 2012, Russian President Vladimir Putin signed the federal law Modifications on relevant Provisions of Commercial Shipping in the Northern Sea Route, which modified three legal documents—The Russian Natural Monopoly Law, Federal Act on the Internal Maritime Waters, Territorial Sea and Contiguous Zone of the Russian Federation, and The Merchant Shipping Code of the Russian Federation—and replaces mandatory fees with fees charging according to services. This move will significantly improve the competitiveness of transporting through the Northeast Passage. Note that there may be an Arctic Central Passage, which mainly lies in the high seas, and avoids the expensive management and service fee and could compete with the Northeast Passage and Northwest Passage. Therefore, it is an inevitable that the management and service fee for Arctic routes will reduce.

(4) If the Arctic routes permit all-seasons navigation, the results of market competition between the Arctic routes and traditional routes must be an equal sharing of the container volume. As a seasonal route, the Arctic routes have idle ships for the liner container operation for several months, which has been reflected in the cost, although the navigation time has increased from 3 to 5 months. Additionally, the uncertainty of the distribution and the movement of sea ice affects the plans of liner operators, which require a higher level of punctuality. This is the main reason why there are few trail ships on the Arctic routes. If there are breakthroughs in the construction technology of ice-class ships, an optimal design of the operating links, and changes in navigation tax, then the disadvantage of transporting on Arctic routes will be overcome. At that time, the advantage of the Arctic route, compared with the traditional routes, will show up.

The shipping of natural gas through the Northeast Passage is important in the early and middle terms of Arctic transportation, while there will be increasing demand for container shipping on the Arctic route against a backdrop of a steadily developing Chinese economy. The history of world shipping shows that demand stimulates capital to open up new routes, generating advanced technology. At the same time, the continued melting of sea ice will decrease technical difficulties and reduce costs. Furthermore, we should hold an optimistic view for the development of a ship that does not require a nuclear-powered icebreaker for navigation, costs as much as an ordinary ship, and operates in all seasons.

Acknowledgements This research is supported by the Ocean Public Welfare Scientific Research Project of China "Seaworthy Evaluation of the Arctic Sea Route and Research and Demonstration of Channel Forecast (Grant no. 201205007-6)", the Chinese Polar Environment Comprehensive Investigation & Assessment Programmes (Grant no. CHINARE2013-04-05-01).

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