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CONTAINER SHIPPING ON THE NORTHERN SEA ROUTE

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Abstract:

Since the beginning of the 20th century, the principal commercial maritime routes have changed very little. With global warming, the Northern Sea Route (NSR) has opened up as a possible avenue of trade in containerized products between Asia and Europe. This paper verifies the technical and economic feasibility of regular container transport along the NSR. By adopting a model schedule between Shanghai and Hamburg, we are able to analyze the relative costs of various axes in the Asia-Europe transport network, including the NSR. While shipping through the Suez Canal is still by far the least expensive option, the NSR and Trans-Siberian Railway appear to be roughly equivalent second-tier alternatives.

Key-words: Northern Sea Route, Maritime transport, Container shipping, Operating costs, Asia-Europe corridor

1. Introduction

The economic concept of globalization appeared just after the end of World War II, reflecting an emerging awareness of the new economic geography engendered by rapidly increasing mobility of humans and merchandise across natural and national borders. Indeed, the great commercial dynamism of recent decades may be partly explained by the fact that logistical chains, infrastructure, and means of transport are extremely well organized (Krugman, 1991a).

This line of questioning is especially relevant for the “Royal Road” through the Suez Canal, which serves nearly all of the Asia-Europe market. The current mode of operation of the Suez Canal will have to adapt to a rise in traffic if congestion is to be avoided (Drewry, 2008). It is thus possible that in years to come this avenue of communication will reach the limit of its capacity for container ships (Selkou and Roe, 2004). In this scenario, alternative routes must be envisaged to smooth the circulation of containerized products between Asia and Europe. One of these, the Northern Sea Route (NSR), has seen little use but now demands further study (Map 1). In this article, we wish to determine whether the development of regular maritime transport along the NSR is feasible and pertinent.

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The sources cited in this article are drawn from all three of the disciplines mentioned above. Almost none of them, however, have addressed the specific problem raised in this paper. Thus, in order to optimize the scheduling model proposed here and verify the feasibility and pertinence of the NSR for container transport, we have supplemented our literature search by conducting informal discussions with actors in the maritime transport industry. These persons include institutional actors, shipowners, transport organizers, insurers, warehouse workers, loaders, etc.

Section 2 presents the international commercial routes. This discussion leads us naturally into an analysis of container transport along the NSR (Section 3). Section 4 determines the cost of shipping a single TEU by the NSR. Section 5 concludes.

2. International commercial transport

The discussions in this paper are founded on the concept of economic globalization. It is from this perspective we consider the strategic position of a new international commercial route.

2.1. Maritime transport and demand

Globalization reflects an increase in the density and dynamism of merchandise flux, not just between continents but also between regions of the same continent. The trend toward further internationalization of trade and production has accelerated over the past two decades (Hammami *et al.,* 2008; Robertson and Scholte, 2006; Verny, 2007a). P. Krugman noted that consumers favor diversity in offered products, a tendency that reinforces competition between industries (Krugman, 1979). This process drives sales prices ever lower, notably thanks to economies of scale. In effect, every enterprise sees its consumer base increase well beyond the captive local market. The enlargement of customer catchment areas has given rise to a wide variety of business organizations (clusters, local productive systems, etc.), but all share the same goal: adapting to diverse territories in a globalized world economy (Giaoutzi *et al*., 1987; Howells, 2005). This evolution of the world's commerce has relied heavily on the development of efficient transport networks, which reduce shipping costs to a negligible fraction of the product's factory price (Baldwin, 1991; Baykasoglu and Kaplanoglu, 2008). In 2007, more than 7 billion tons of merchandise were transported worldwide (Guillaume, 2008). About 80% of this flux, or 5.6 billion tons, was carried on commercial shipping lines. In terms of value, the commercial exchange of merchandise has increased by a factor of 180 from 1948 to 2006 (WTO, 2008). This growth is mainly attributable to manufactured products.

Shipping containers have seen extensive use ever since the 1960s, and for good reason. The medium has allowed the world to move beyond the transport of bulk goods to a rapid, smooth and secure trade in all sorts of merchandise, simply by asking handlers to work with the packaging rather than the content during loading and transshipment. The uniformity and ease of handling of these boxes account for the low cost of containerized transport. The progressive containerization of maritime traffic since 1960 has been the primary force behind trade internationalization. As a consequence of this phenomenon, a new field of study has appeared: the geography of places and flows (Hall *et al*., 2006).

The world economy is largely driven by what K. Ohmae names "the Triad": North America, Europe, and the "Asian 2+6" (China, Japan, and the 6 emerging economies of South Korea, Indonesia, Malaysia, the Philippines, Singapore and Thailand) (Ohmae, 1985). In 2006, these three sources of flux accounted for 80% of exports and 83% of imports. Trade in merchandise, especially containerized products, is essentially confined to the Northern hemisphere and traffic between North America, Europe and Asia. This fact explains the preeminence of certain commercial maritime routes, notably those going through the Suez and Panama canals (Knowles *et al*., 2008). Since the 1980s, Asia has become the planet's principal industrial center (Leinbach and Capineri, 2007) and its consumer market is booming. Maritime routes linking Asia to the powerful consumer markets of Europe and North America have become the principal axes of container transport.

In the framework of this study, we are particularly interested in the Asia-Europe market. In 2008, with 21.6 million TEU (twenty-foot equivalent units, a reference point commonly used to describe maritime transport along regular lines), the Asia-Europe axis represents 30% of containerized freight transported on shipping lanes all over the globe (Global Insight, 2008). United Nations economists have estimated that this market will grow at an annual rate of 5-6% between 2008 and 2015. Assuming that the three other principal corridors of maritime freight (transpacific, transatlantic, and intra-Asiatic) maintain their share of international commerce, we should apply a coefficient of 1.9 to the 2005 data to obtain an estimate of the volume transported in 2015 (United Nations, 2005). The Asia-Europe axis will thus handle a volume close to 33 million TEU in 2015. Over a longer term, from 2005 to 2030, certain studies anticipate that the volume of containerized traffic between Asia and Europe will increase by more than 600%. This figure corresponds to a mean annual growth rate of 24% over 25 years (HWWI, 2006). In order to accommodate this continuous growth in containerized trade, the transport network will have to provide adequate infrastructure and container ships. There are limits, however, to how much the network can evolve.

2.2 Limitations of the transport supply

Developing markets tend to have weak road and railway infrastructures, but it has been possible to serve them thanks to evolution of their ports (Wilmsmeier *et al*., 2006; Song and Panayides, 2008). Shipping companies are always trying to balance the gains obtained at sea by employing large vessels (economies of scale) against the additional port fees incurred by such a strategy: "the diseconomies of scale" (Jara-Diaz and Basso, 2003; Lai *et al*., 2004; Van Der Horst and De Langen, 2008). China has responded rapidly to demand, efficiently developing its ports to the point where it now holds fourth place in the world GDP (Haralambides and Yang, 2003). In contrast, the principal European ports situated along the Northern Range (from Le Havre, France to Hamburg, Germany) are facing congestion in their access routes, quays, and terminals (Wang *et al*., 2007). To remedy this situation, port cities are now investing in improvements that will prevent any perturbation in the flow of containers from Asia (Baird, 2006). The port of Rotterdam (the Netherlands) is expecting improved capacity thanks to the Maasvlakte II project. The ports of Anvers (Belgium) and Le Havre (France) have already expanded by constructing the Deurganck and Port 2000 docks respectively.

While the capacity of many ports can be improved, it is difficult to envisage applying the same strategy to a key component of growing Asia-Europe trade: the Suez Canal. It accommodates most of the containerized traffic between Asia and Europe: more than 20 200 ships and 745 million tons of freight in 2007 (Drewry 2008). The canal is already beginning to feel the effects of increasing containerized traffic from Asia. At present, 46% of vessels transiting the Canal are container ships. Despite construction intended to increase the maximum ship size (14 000-16 000 TEU) in 2010, the Suez Canal will soon reach its limits (Drewry, 2008). In fact, granting access to larger and heavier ships will inevitably diminish the number of ships in each convoy. In consequence, the waiting time will increase and the canal will be able to offer its services less frequently. As shipping companies choose to pass through the Suez Canal mainly to save time, these extremely localized technical and financial (more days, more costs) problems could undermine the dynamism of the Asia-Europe economic environment.

Can the limited capacity of the Suez Canal, tied as it is to an antiquated mode of operation, be overcome by increasing the size of container ships? To respond to the demands of Asian loaders, who want to efficiently evacuate consumer products (especially those destined for the European market), shipping companies are investing in ever larger, faster and less polluting vessels (United Nations, 2008). Ships with capacities greater than 10 000 TEU are already in service on the Royal Road.

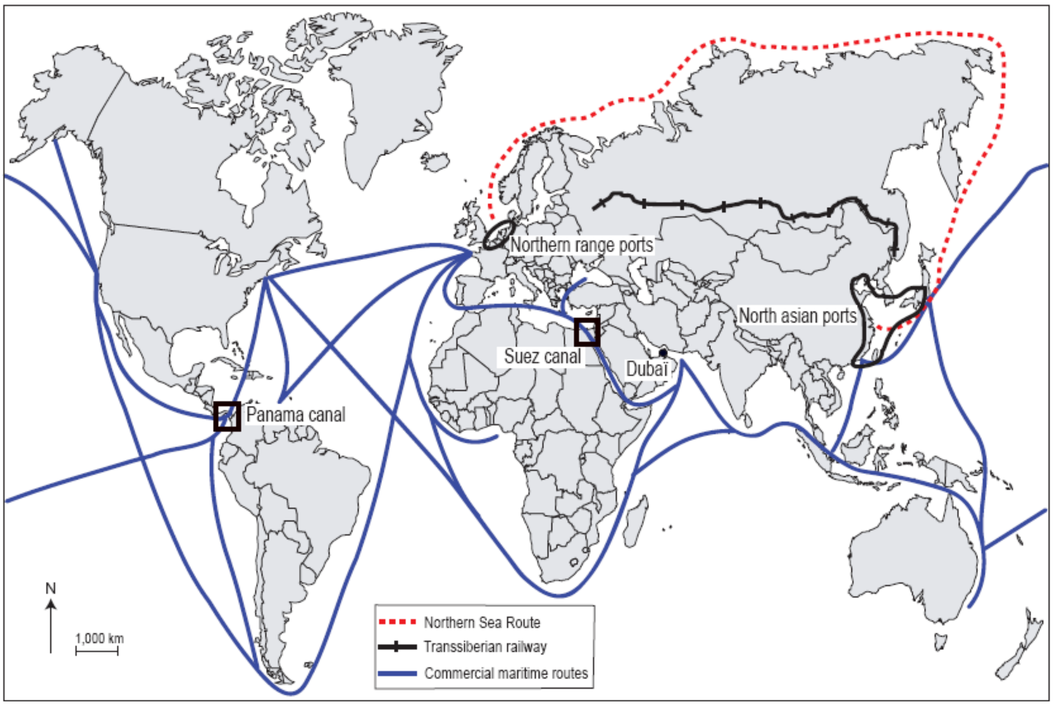
Increasing the size of container ships has certainly allowed these companies to meet growing demand, but it has also enabled then to limit another significant economic factor: the market price of westbound containers. This price has grown in recent years due to an imbalance in traffic between Asia and Europe. The flux of filled containers is dominated by Asian production sites shipping to European consumers: about two TEUs leave Asia for every TEU leaving Europe (OECD, 2006).

This phenomenon naturally affects the cost of transport; in effect, the price of sending a container to Europe includes the cost of returning an empty container to Asia (Shy, 2008). In 2007, the cost of transporting a container between two fixed ports was on average three times higher for routes from Asia to Europe than the inverse (Verny, 2007a). This coefficient dropped to about 2 towards the end of 2008, due to the commercial launch of several large, new container ships in the Asia-Europe network. The supply of containers leaving from Asia thus increased, the direct consequence being a mild decrease in the cost of transport. If the trend of exchanging containerized products continues as previously described, however, this dip in prices will only be temporary. Thus, increasing the size of container ships will not compensate for the limited capacity of the Suez Canal. This conclusion leads us to believe that alternative routes must be envisaged to serve the Asia-Europe market.

2.3 Alternatives to the Royal Road

The network of trade routes between Asia and Europe has several axes, the Royal Road seeing most use (OECD, 2003). Comprising land, sea, and air routes, the network provides a diverse supply of transport options (McCarthy, 2001).

Map 1. **Some international commercial routes**



One alternative to the Royal Road is rail transport through Russia, a traditional interface between Northern Asian and Northwestern European markets. Russia is currently trying to present itself as an attractive territory for shipping, investing massively in its transcontinental train network (especially the Trans-Siberian and Trans-Aralian Railways) (OECD, 2004). This axis has an annual capacity of 100 million tons (Verny, 2007b). In the aforementioned context, it could interest loaders attracted to the gain in time. By way of example, the transit time from Shanghai to Hamburg is 18 to 20 days by train compared to 28-30 days through the Suez Canal. Only 182 000 TEU were conveyed by this infrastructure in 2007, however, less than 1% of the total container flux between Europe and Asia. If this axis is to become more attractive, Russia needs to further improve its infrastructure: doubling the number of tracks, improving the network's signals and electrical supply, etc. Russia must also optimize the network's *organization* by establishing regular lines (higher frequency), facilitating border crossings, increasing security, improving automated container tracking, creating a dedicated ticket office for freight, and adapting its rails to European standards (the separation is 1.52 m in Russia, compared to 1.435 m in most European countries). An intense marketing campaign is currently underway for the Trans-Siberian Railway, emphasizing reduced transit times, shorter routes and attractive prices. By this means Russia hopes to soon (by 2010) increase its container traffic to about 400 000 TEU, 1.5% of the total Asia-Europe flux (OECD, 2004). This forecast falls well short of the train system's total capacity. Nonetheless, it appears that shifting container traffic from sea to train routes remains a marginal option.

Another alternative to the Royal Road is combining two modes of transport, for example sea and air. This method is also an alternative to door-to-door air delivery, which is very expensive (Wornlein, 1999). In sea-air transport, both legs of the journey are specified in a single "combined transport document". It typically consists of a maritime segment between ports in Asia and the Persian Gulf, followed by an air segment linking the Gulf country to a major European airport. Sea-air transport is more rapid than maritime transport, and less costly than air transport.

Shipping dry goods equivalent to a 20-foot container from Shanghai to Frankfurt, for example, is nearly 3 times less expensive via sea-air than by airplane (Table 1). Another advantage of sea-air transport is that it avoids the principal ports of the Northern Range, which are frequently congested by liners. The aforementioned route between the port of Shanghai and Frankfurt airport can be completed in just 15 days, including 2 days at Dubai to transfer the cargo, half the door-to-door time for the Royal Road. Note that the cost of transferring cargo in sea-air transport is generally minimized thanks to logistics services (*i.e.* packing the merchandise into air containers) offered at the shipping container depot. Despite these advantages, the sea-air alternative remains expensive compared to maritime transport and thus viable only for containerized products with high added value.

Table 1. **Comprehensive rates between Shanghai and Frankfurt**
20', 14-tonne dry container

	Sea-air	Air
Freight cost, USD/kg	1.06	3.47
Fuel surcharge, USD/kg	0.66	1.51
Security surcharge, USD/kg	0.10	0.10
All-in rate, USD	**25 840**	**71 120**

3. The Northern Sea Route

Each of the alternative modes cited so far (rail, air-sea, and air transport) has significant advantages, but also obstacles limiting the possibilities for transferring a large volume of traffic. We are thus led to consider maritime transport once again, this time along a different route. With global warming and the melting of polar ice, a new itinerary can be imagined permitting maritime transport on regular lines between the markets of Northern Asia and Northwestern Europe: the Northern Sea Route (NSR), passing through the Arctic Ocean. Here we wish to verify the feasibility of this proposition for enlarging the transport network between Asia and Europe.

Several factors justify renewed interest in containerized transport via the NSR. So far, we have mainly discussed the goal of overcoming practical limitations on the Royal Road. The NSR presents other advantages linked to its geography, but also some logistical drawbacks (Ragner, 2000a). In this section we wish to discuss this route's advantages and drawbacks in detail, while reminding the reader that the NSR could not be exploited at all were it not for the current effects of global warming. It is thought that by 2015 the Arctic Ocean will be navigable year-round, in particular along the Russian coast (Valsson, 2006). The geopolitical climate has also grown more peaceful since 1991, when the dissolution of the USSR opened this ocean to international traffic, so this natural phenomenon is taking place in a context favorable to exploitation of the NSR (Brubaker, 1999). If the NSR begins seeing regular traffic, however, it could awaken the avarice of coastal nations in this part of the world. If so, the route could rapidly become a key issue in international relations.

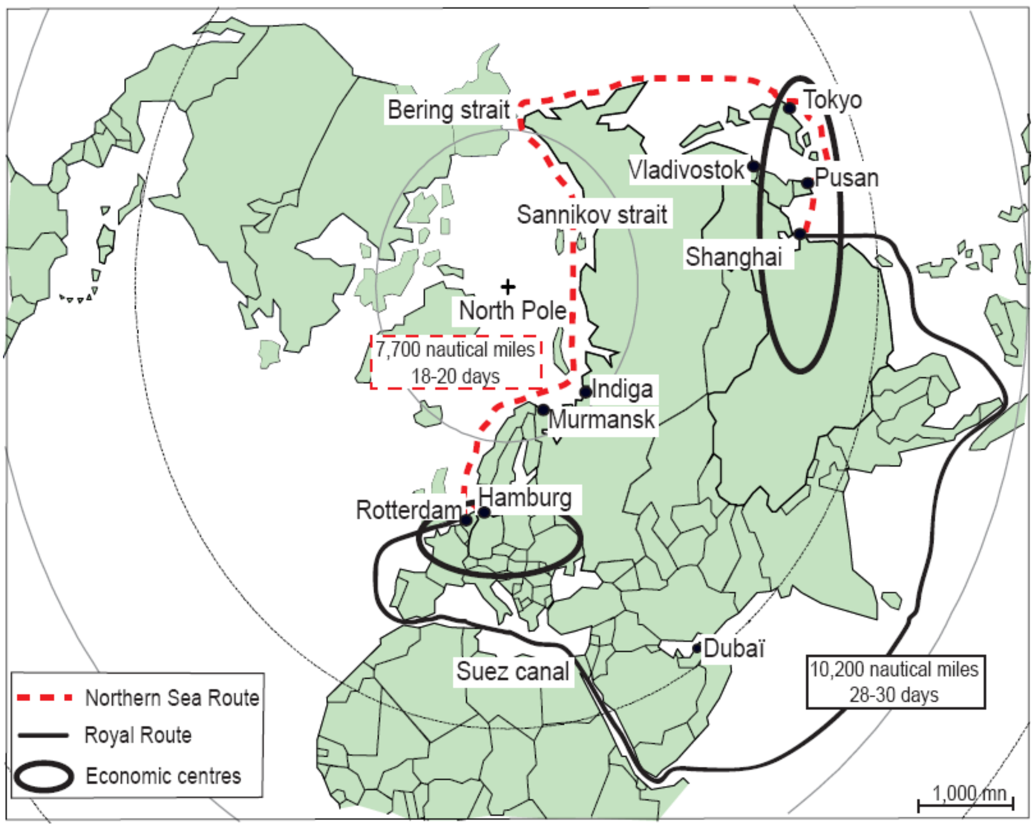
The advantages of the NSR are closely tied to an international "geography of places", a new discipline describing the displacement of production centers and consumer markets (Das and Sengupta, 2009; Ragner, 2000b). In Europe, the economic "center of gravity" is shifting from the West to the Northeast due to the ongoing development of Central and Eastern Europe. At the same time, the growth of China is moving Asia's economic center of gravity from the Southeast to the North. Among the twenty largest container ports in the world (2007), 13 are Asian and 8 of these are Chinese (AAPA, American Association of Port Authorities). Asian mother ships are gradually abandoning Southeast Asia for northern China. On the basis of this new geography, it would seem worthwhile to transfer part of the containerized freight from the Royal Road to the NSR. Indeed, the NSR would reduce the length of voyages from North Asia (mainly the ports of Japan, South Korea, and China) to Northwestern Europe (ports on the Northern Range, starting with Hamburg, Bremen and Rotterdam) by about 2500 nautical miles (Map 2). This translates into a gain of about 10 days, which is one-third of the time required for maritime transport by the Royal Road.

However, the advantages of the NSR run up against significant obstacles linked to the geographical characteristics of the territories traversed. About 2500 nautical miles of Siberian coast between the Bering strait and the port of Murmansk are nearly uninhabited, so no stopovers are possible. The most important consequence of this fact is that regular container lines on the NSR cannot be optimized following the model used in Royal Road transport, which relies on a network of developed communication lines in the hinterlands of port cities (river transport and high-quality rails for transshipment and feedering). A second consequence is that there can be little or no outside response to technical problems brought on by the hazards associated with extreme climatic conditions: floating ice sheets, icebergs, fog, and violent winds (Berglund *et al*., 2007). Maintaining the pace of a regular line requires certain guarantees: that ship can receive assistance with minimal delay, that replacement ships are available, the use of ice-breakers, and a suitable means of transshipment. We can add to this the obvious fact that climatic hazards translate into higher insurance premiums. Even if conditions improve, this extra cost could weigh on the portfolios of clients who trust their goods to a shipping company wishing to transfer some of their traffic to the NSR. At the moment, only certain types of products indifferent to the long period of isolation (dangerous materials and very heavy packages) can benefit from the NSR. The final obstacle to consider concerns Russia's competent authority, the Northern Sea Route Authority (NSRA), which imposes a heavy administrative burden that could drive away maritime companies.

It seems evident that the liberalization of the Russian economy will spur demand for imported manufactured products, rendering the passage of container ships more attractive and profitable. This Russian boom has been slow in coming, however. Following the example of Egypt for the Suez Canal, rights of passage would represent an important source of profits for Russia were the NSR to become a major axis of international transit. Authorization to travel the NSR is currently obtained by paying multiple fees and taxes to the NSRA (Stokke, 2007). The total amount ranges from 4.36 to 23.82 USD/ton, depending on the type of hull and the season of passage (the lowest rates are applied to ice-breaker hulls transiting in summer). These fees include payment for the assistanc of an ice-breaker ship, meteorological forecasts, and the creation of an adequate itinerary. For comparable ships, NSR fees are about two times more expensie than right of passage through Suez Canal.

The above analysis raises several points in opposition to the basic principles of container transport, explaining why the NSR appears to be poorly adapted to regular traffic. But for all that, the technical difficulties are not significant enough to prevent shipping companies from transferring some of their traffic from the Royal Road to the NSR. We conclude that the NSR alternative is capable of responding favorably to questions regarding its pertinence on the economic level.

Map 2. **The Northern Sea Route and the Royal Route**



4. The cost of shipping one TEU on the Northern Sea Route

In order to verify the hypothesis that a regular NSR line is economically pertinent, we choose to imagine a specific regular schedule between a North Asian port and a Northwestern European port. This will permit us to determine the operating costs of the line. The objective of this exercise is to evaluate the cost of transporting a container via the NSR, and compare this mode to the other axes of merchandise trade between Asia and Europe.

4.1. Creation of a schedule

The ship owner operates vessels in rotation on a given maritime route or loop. The principal characteristics of these loops are described in an informative schedule intended for the clientele. This commercial tool provides estimated arrival (ETA) and departure (ETD) times of the ships, organized by voyage and port of call. Shipping companies communicate with their clients largely by issuing continuous updates to the schedule (by e-mail, on their website, etc.). The model schedule developed here is intended to be as representative as possible of real shipping schedules, while remaining sufficiently modular to estimate a range of possible operating costs.

Take the case of a fictional regular line that we name the NSR Express. The ship leaves from Hamburg, stops at Rotterdam, then follows its eastbound segment all the way to Shanghai. It then starts a westbound export rotation, optimizing its load by stopping at Pusan and Tokyo before returning to Hamburg, its point of departure. Passing through the Royal Road, the whole loop is executed at an average speed of 24 knots. Note that the trend in 2007-8 has been to sail at 22 knots, mainly to conserve energy (Kirschbaum, 2008; Levinson, 2006; Oceana, 2008), but this change is not adopted in our model. The NSR is currently navigable at an average speed of about 15 knots from June to December (Niini, 2008). From January to May, the speed is closer to 11 knots due to climatic hazards (Jensen, 2006). According to the National Ice Center, the speed achievable by ships during the winter period will gradually increase in coming years due to global warming (Bertoia *et al*., 2003; Stroeve *et al*., 2007). Moreover, the President of Aker Arctic, a subsidiary of the naval shipyard Aker Finnyards, tells us that in 2007 the company produced an Arctic container ship capable of sailing at 11-12 knots during the winter period. When the Earth warms enough that ice sheets no longer reform completely each winter, this ship will easily navigate the NSR at an average speed of 15 knots. Taking into account scientific research on the subject, we retain an average commercial speed of 17 knots for the model schedule during the period 2015-2025, when regular shipping routes can be in full swing on the NSR.

In creating a schedule for the NSR Express, we chose to have the container ship travel at a speed of 17 knots in those portions of the NSR that are occasionally iced over. Recall however that in the years to come, this residual ice will gradually disappear—an evolution that will further ease conditions on this section of the route. On all other parts of the voyage, the ship sails at 24 knots. Under these assumptions, the transit time for a complete loop between Hamburg and Shanghai will be 37 days. During this time the ship will make 5 stops, remaining at each port for 24 hours, and spend 14 days sailing through occasionally icy Russian waters.

Now that the transit time is known, we can determine the number of ships necessary to ensure that each of the five ports benefits from a weekly departure (Table 2). Each ship traverses the loop in 37 days, accomplishing nearly 10 (actually 9.8) loops per year.

The NSR Express Schedule

Physical distance of the whole loop: 16 100 nm -

- Russian segment in Arctic waters (17 knots): 2 x 2 777 = 5 554 nm
- European and Asian segments (24 knots): 10 546 nm

Distance/time for the whole loop: 32 days -

- Arctic segment: 5 554/17 = 327 hours and 327/24 = 14 days
- Remaining segment: 10 546/24 = 439 hours and 439/24 = 18 days

Table 2. **NSR Express Port Call Schedule for the loop**

	Port	Transit time*
Eastbound	Hamburg	0
	Rotterdam	1
	Shanghai	17
Westbound	Shanghai	18
	Pusan	19
	Tokyo	21
	Hamburg	37

NSR Express:

A vessel completes a loop in **37 days**, serving **5 ports**.

It can therefore complete 9.8 loops in a year (=365/37).

To provide a weekly service, 52 sailings will therefore be needed 52/9.8 = 5.3 or **6 ships on rotation.**

* On the basis of port calls lasting 24 hours, although numerous variations are possible.

Mathematically, a fleet of 5.3 ships on this schedule is required to offer weekly departures at each port. But this calculation supposes the absence of buffer time, which is impossible. Climatic phenomena such as storms and cold snaps will disturb the schedule. One must also set aside time to deal with possible technical hazards, or simply to carry out any scheduled maintenance that cannot be done during the stops. There is also the possibility of encountering congestion in the terminals, quays and access lanes of a port, an eventuality which will introduce slight delays that cannot be made up simply by sailing faster. It would be foolhardy and costly to maintain a fleet of only 5.3 vessels on the NSR schedule - to avoid undermining client satisfaction when a ship falls behind schedule, replacements would have to be available every step of the way. Even if the mathematical solution were practical (for example, if exactly 5,3 ships were needed), it would not necessarily be financially tenable. It is far preferable to leave an operating margin so that hazards can be faced directly. In consequence, our model assumes that 6 ships are used on this schedule. The NSR Express schedule takes into account all the geographical dimensions and logistical constraints previously discussed. It is now time to determine the cost of operating this imaginary line of container transport.

4.2. Expected operating costs of a regular line

Shipping companies must continuously adjust their supply in response to growing international demand—they may deploy their capacities to growth sectors, or reduce their commitment to services that perform poorly. In this manner they remain active players in the internationalization of trade, and participate in the globalization of the economy. To this end, it is imperative to have a perfect mastery of the various costs in maritime transport. The objective of this section is to compute a base rate for one TEU of freight, so that the NSR can be compared to other axes linking Asia to Europe. The mode of operation presented above includes all the key features of a regular line on the NSR, but these points can be customized to reflect the strategies implemented by ship owners.

Vessel characteristics and the TEU offering

The category of container ship most frequently used for the Asia-Europe market is the so-called "5th generation". These 5th generation ships provide 52% more capacity compared with the 3rd or 4th generation based on an increase in vessel width (from 32.2m and 40m respectively to 42.8m) and the number of container stacks on the deck (from 13 to 17) (Notteboom and Rodrigue, 2008b). Such 5th generation ships, ranging approximately from 6 700 to 8 400 TEU, make maximum use of the capacity offered by the Panama Canal (Panamax). The NSR imposes no restrictions in terms of ship width, but draught cannot exceed 13 metres (depth of the strait of Sannikov). For this reason, it will not accommodate ships bigger than those of the 4th generation.

For the purposes of the present economic study, we have chosen a ship of Sambhar type, with a theoretical capacity of 4,000 TEU, operated by CMA-CGM, with a draught of 12.5m and a deadweight of 51 870. The daily charter rate is estimated at 32 000 USD. The selling price of this type of vessel with a suitable hull and the systems required for NSR navigation would not be far off 180 million USD. It is important to make clear that this type of ship offers a theoretical load capacity of 4 000 TEU but if all the containers are loaded to 14 tonnes, its capacity will be reduced to 2 800 TEU (the deadweight limit being reached). The potential for goods transfer and the competitiveness of this route will therefore be affected by factors relating to container weight, which will vary by the direction of travel. On the westbound leg, the load factor would be 100%, but eastbound, the empty returns containers and the low level of European exports would depress the load factor to 30%. Therefore, of a theoretical capacity of 8 000 TEU available for the two directions of travel, it is very likely that a shipping line can invoice only 2,800 TEU westbound and 1 200 TEU eastbound. It is worth noting that of the 4 000 TEU that can be invoiced, all will not receive payment of the same freight rate, since this will depend on the costumer and the direction, eastbound or westbound.

Ship depreciation

Ships using the NSR must have hulls capable of withstanding the shocks and friction by ice. This extra cost will be inversely proportional to the level of global warming and therefore to the reduction in the area of pack ice in the Arctic Ocean. In order to finance the procurement of this type of ship, shipowners make use of bank loans from companies such as Crédit Suisse Ship Finance, the German bank HSH Nordbank AG or the Norwegian DnB Nor Group, these being among the top ten in this sector. Generally speaking, bankers propose to shipowners, before or after delivery, loans covering between 60% and 80% of the market value of a new vessel. Such loans must be repaid before the 20th anniversary of the ship. The loans are indexed to the LIBOR rate (London Inter Bank Offered Rate), the average applied was 5.06% (from January to June 2008). To this rate, an additional margin varying according to the shipping line's reputation has to be added.

The charter market is highly volatile. A 4 000 TEU standard container ship that could be chartered for 10 000 USD a day in April 2002 would have seen its rate vary up to 45 000 USD a day in September 2005. The market appears to be more stable since January 2008, and has levelled out at around 32 000 USD a day (World Bank, 2008). This volatility can be explained by the existence of a dynamic economic environment that is a source of instability in the balance between supply and demand. While this result obviously depends on the evolving prices of raw materials and modern technologies, as of January 2008 the cost of operating a 4 000-TEU container vessel designed to navigate the NSR is estimated at 73 000 USD per day. In contrast, a similar ship navigating the Royal Road costs 32 000 USD per day. The bigger the vessel, the more profitable any port call needs to be. Serving five ports, the NSR Express line needs to take on around 2 000 TEU in Hamburg and Rotterdam, although obviously the return leg from the Asian ports raises few issues in terms of load factor or goods handling.

Crew and fuel

A 4 000 TEU ship with a conventional hull and 51 000 gross tonnage will burn 125 tonnes of fuel a day. For navigation at sea, IFO 380 fuel (Intermediate Fuel Oil) costs 420 USD per tonne (the Rotterdam index value recorded on Bunker World in February 2008). On the approach to port, the auxiliary engines will run with a lighter distillate than IFO, the MDO (Marine Diesel Oil, 717 USD per tonne). The MDO consumption represents the equivalent of 2% of the daily cost of heavy fuel oil (similar estimation for lubricant prices).

For our NSR Express liner service, bunkering costs for a loop will total 1 885 000 USD or 47 125 USD per day. A crew of 19 is required for a 4 000 TEU container ship (Drewry, 2007). The monthly cost of a crew of 19 can be estimated at 100 000 USD. These cost headings are quantified here at the lowest reasonably conceivable level. The Northern route will also require the installation of sophisticated navigation systems on board, for iceberg detection for example, as well as a high level of technical training for the officers (navigation in glacial waters). Seamen who have already worked in such extreme conditions will not find it difficult to profit from their experience, consequently obtaining higher wages than on the Royal Route.

Insurance cover and the limitations of P&I Clubs

Marine insurance covers three categories: hull, cargo and marine liability. Cargo and hull insurance – *i.e.* the ship and the goods it is carrying – are handled by commercial insurers whereas liability insurance is provided for 90% of vessels by mutual companies known as P&I Clubs. These mutual societies, which sprang from groupings of shipowners, provide compensation of the damage victims (transport users). P&I Clubs guarantee the ship's creditors that the owner will not be deprived of the operating revenue from the vessel due to confiscation since these mutual societies provide the necessary guarantees to allow such operation to continue. Concerning the navigation conditions on the NSR, ESA (European Space Agency) experts working in IICWG (International Ice Charting Working Group*)* are adamant: icebergs will continue to be a threat to ships in the years to come (Renfrow, 2006). Due to the extreme navigation conditions on the NSR, insurers such as Axa Corporation would not provide cover to clients (Maersk, CMA-CGM, etc.) wishing to run a regular shipping service. In the summary table that follows (Table 3), the average insurance cost figures come from the Drewry report.

Nevertheless, any insurance policy will need to take into account a fair value for the goods to be insured. The daily operating cost of a 4 000 TEU container ship providing the NSR Express liner service would be around 129 500 USD (Table 3). The value of the cargo it is carrying would be in the region of 100 million USD (the value of a 2 800 TEU load with each container holding 14 tonnes of general cargo worth 35 000 USD). Given this and taking due account of the direction of travel, the average value in a complete loop would be 133 million USD in terms of goods carried. With six ships on rotation providing a weekly frequency (9 loops, 37 days per ship), the shipowner would need to take out a policy providing cover for a total value of 7.5 billion USD including goods and ships. Face with the size of this number and the navigation difficulties on the NSR, we are forced to conclude that insurance is among the least predictable cost headings.

By evaluating the principal costs of exploiting a regular "NSR Express" line, we can calculate the cost of shipping an empty TEU by this route: 648 USD (Table 3). For a filled TEU the cost would likely depend on the direction of travel, due to differences in the volume of containers exchanged (fewer eastbound than westbound), and could increase by a factor of two in the worse case. Note that in the breakdown of Table 3, "ship" and "fuel" costs account for 93% of the total. In creating an actual schedule, determining the number of ships would therefore be one of the most important strategic points. This decision is related to the choice of operating speed for commercial runs, which plays into the "fuel" cost. (The faster a ship goes, the more fuel it consumes for an identical distance.) The "insurance" entry is set to about 2.5% of the total operating cost. Even taking into account our previous remark on the difficulty of estimating insurance premiums, we can deduce from this cost breakdown that even significantly higher premiums would have little impact on the cost of container transport by the NSR.

Determining the operating cost of a regular NSR line brings a useful perspective to our evaluation of this alternative route. However, these figures are not really interesting unless we compare them to other axes offered by the Asia-Europe transport network. The cost of shipping a filled TEU is a well-suited indicator for this sort of comparative analysis.

Table 3. **Operating costs on the Northern Sea Route**

Cost heading	Average cost USD/year	Average cost USD/loop	Average cost USD/day	Cost per filled TEU (USD) West- & Eastbound		Cost per empty TEU (USD)	Share of cost pct
(1) Ship	26 280 000	2 920 000	73 000	521	1 043	365	56.4
Fuel Oil	16 965 000	1 885 000	47 125	337	673	236	36.4
Crew	1 200 000	133 333	3 333	24	48	17	2.6
(2) Maintenance	460 800	51 200	1 280	9	18	6	1
P&I insurance	423 820	47 091	1 177	8	17	6	0.9
H&M insurance	420 000	46 667	1 167	8	17	6	0.9
(3) Other insurance	360 000	40 000	1 000	7	14	5	0.8
Lubricants	155 000	17 222	431	3	6	2	0.3
Management and sundry expenses	365 000	40 556	1 014	7	14	5	0.8
TOTAL	**46 629 620**	**5 181 069**	**129 527**	**925**	**1 850**	**648**	**100.0**

Sources : Drewry 2007, Russian P&I clubs

(1) Depreciation of a 4 000 TEU container ship costing 180 million USD.

(2) Calculation based on a daily cost of 631 USD in spare parts required for the maintenance and repair of a 4 000 TEU container ships, budget figure has been doubled here to take account of the specific nature of an “Arctic” vessel and, by the same token, its spares.

(3) The pack contains “War Risk + TDI Strikes + COFR/OP Surcharge + FD&D.

The transport of containerized products on the Asia-Europe market occurs mainly along the Royal Road, through the Suez Canal. It is also possible to move these goods by train, plane, or a combination of the two. These avenues of transport, currently used to relieve the Royal Road of its overflow, are likely to become more important in years to come due to Russia’s heavy investment in the Trans-Siberian Railway and improvements in the performance of sea-air transport.

A new axis passing through the Arctic Ocean would be rather similar to the Royal Road in that the route is almost entirely maritime. Of course, the determining factor for any decision on the matter is generally economic. Below we propose a detailed comparison of the costs involved in transporting a single TEU along the various axes between Asia and Europe. This comparative study assumes a route running from Hamburg to Shanghai, with a stopover in Frankfurt for the air and sea-air modes. First and foremost, our results reveal the attractiveness of the Royal Road (Table 4) from a cost standpoint. However, its inadequacy in terms of the physical distance and time required is also manifest. It would thus appear difficult for the NSR to compete with the Royal Road. Interestingly, rail transport is actually the closest competitor to shipping along the NSR, assuming that the fees imposed by the Trans-Siberian railroad (these figures were unavailable) do not exceed those of the NSRA.

Table 4. **Multimodal alternatives between Shanghai and Hamburg port / Frankfurt airport**

Cost heading	Royal Route (via Suez)	Trans-Siberian Railway	NSR	Sea & air (via Dubai)		Air (Direct)
Mode	Sea	Rail	Sea	Sea	Air	Air
Distance (nautical miles)	10 200	5 375	7 700	5 910	2 690	4 345
Transport time (door-to-door)	28-30	18-20	18-20	13	2	2
Average speed (knots)	24	54	17-24	24	486	486
Type of transport used	CS	Unit train	Special CS	CS	Cargo aircraft	Cargo aircraft
Carrying capacity (TEU à 14 t)	9 600	110	2 800	7 200	8	8
(1) Capacity supply (TEU/year/unit)	124 800	1 980	72 000	216 000	832	832
Approximate rates (USD/TEU)	1 000	1 800 – 2 200	2 000	15 000		48 500
Estimated surcharges (USD/TEU)	400-800	Not determined	500-800	10 000		22 500
TOTAL (USD/TEU)	**1 400-1 800**	**1 800-2 200**	**2 500-2 800**	**25 000**		**71 000**
Baseline 100, Royal Route	**100**	**+ 30%**	**100%**	**+ 1 500%**		**+ 5 000%**

(1) Based on a weekly service frequency

CS = Containership

5. Conclusion

The creation of regular transport lines along the Northern Sea Route is a real possibility for the near future. Several criteria confirm the pertinence and feasibility of container transport along this international route. Global warming is opening the door to regular lines on the Arctic Ocean, thanks to the progressive lifting of technical constraints on navigation (*i.e.* the ice sheets are melting). In addition, the ongoing changes in business localisation strategies are tending to increase the separation between production centres and consumer markets for certain families of products. This new geography of places and flows, reflecting changes on a planetary scale, reinforces the advantages of the Northern Sea Route. In effect, this new axis of transport would reduce the distance/time required to move goods between the ports of northern Asia and those of northwestern Europe. These conclusions are supported by a detailed economic analysis of a model container ship schedule plying the Northern Sea Route. The estimated cost of exploiting a regular line on this axis justifies the transport of containerised products between Asia and Europe.

In this paper, a model schedule between Shanghai and Hamburg was used to compare the cost of transporting one container (TEU) along various axes of the commercial network. The cost of conveying a container along the Northern Sea Route is not prohibitive, despite the fact that the operational costs of the line would be relatively high. The specificity and rarity of container ships capable of taking this route weighs heavily on expenses, such that the cost of one TEU is about twice as high on the Northern Sea Route as on the Royal Road. We can therefore deduce that the Northern Sea Route is a viable alternative to the Royal Road for container transport. The Suez Canal is expected to see several improvements in years to come, so that it may accommodate the increasing flux of containers between Asia and Europe. During periods of construction, however, as well as in anticipation of future demand, it is important to increase the capacity of the international commercial network. Our research has shown that along with the Trans-Siberian Railway, the Northern Sea Route is capable of preserving the flow of containerised products through this network. While shipping through the Suez Canal is still by far the least expensive option, the Northern Sea Route and Trans-Siberian Railway appear to be roughly equivalent second-tier alternatives.

Our empirical work also illustrates certain theoretical results related to the economics of networks. When analysis of an economic environment reveals the structural growth of traffic, it becomes necessary to develop new connections in the network. This study has brought to light important findings on the feasibility of container transport via the Northern Sea Route. We recognize, however, that this research has certain limitations. First of all, as the economic environment is continuously evolving, any results based on our model schedule are subject to change. The various expenses contributing to the global cost of exploitation are likewise time-dependent and directly linked to independent external factors (the price of raw materials, notably that of a barrel of oil; political instability; etc.). Second, all this discussion rests upon a complex, uneven, variable, and uncertain planetary process whose eventual outcome remains beyond our knowledge: the climate. Due to the paucity of reliable results on this subject, other qualitative and quantitative studies of container transport via the Northern Sea Route are doubtless necessary.

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