Arctic shipping: a systematic literature review of comparative studies

Abstract

Following the gradual decline of Arctic sea ice, shipping using Arctic routes increased from 2010. This led to an upsurge in the number of studies investigating the potential of Arctic maritime routes. A systematic literature review was conducted to assess the extant literature from 1980 to 2017 on comparative studies between Arctic and traditional routes. This review also aimed to provide an initial understanding on route choice decision-making factors and to contribute to the literature by providing suggestions for future research and methodological considerations. The competitiveness of Arctic routes is evaluated from both economic and environmental perspectives. Research themes and methodological characteristics are analysed in order to establish an evidence base in Arctic shipping literature. It is identified that analytical research methods and transport cost models are mainly employed. The results indicate that although Arctic routes can be more cost-effective and energy efficient compared to traditional ones, especially in the long-term, they can mainly serve as seasonal alternatives for bulk and specialised shipping in the short-term.

Keywords: systematic literature review; Arctic shipping; maritime routing; economic and environmental assessment; methodological characteristics; decision-making factors

1. Introduction

Arctic routes could reshape maritime transport geography with respect to global container shipping networks and tramp shipping. The implications for liner shipping could be a possible reconfiguration of existing networks or the launch of new ones depending on the origin-destination (OD) pairs. For bulk and specialised shipping, this could mean the opening of new routes for transport of raw materials, refined products and refrigerated cargoes between ports in Northwest Europe, the Baltic and the Arctic to Northeast Asia. The gradual change in Arctic sea ice conditions could potentially open up opportunities for the more frequent use of polar routes. Increased accessibility could facilitate shorter transit times, lower fuel and overall costs, improve network connectivity and lower carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions. According to recent studies projecting future accessibility to the Arctic, more routeing alternatives for both the Northern Sea Route (NSR) and the Northwest Passage (NWP) will become available by 2050 for non-ice class vessels. The Transpolar Sea Route (TSR) will also become accessible for Polar Class 6 (PC6) vessels by that time (Smith and Stephenson, 2013; Melia et al., 2016). The possibility of operating via the TSR increases by mid-century, even for non-ice class vessels (Melia et al., 2016).

According to Eguíluz et al. (2016), in 2014 shipping activity in Arctic waters accounted for 9.3% of global shipping traffic (including domestic, destination and transit traffic). This included 5.9% of dry bulk and general cargo and 4.2% of liquid bulk cargo. A steep increase in transit traffic (i.e. voyages between the Atlantic and the Pacific) through the NSR was recorded between 2011 and 2014 followed by a sharp decline in 2015. The average duration of the sailing season was between 4 and 5 months (Zhang et al., 2016). To date domestic and destination shipping predominate with bulk and general cargo being the main drivers behind the emergence of this route (Zhang et al., 2016).

Arctic shipping is an emerging topic within maritime transport research, demonstrating an exponential increase in publications during the last ten years. Lasserre (2014; 2015) identified 26 comparative studies between Arctic and traditional routes from 1991 to 2013. Meng et al. (2016) reviewed 25 studies regarding navigational and commercial perspectives. However, to

date, there has not been any systematic literature review evaluating the economic feasibility of Arctic routes. Moreover, no account has been taken of studies reporting on the environmental assessment of these routes. Further, the aforementioned studies focus on research aspects and do not discuss the research methodological characteristics. The large number of discrepancies and differing assumptions regarding the parameters and results of the studies identified by Lasserre (2014; 2015) stress the need to evaluate the literature in a systematic way in order to identify factors that affect the viability of Arctic routes and add complexity to the route choice decision-making process.

This study systematically reviews the extant literature regarding comparative studies between the Arctic and traditional routes from both economic (costs, profits) and environmental (emissions) perspectives between 1980 and 2017. The current state of Arctic shipping literature is evaluated in order to establish a new evidence base, and to suggest areas for future research, and various methodological approaches. This review also serves as the starting point for developing a conceptual framework of route choice decision-making factors which could be used in future research within the context of Arctic maritime routeing by including other sea and non-sea based routes.

The following research questions were formulated in order to address the objective of this study:

MAIN RQ: According to the extant literature, what is the cost effectiveness, and what is the likely impact on emissions, of using Arctic compared to traditional routes, between 1980 and 2017?

Two further sub-questions were developed for the purposes of this study:

RQ1: Which research methods and data analysis techniques are employed to address the research questions in comparative studies on Arctic shipping literature?

RQ2: What are the emerging issues that need to be addressed?

The remainder of this paper is organised as follows: First, the methodology used in the systematic review is explained. Subsequently, general statistics, methodological characteristics, and route choice decision-making factors are discussed and recommendations for future research made. Conclusions are drawn by reflecting on research gaps identified and methodological issues.

2. Review methodology

This study adopted the review design for systematic literature reviews in the field of management and business studies proposed by Tranfield et al. (2003). A systematic review of the literature is based on comprehensive and unbiased searches of relevant studies by explicitly formulating review questions and using specific search terms and inclusion criteria for that purpose. The findings are synthesised through various approaches in order to identify emerging themes, key results or any links to theory or concepts (Ibid, 2003). Traditional routes and oceanic canals dominate bulk shipping and determine connectivity in global liner networks. However, the emergence of new hubs (Notteboom, 2012), future canal development or expansion (Yip and Wong, 2016; Rodrigue and Ashar, 2016, Martinez et al., 2016) and the potential opening of polar routes (Tavasszy et al., 2011) could redefine the maritime transport geography landscape and increase maritime flows and network diversity (Ducruet, 2013). On the one hand, economic and environmental sustainability in shipping is achieved by employing vessels on traditional maritime routes and shipping canals. Different approaches to make

shipping more cost-effective and greener include: slow steaming (e.g. Corbett et al., 2009; Notteboom and Vernimmen, 2009), scheduling optimisation (Lam, 2010), expansion of existing canals (De Marucci, 2012) or new ship sizes and designs (Knowles, 2006, Lindstad et al., 2013). On the other hand, Arctic routes could potentially become a viable alternative option to the classical shipping routes and canals so as to address both the economic and environmental sustainability in shipping, possibly by reducing the extent of the trade-offs involved between the latter two (Mansouri et al., 2015). All else being equal, the comparative advantage of Arctic routes stems from the fact that shorter geographical distances mean shorter transit times and operating costs, higher service frequency, potentially lower fuel consumption, which in turn means lower voyage costs, as well as lower CO_2 and GHG emissions.

2.1 Search strategy

Arctic shipping literature contains studies spanning a broad spectrum of issues including economics, legal, geopolitics, geo-economics, climatic and technical and is informed by various disciplinary bases. The research scope of this review was narrowed according to the research questions so as to include only papers reporting original results on the economic (costs, profits) or environmental (emissions) assessment of Arctic routes compared to traditional ones. According to David and Han (2004), quality control is increased only by restricting the searches to journal papers and therefore excluding unpublished studies or book chapters.

Scopus was used for the initial scoping searches. Title, abstract and keywords of a sample of papers were searched covering all subject areas (fields of study) without specifying the period. The initial keywords used in Scopus were "arctic shipping "OR "northern sea route" OR "northwest passage", and resulted in 512 documents across a large range of disciplines. Abstracts of a sample of relevant papers were subsequently read and keywords were refined according to the aim and review questions of the study. Major shipping canals and maritime routes were used as keywords, as well as variations of terms that have similar meanings. The final set of keywords employed in the searches is presented in Table 1.

Table 1. List of keywords used in the systematic review

arctic shipping	Nicaragua(n) Canal	Ship* canal(s)
Cape Horn	Northeast Passage	Ship* corridor(s)
Cape of Good Hope	Northwest Passage	Ship* lane(s)
Magellan Strait(s)	Northern Sea Route	Ship* passage(s)
Maritime canal(s)	Panama Canal	Ship* route(s)
Maritime corridor(s)	Sea canal(s)	Ship* strait(s)
Maritime lane(s)	Sea corridor(s)	Strait(s) of Magellan
Maritime passage(s)	Sea lane(s)	Suez Canal
Maritime route(s)	Sea passage(s)	transpolar passage
Maritime strait(s)	Sea route(s)	transpolar sea route
	Sea strait(s)	

*ship or shipping

Relevant publishers and databases were covered such as Elsevier, Emerald Insight, Taylor & Francis, Cambridge Journals and Springer/Palgrave Macmillan. Two additional journals were identified: the *Journal of Maritime Research* (JMR) and the *International Journal of Transport Economics* (IJTE) that were not found in these databases. To ensure that the extant literature from 1980 to 2017 was covered, the searches were extended to include Thomson Reuters' database Web of Science, as well as the reference lists of the retrieved papers.

A total of 33 unique papers were retrieved and analysed based on their methodological and research considerations. Descriptive analysis is used to discuss the classification of the

reviewed papers in publications per journal; total number of papers published per decade; total number of papers per country as well as the methodological considerations such as research methods and data analysis techniques reported in the data. Narrative synthesis is used for the analysis of the research considerations whilst the results are classified based on Stopford's cash flow model (Stopford, 2009).

3. Results

3.1 General statistics

Figure 1 shows the number of papers published from 1980-2017 included in the review. It is noticeable that a small number of papers assessed the potential of Arctic routes during the 1980s and most importantly from 1991 to 2000. Nevertheless, the lack of research interest during that period could be attributed to the underutilisation of Arctic routes and the lack of interest from the shipping industry in general. Of the 33 papers reviewed, two were published in the 1990s, seven between 2001 and 2010 and 24 between 2011 and 2017.

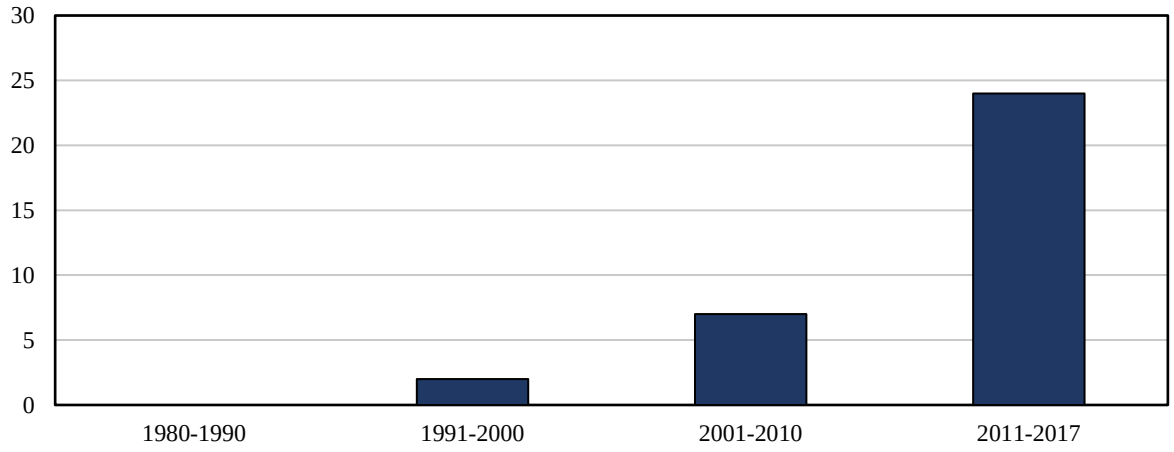

Fig. 1. Number of articles published between 1980 and 2017

This rising trend of publications appears to be consistent with the view that scholarly research followed the recent developments regarding the utilisation of Arctic routes. For instance, it was only in 2011 onwards that an increasing number of non-Russian flagged vessels started to use the Northern Sea Route (NSRIO, 2018). The 33 papers selected for this review were published in 22 journals. The *Journal of Transport Geography* and *Transportation Research Part A: Policy and Practice* have the most frequent publications followed by *Maritime Policy & Management* and *Maritime Economics & Logistics*, whereas the remaining journals each published one paper between 1992 and 2017 (Table 2).

Table 2. Number of articles published per academic journal

Country	No. of Articles
Journal of Transport Geography	5
Transportation Research Part A: Policy and Practice	5
Maritime Policy & Management	3
Maritime Economics & Logistics	2
European Journal of Operational Research	1
International Journal or Production Economics	1
The Asian Journal of Shipping and Logistics	1
International Journal of e-Navigation and Maritime Economy	1
International Journal of Geographical Information Science	1

Journal of Maritime Research	1
Transport Policy	1
Polar Record	1
Journal of Navigation	1
International Challenges	1
Journal of Ocean Technology	1
Applied Mechanics and Materials	1
Advanced Science Letters	1
Transportation Research Board	1
Ambio	1
Climatic Change	1
Izvestiya, Atmospheric and Oceanic Physics	1
Journal of Nuclear Science and Technology	1

Twelve countries have contributed to Arctic shipping research concerning the economic and environmental assessment of Arctic routes (Table 3). The selection of countries was based on the country of affiliation of the first author of each paper. Canada and China have the biggest contributions whereas Germany and Singapore have the lowest rate of contribution with one paper each.

Table 3. Contribution of publications based on country affiliation

Country	No. of Articles
Canada	5
China	5
Norway	4
France	3
Taiwan	3
The Netherlands	3
Japan	2
Russia	2
USA	2
South Korea	2
Germany	1
Singapore	1

3.2 Methodological considerations

The categorisation extended to include the methodological characteristics of the reviewed papers, such as research methods and data analysis techniques. Arctic shipping is a topic within maritime transport research rather than a discipline per se. However, the differing assumptions reported in the extant literature regarding the cost assessments and determinant factors influencing route choice decision-making, as well as the growing trend of addressing the main research questions through different methodological perspectives, all stress the need to explore the methodological background of these studies apart from the research considerations.

3.2.1 Research methods

The categorisation scheme of research methods was adopted from Wacker (1998). In empirical research, data from the 'real world' are used in order to verify the relationships under investigation by using an inductive approach to theory, whereas in analytical research, logic,

mathematics and/or statistics are primarily employed by using a deductive approach to theory to reach a conclusion (Wacker, 1998). Analytical mathematical methods (modelling or simulation) were reported in 27 papers, whereas empirical statistical and case studies were found in four and two papers respectively (Table 4).

Analytical modelling and simulation are used with the aim to develop mathematical relationships to explain the behaviour of real-world systems by investigating the performance of dependent variables or models under different conditions (Meredith et al., 1989). Papers that used transport cost models, optimisation or mathematical simulation techniques through case examples and Multi-Criteria Analysis belong to the category of analytical mathematical methods.

Empirical statistical research aims at verifying theoretical relationships by analysing large samples of data from real business processes (Wacker, 1998). Studies that employed regression analysis or structural modelling fall under this research methodology. Case studies focus on a specific phenomenon with the aim of revealing empirical relationships and usually serve for exploration in the early stages of research. They are also used to examine dependent variables under different scenarios or to provide counter-arguments to prior hypotheses or even to come up with new insights in debatable areas (Meredith et al., 1989). Papers classified under this research method have not made use of data analysis techniques.

3.2.2 Data analysis techniques

According to Sachan and Datta (2005), analytical techniques aid the researcher to deal with the summation of large amounts of data, identification of causal relationships and exploration of the effects on the outcome on alternative scenarios. Optimisation models were reported in four papers. Regression and Monte Carlo simulation accounted for three and two papers respectively, whereas logit model, Multi-Criteria Decision-Making (MCDM), GIS simulation and structural economic modelling accounted for one paper each. On the other hand, 18 studies focused on general scenario-based transport cost models rather than employing specific data analysis techniques (Table 4). Woo et al. (2011) argued that some techniques are employed for particular problems and topics and therefore this could explain the emergence of more purpose specific techniques (e.g. SEM, DEA, logit models) apart from descriptive statistics in port research between 1980s-2000s.

In a similar vein, it could be argued that scenario-based cost models and optimisation techniques, to a lesser extent, are prevalent in the literature because of the attention that researchers give to the investigation of the overall competitiveness of Arctic routes over the traditional ones. Thus, they have focused on specific aspects and operational problems and provided new insights and counter-arguments by capitalising on the various modelling approaches developed between 1992 and 2017. At the same time researchers from various disciplinary backgrounds have been trying to address their research questions through more sophisticated techniques. Nevertheless, Arctic shipping is an emerging topic within maritime transport research and it is expected that new techniques will emerge in the future to address specific research inquiries. Besides, it was only from 2011 that model-based techniques other than transport cost models have been employed extensively, except for two papers reporting Monte Carlo simulation between 2007 and 2009.

Table 4. Methodological considerations of the reviewed articles

Methodological Characteristics	Categories	No. of articles
Research Methods	Analytical Mathematical	27
	Empirical Statistical	4
	Empirical Case Study	2
Data Analysis Techniques	Transport cost model	18
	Optimisation model	4
	Regression analysis	3
	Monte Carlo simulation	2
	Logit model	1
	Multi-Criteria Decision-Making	1
	GIS simulation	1
	Structural Economic Model	1
	None	2

3.3 Research considerations

This section describes the results of the review through a narrative synthesis approach. The emphasis lies in the problems investigated and areas explored in the literature. The basic attributes of the reviewed studies such as routes, transport systems, comparison mode, and period of operations as well as the origin-destination (OD) pairs are reported in Table 5.

3.3.1 Routes, transport systems and OD pairs

The majority of the reviewed papers undertook an assessment of the NSR (22), six studies displayed the choice of the NWP, four assessed both routes and one tackled with the feasibility of both the NSR and the TSR. Eight studies included environmental assessments based on either CO_2 emissions or other relevant GHG emissions. Most of them juxtaposed Arctic routes with the Suez Canal route (27), seven of them chose the route via the Panama Canal and one considered the route via the Cape of Good Hope amongst others. Three papers reported the Trans-Siberian Railway, one an all-air route, five papers included intermodal routes (sea-air/sea-rail/truck-rail) as alternatives, whereas three studies examined a combined schedule (summer season in the NSR and winter season in the Suez Canal route).

Liner shipping is the dominant transport system studied (20 studies), six studies selected dry bulk segments, three studies examined oil tanker segments, two studies dealt with liquefied natural gas (LNG) tanker shipping, and two studies investigated both liner and bulk shipping. The OD pairs vary widely in terms of the ports chosen by the identified studies. The majority of the reviewed papers focus on origins in Northwest Europe and destinations in East Asia, one included a large number of ODs whilst some others opted for ports in Russia, USA, Mexico and Canada.

Table 5. Comparative studies between Arctic and traditional routes

Author(s) and year	Title	Journal	Comparison & Scope	Transport Systems	Routes	Time frame of operations	Origin-Destination Pairs
Wergeland (1992)	The northern sea route – rosy prospects for commercial shipping?	International Challenges	Transport costs per tonne per month in US$	Liner Shipping (Multi-purpose)	Northern Sea Route – Suez Canal & Panama Canal	Single leg voyage	1. Dutch Harbour – Hamburg 2. Hamburg – Yokohama
Kondo and Takamasa (1999)	The economic potential of a cassette-type-reactor installed nuclear ice-breaking container ship	Journal of Nuclear Science and Technology	Transport costs per TEU per year in US$ & per 20/40-year period; Total Shipper's Costs; Emission taxes included	Liner Shipping	Northern Sea Route – Suez Canal	Year-round (20- and 40-year period)	Hamburg – Yokohama
Guy (2006)	Evaluating the viability of commercial shipping in the Northwest Passage	Journal of Ocean Technology	Transport costs and profits in US$	Liner & Bulk Shipping (Dry)	Northwest Passage – Suez Canal	Single leg voyage	1. Rotterdam – Shanghai 2. Arctic region –?
Somanathan et al. (2007)	Feasibility of a sea route through the Canadian arctic	Maritime Economics & Logistics	Required freight rate (RFR) per TEU in US$	Liner Shipping	Northwest Passage – Panama Canal	Year-round	1. New York –Yokohama 2. St. Johns, Newfoundland – Yokohama
Somanathan et al. (2009)	The Northwest Passage: A simulation	Transportation Research Part A: Policy and Practice	Required freight rate (RFR) per TEU in US$	Liner Shipping	Northwest Passage – Panama Canal	Year-round	1. New York –Yokohama 2. St. Johns, Newfoundland – Yokohama
Verny and Grigentin (2009)	Container shipping on the Northern Sea Route	International Journal of Production Economics	Transport costs per TEU in US$	Liner Shipping	1. NSR – SCR 2. Trans-Siberian Railway 3. Sea and air 4. All-air	Year-round	1. Hamburg – Shanghai (eastbound stop at Rotterdam, westbound stops: Pusan, Tokyo) 2. via Dubai (Sea and air)
Liu and Kronbak (2010)	The potential economic viability of using the Northern Sea Route (NSR) as an alternative route between Asia and Europe	Journal of Transport Geography	Profits per year in US$	Liner Shipping	Combined use of Northern Sea Route and the Suez Canal – Suez Canal	1. Year-round for SCR 2. Combined: Three, six and nine month periods for the NSR and the rest on SCR	Rotterdam – Yokohama
Khon and Mokhov (2010)	Arctic climate changes and possible conditions of Arctic navigation in the 21st century	Izvestiya, Atmospheric and Oceanic Physics	Transport costs per year in US$	Liner Shipping (Multi-purpose)	Northern Sea Route – Suez Canal	Year-round (end of 21st century)	Western Europe – Far East

Author(s) and year	Title	Journal	Comparison & Scope	Transport Systems	Routes	Time frame of operations	Origin-Destination Pairs
Khon et al. (2010)	Perspectives of Northern Sea Route and Northwest Passage in the twenty-first century	Climatic Change	Transport costs per year in US$	Liner Shipping (Multi-purpose)	Northern Sea Route – Suez Canal	Year-round (end of 21st century)	Western Europe – Far East
Schøyen and Bråthen (2011)	The Northern Sea Route versus the Suez Canal: cases from bulk shipping	Journal of Transport Geography	Transport costs per metric tonne (mt) in US$; CO_2 emissions assessment	Bulk Shipping (Dry)	1. Northern Sea Route – Suez Canal & Cape of Good Hope 2. NSR – SCR	Single leg voyage	1. Porsgrunn (Norway) – Shekou (China) 2. Narvik (Norway) – Qingdao (China)
Tavasszy et al. (2011)	A strategic network choice model for global container flows: specification, estimation and application	Journal of Transport Geography	Container flows in TEU; Transport costs per TEU/km in US$		NSR & NWP? & many other global land- and sea-based routes	Year-round	437 ports
Xu et al. (2011)	The potential seasonal alternative of Asia–Europe container service via Northern sea route under the Arctic sea ice retreat	Maritime Policy & Management	Transport costs in US$	Liner Shipping	Combined use of Northern Sea Route and the Suez Canal – Suez Canal	1. Year-round for SCR 2. Combined schedule including a seasonal transit via the NSR	Series of ports between North-west Europe and East Asia (including Taiwan)
Fan et al. (2012)	Impacts of new routes and ports on spatial competition for containerized imports into the United States	Maritime Policy & Management	Transport costs per TEU in US$; Container Flows in TEU	Liner Shipping	1.Trans-Pacific to US West Coast 2. Panama Canal-Gulf/US East Coast 3. NWP – US East Coast 4. Trans-Atlantic – Gulf/US East Coast 5. US & Canadian Inland rail/truck corridors	Seasonal: One third of the year on the NWP Annual for all other routes	31 US Ports Canadian Ports: Vancouver, Prince Rupert, Halifax, Montreal, Toronto Mexican West Coast Ports: Manzanillo, Lazaro Cardenas, Punta Colonet
Song and Zhang (2013)	The economy analysis of sailing in the arctic Northeast Passage	Applied Mechanics and Materials	Required freight rate (RFR) per tonne in US$	Bulk Shipping (Oil Tanker)	Northern Sea Route – Suez Canal	Summer season (100 days)	Murmansk – Shanghai
Lasserre (2014)	Case studies of shipping along Arctic routes. Analysis and profitability perspectives for the container sector	Transportation Research Part A: Policy and Practice	Transport costs per TEU in US$	Liner Shipping	1. Northern Sea Route – Suez Canal 2. Northwest Passage – Suez Canal	Summer season (six months)	1. Rotterdam – Shanghai/ Yokohama 2. Rotterdam – Shanghai/Yokohama

Author(s) and year	Title	Journal	Comparison & Scope	Transport Systems	Routes	Time frame of operations	Origin-Destination Pairs
Raza and Schøyen (2014)	The commercial potential for LNG shipping between Europe and Asia via the northern sea route	Journal of Maritime Research	Transport costs per tonne and MMBtu in US$	Specialised Shipping (LNG tanker)	Northern Sea Route – Suez Canal	Round voyage	Hammerfest (Norway) – Tobata (Japan)
Lu et al. (2014)	An Economic Analysis of Container Shipping through Canadian Northwest Passage	International Journal of e-Navigation and Maritime Economy	Transport costs in US$	Liner Shipping	Northwest Passage – Panama Canal	Single leg voyage	New York – Busan
Lasserre (2015)	Simulations of shipping along Arctic routes: comparison, analysis and economic perspectives	Polar Record	Transport costs per TEU in US$	Liner Shipping	1. Northern Sea Route – Suez Canal 2. Northwest Passage – Suez Canal	Summer season (six months) & Year-round	1. Rotterdam – Shanghai & Rotterdam – Yokohama (Both NSR and NWP) 2. Rotterdam – Yokohama (Year-round, NSR, NWP)
Furuichi and Otsuka (2015)	Proposing a common platform of shipping cost analysis of the Northern Sea Route and the Suez Canal Route	Maritime Economics & Logistics	Transport costs per TEU in US$; CO_2 emissions assessment	Liner Shipping	Combined use of Northern Sea Route and the Suez Canal – Suez Canal	1. Year-round for SCR 2. Combined: 105; 135; 165; 195; 225 days in NSR and the rest on SCR	Hamburg – Yokohama
Moon et al. (2015)	A study on competitiveness of sea transport by comparing international transport routes between Korea and EU	The Asian Journal of Shipping and Logistics	Transport costs per TEU in US$ Other quantitative and qualitative factors	Liner Shipping	Trans-Korean Railway/Trans-Siberian Railway – NSR – SCR	Single leg voyage	Busan – Berlin
Fan et al. (2015)	Risk analysis in port competition for containerized imports	European Journal of Operational Research	Container import flows; Transport costs per TEU in US$	Liner Shipping	Same as in Fan et al. (2012)	Year-round?	Same as in Fan et al. (2012)
Chou et al. (2015)	The impact on the operation costs of bulk ship after the opening of the arctic route	Advanced Science Letters	Transport costs in US$	Bulk Shipping (Dry)	Northern Sea Route – Suez Canal	Single leg voyage	Kaohsiung/Keelung/ Shanghai/Busan – Rotterdam
Chang et al. (2015)	Route planning and cost analysis for travelling through the Arctic Northeast Passage using public 3D GIS	International Journal of Geographical Information Science	Transport costs in US$	Bulk Shipping (Dry)	Northern Sea Route – Suez Canal	Single leg voyage	Series of ports between North-western Europe and Northeast Asia
Cariou and Faury (2015)	Relevance of the Northern Sea Route (NSR) for bulk shipping	Transportation Research Part A: Policy and Practice	Transport costs in US$; Carbon tax included	Bulk Shipping (Dry)	Northern Sea Route – Suez Canal	Single leg voyage	Porsgrunn (Norway) – Shekou (China)

Author(s) and year	Title	Journal	Comparison & Scope	Transport Systems	Routes	Time frame of operations	Origin-Destination Pairs
Lindstad et al. (2016)	Economic savings linked to future Arctic shipping trade are at odds with climate change mitigation	Transport Policy	Transport costs per tonne in US$; Emissions assessment	Bulk Shipping (Dry)	Northern Sea Route – Suez Canal	N.A.	Asia – Europe (Not specified ports)
Pruyn (2016)	Will the Northern Sea Route ever be a viable alternative?	Maritime Policy & Management	Transport costs/charter rates per tonne in US$	Bulk Shipping (Dry)	Northern Sea Route – Suez Canal	Year-round	Baltic/Hamburg and Le Havre Range – China/Southeast Asia
Zhao et al. (2016)	Study on China-EU container shipping network in the context of Northern Sea Route	Journal of Transport Geography	Profits per year in US$	Liner Shipping	Northern Sea Route – Suez Canal	Year-round	Series of ports between North-western Europe (including Spain) and Northeast Asia
Zhao and Hu (2016)	Study on economic evaluation of the northern sea route: taking the voyage of Yong Sheng as an example	Transportation Research Board	Transport costs in US$; Emissions assessment	Liner Shipping (Multi-purpose)	Northern Sea Route – Suez Canal	Year-round & Single leg voyage	Taicang (China) – Rotterdam (The Netherlands)
Zhang et al. (2016)	Shipping efficiency comparison between northern sea route and the conventional Asia-Europe shipping route via Suez Canal	Journal of Transport Geography	Transport costs per tonne in US$ and profits per TEU in US$	Liner & Bulk Shipping (Oil Tanker)	Northern Sea Route – Suez Canal	Round voyage for both cases	Liner Shipping: Shanghai – Rotterdam (including stopovers) Bulk Shipping: Mongstad (Norway) – Mizushima (Japan)
Faury and Cariou (2016)	The Northern Sea Route competitiveness for oil tankers	Transportation Research Part A: Policy and Practice	Transport costs in US$ and transit time per month	Bulk Shipping (Oil Tanker)	Northern Sea Route – Suez Canal	June – February (Lower Bound) July – December (Higher Bound)	Murmansk (Russia) – Daesan (South Korea)
Wang et al. 2016	Comments on "Case studies of shipping along Arctic routes. Analysis and profitability perspectives for the container sector"	Transportation Research Part A: Policy and Practice	Transport costs per TEU in US$ (In-transit inventory costs included)	Liner Shipping	1. Northern Sea Route – Suez Canal 2. Northwest Passage – Suez Canal	Summer season (six months)	1. Rotterdam – Shanghai/Yokohama 2. Rotterdam – Shanghai/ Yokohama
Chou et al. (2017)	Fuel consumption ratio analysis for transiting from various ports and harbours in Asia through the Northern Sea Route	The Journal of Navigation	Fuel consumption per TEU; CO_2 emissions per TEU	Liner Shipping	Northern Sea Route – Suez Canal	Single leg voyage	Rotterdam – Busan/Yokohama/ Shanghai/Kaoshiung/ Hong Kong/ Singapore
Schröder et al. (2017)	Environmental impact of exhaust emissions by Arctic Shipping	Ambio	Fuel consumption in t/day Emissions in kg/voyage	Bulk & Specialised Shipping (Oil & LNG Tanker)	NSR (Three sub-routes) – TSR – SCR	Single leg voyage April/July/ September/ November 1960/2000/2040	Rotterdam – Yokohama

3.3.2 Cost, operational and revenue factors

A breakdown of the cost structure according to Stopford's (2009) cash flow model and other operational characteristics was further attempted in order to expound the assumptions, based on which these studies determined the competitiveness of Arctic routes (Appendix A). The operating costs discerned from the reviewed papers are crew wages, insurance, and repair and maintenance. The voyage costs or factors which affect them are fuel consumption, speed, bunker fuel prices and transit fees. Further, capital costs were reported, including additional expenses (premium) required for an ice-class vessel (vessel equipped with an enhanced hull and other arrangements to be able to sail in icy waters). The ship revenue factors are operating speed, ship size and ice-class and dwt utilisation (Stopford, 2009, p. 220).

Five studies merely report additional operating costs for either the NSR or the NWP without providing a more detailed analysis on the specific elements of these costs. Guy (2006) assumed trip charter premiums between 15-200%, reflecting increased operating and capital costs of an ice-strengthened vessel. In a similar vein, Schøyen and Bråthen (2011) asserted that when considering Arctic maritime operations in the NSR, then a 20% premium should be applied in the usual operating expenses whilst Zhang et al. (2016) and Faury and Cariou (2016) used the same premium for oil tankers in their study.

Increased crew costs range from 10% (Liu and Kronbak, 2010; Lasserre, 2014; Zhao et al., 2016; Zhang et al., 2016) to 28% (Song and Zhang, 2013). Five studies did not include crew costs (Xu et al., 2011; Raza and Schøyen, 2014; Lu et al., 2014; Chang et al., 2015; Pruyn et al., 2016). It is possible that most of these studies assumed that manning costs are same regardless of the route, whilst others considered differences depending on the route but these could not be discerned from their assumptions. Higher repair and maintenance costs were assumed at a range of 20% (Zhang et al., 2016) to 100% (Verny and Grigentin, 2009, Liu and Kronbak, 2010) in most of the cases.

Most of the papers incorporated insurance premiums related to Hull and Machinery (H&M), and Protection and Indemnity (P&I) insurance. The insurance premiums discerned from the review range from 5% (Song and Zhang, 2013) to 50-80% (Lasserre, 2015) concerning both the H&M and P&I. Pruyn (2016) assumed a 100% premium for P&I and a 200% premium for H&M whereas Zhao et al. (2016) and Zhang et al. (2016) included 25% premium for P&I and 100% and 50% for H&M respectively in the case of ice class containerships. Xu et al. (2011) assumed a NSR with less prevalent ice conditions and hence they went for non-ice class vessels and same insurance costs in both routes. Furuichi and Otsuka (2014) adopted a premium of 10 US$/GT per year and a piracy premium of 40 US$ per TEU.

Five of the studies referring to the NWP did not include any ice breaking fees (Somanathan et al., 2007; 2009; Lasserre, 2014; 2015; Lu et al., 2014). Five studies referring to the NSR assumed discounted fees which are in accordance with some references from shipping operators: they range from 3 US$/tonne (ballast) to 6.8 US$/tonne (laden) (Raza and Schøyen, 2014), 5 US$/GT (Furuichi and Otsuka, 2014; Zhang et al., 2016) and 8.2 US$/tonne (Lasserre, 2015). Nine of them consider the official NSR administration (NSRA) tariffs in their models. Pruyn (2016) assumed a scenario of no fees and a range of 4-19 US$/tonne when fees are applied, whereas Zhao et al. (2016) assumed three scenarios based on historical data.

The average vessel speed reported differs across the papers and depends on various assumptions regarding the speed on ice, the time frame of operations and the scheduling between rival routes. Some papers emphasised on a lower speed on ice waters and a higher one on open

waters. The speed on ice-infested waters range from 6-12 kts (Chang et al., 2015) to 14 kts (Pruyn, 2016) for bulkers and tankers and from 3-4 kts (Fan et al., 2012) to 17.7 kts (Lasserre, 2014; 2015) for containerships.

Some of the studies hypothesised the effect either of the ice resistance or of the increased weight of an ice-class vessel on fuel consumption and therefore assumed increased rates for the Arctic routes: For containerships, they range from 8-15% (Lasserre, 2015) to 50-58% (Somanathan et al., 2009) and 10% increased specific fuel oil consumption (Furuichi and Otsuka, 2015). For bulk carriers and oil tankers, they range from 5% (Cariou and Faury, 2015, Pruyn, 2016, Faury and Cariou, 2016) to 30% (Zhang et al., 2016). Most of the studies included a capital premium in their analyses, ranging from 5% (Song and Zhang, 2013) to 35% (Wergeland, 1992). Three papers assumed no premium whilst it was not discernible in the rest.

Five papers considered the costs of periodic maintenance, that is, the undertaking of regular surveys and dry docking of a vessel instead of routine repairs and maintenance which constitute part of the operating costs, ranging from 20% to 150% (Somanathan et al., 2007, 2009, Lasserre, 2014, 2015). Load factors were also reported for both westbound and eastbound cargoes. These factors range from 30% to 100% with some of the studies assuming lower load factors for eastbound cargoes, taking into account the trade flows between Europe and Asia.

The reviewed papers were categorised further according to the results of the Arctic routes' economic feasibility and emissions assessment (Table 6). 31 papers considered either costs/profits or emissions whereas two focused solely on emissions. Thirteen papers consider the Arctic routes either cost-competitive or profitable whilst five studies project their cost-effectiveness in the long-term. Somanathan et al. (2007; 2009) and Lasserre (2014; 2015) asserted that only specific trades are profitable whereas six studies considered the Arctic routes unprofitable or not cost-competitive. Guy (2006) found that the NWP is cost-competitive under specific scenarios whilst Faury and Cariou (2016) found the NSR to be cost-competitive in specific months of the year. Of the eight studies that appraised emissions, one concluded that Arctic routes are less energy efficient than the traditional ones (Lindstad et al., 2016).

The results listed in Table 6 make reference to the basic scenarios of the reviewed studies. The various discrepancies make the cross-comparison of the results rather difficult, especially the differences in the assumed time frame of operations. Thus, the reviewed papers were clustered by taking into account this critical factor (Figure 2).

The NSR and/or the NWP are shown not to be competitive in five out of nine papers that consider year-round operations, whilst two report mixed results. The costs using the NSR could be as high as 35.7% (Verny and Grigentin, 2009) compared to the Suez Canal route whilst the required freight rate (RFR) in NWP could be as higher as 13.4% than in the Panama Canal route (Somanathan et al., 2009).

When it comes to papers that considered a seasonal navigation period, the costs in the NSR could be 41% higher than those on the Suez Canal route. On the other hand, the NWP could be more competitive by 19.5% on the Rotterdam-Yokohama route but less competitive by 12% on the Rotterdam-Shanghai route than the Suez Canal (Lasserre, 2014; 2015). Wang et al. (2016) argued that if the time value of cargo is included in Lasserre's (2014) calculations, then both the NSR and NWP are more competitive than the Suez route by 3% and 65% respectively on the Rotterdam-Shanghai route and 52% and 85% on the Rotterdam-Yokohama route respectively.

Table 6. Cost and emissions assessment results of the reviewed articles

Author(s) and year	Arctic Route(s)	Competitive	Not Competitive	Include emissions assessment	Do not include emissions assessment
Wergeland (1992)	NSR	•			•
Kondo and Takamasa (1999)	NSR	Total shipper's cost depending on time value of freight	First year transport cost & 20/40-year RFR	•	
Guy (2006)	NWP	Optimistic Scenarios	Pessimistic Scenarios		•
Somanathan et al. (2007)	NWP	Yokohama – St. John's	Yokohama – New York		•
Somanathan et al. (2009)	NWP	Yokohama – St. John's	Yokohama – New York		•
Verny and Grigentin (2009)	NSR		•		•
Liu and Kronbak (2010)	NSR		•		•
Khon and Mokhov (2010)	NSR	2080-2099			•
Khon et al. (2010)	NSR	2080-2099			•
Schøyen and Bråthen (2011)	NSR	•		•	
Tavasszy et al. (2011)	NSR & NWP	Long-term			•
Xu et al. (2011)	NSR	•			•
Fan et al. (2012)	NWP	Long-term			•
Song and Zhang (2013)	NSR	•			•
Lasserre (2014)	NSR & NWP	NSR & NWP: Yokohama	NSR: Shanghai & Yokohama NWP: Shanghai		•
Raza and Schøyen (2014)	NSR	•			•
Lu et al. (2014)	NWP	•			•
Lasserre (2015)	NSR & NWP	NWP Rotterdam –Yokohama	NSR & NWP in four basic scenarios		•
Furuichi and Otsuka (2015)	NSR	•		•	
Moon et al. (2015)	NSR		•		•
Fan et al. (2015)	NWP	Long-term			•
Chou et al. (2015)	NSR	•			•
Chang et al. (2015)	NSR	•			•
Cariou and Faury (2015)	NSR	•		•	
Lindstad et al. (2016)	NSR	•		•	
Pruyn (2016)	NSR		•		•
Zhao et al. (2016)	NSR		•		•
Zhao and Hu (2016)	NSR	•		•	
Zhang et al. (2016)	NSR		•		•
Faury and Cariou (2016)	NSR	July/August – November	December – June		•
Wang et al. (2016)	NSR & NWP	•			•
Chou et al. (2017)	NSR			•	
Schröder et al. (2017)	NSR & TSR			•	

The Arctic routes are shown to be competitive in almost all of the papers considering single/round voyages as well as in Lindstad et al. (2016), who did not explicitly define the time frame. The competitiveness of the NSR ranges from 0.5% (Schøyen and Bråthen, 2011) to 47.2% Chang et al. (2015). The NWP is more competitive by 4.3-32.5% for liner shipping than the Suez Canal route under the optimistic scenarios (Guy, 2006). On the other hand, the Suez Canal route could be 1-66% more competitive than the NWP under the pessimistic scenarios (Guy, 2016).

Five papers consider Arctic routes cost-competitiveness in the long-term with two assuming a positive relationship between sea ice extent and seasonal freight rates by 2080-2099 (Khon and Mokhov, 2010; Khon et al., 2010) and three predicting future cargo flows through the Arctic based on transport costs of alternative routes (Tavasszy et al., 2011; Fan et al., 2012; 2015). On the other hand, the RFR for nuclear-powered ice-breaking ships using the NSR could be 3% (40 years) and 10% (20 years) higher than that on the Suez Canal route but could be 70% higher (20 years) when considering large vessels on the Suez Canal route (Kondo and Takamasa, 1999).

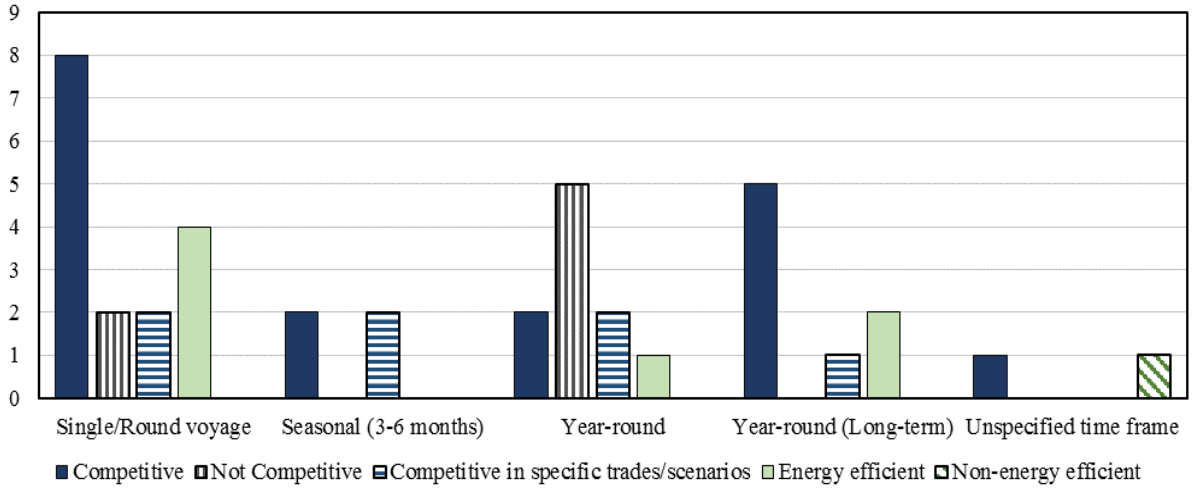

Fig. 2. Cost and emissions assessment results based on the time frame of operations

Overall, Arctic routes were found to be either cost-competitive or profitable in 42% of the studies and unprofitable or not cost-competitive in 19%. 23% suggest that they are competitive under specific scenarios and certain trade routes. The remaining 16% of reviewed papers project that Arctic routes would become cost-effective in the long-term. It is clear from this analysis that, in most of the studies which assume an annual operating period, Arctic routes tend to be either uncompetitive or demonstrate mixed results, especially for liner shipping (e.g. Verny and Grigentin, 2009, Liu and Kronbak, 2010, Lasserre, 2015; Zhao et al., 2016). The picture is similar regarding seasonal sailings (three to six months), where two studies report mixed results in certain OD pairs under liner shipping scenarios (Lasserre 2014, 2015). In contrast, they were found competitive in most of the studies that applied round or single voyages mainly for bulk or specialised shipping (e.g. Wergeland, 1992, Schøyen and Bråthen, 2011; Raza and Schøyen, 2014, Lu et al., 2014, Cariou and Faury, 2015). Finally, the competitiveness of these routes increases for year-round liner shipping operations only in the long-term (Khon and Mokhov, 2010; Khon et al., 2010; Tavasszy et al., 2011; Fan et al., 2012; 2015). A cross-comparison of the various cost components of each study is infeasible due to lack of data and a mismatch on the available variables regarding costs or operational factors.

4. Discussion and future directions

4.1 Research insights

The number of influential factors, which determine maritime route choice, extend to include operational, navigational, cost and revenue factors amongst others. Important variables are now discussed in order to understand how they affect route choice at the operational and tactical level, as well as the interrelations between them.

4.1.1 Route selection

The systematic review has identified a specific preference for simulating shipping scenarios in the NSR in most of the cases. This is not surprising if we were to consider prevailing sea ice conditions and recent infrastructure and project developments in the Arctic region, favouring mainly the NSR amongst others. However, studies within climate science investigating the future accessibility of Arctic routes indicate extended navigation seasons for several vessel types and for all the routes (NSR, NWP and TSR) throughout the 21st century. Khon et al. (2010) estimated the navigation season to be 3-6 (2-4) months for the NSR and NWP respectively regarding low ice class ships by 2080-2099. Stephenson et al. (2013**)** projected the seasonal navigation period in the NSR to be approximately 103, 113 and 120 days for non-ice class, PC6 and PC3 ships respectively by the end of 21st century. Most recently, Khon et al. (2017) projected a longer navigation season for the NSR than that in Khon et al. (2010) for non-ice class ships: 4-6.5 months by late-century.

Smith and Stephenson (2013) estimated the probability of non-ice class ships to transit the NSR using September as a benchmark to be 94-98% and that on the NWP to be 53-60% by 2040-2059. Stephenson et al. (2014) found high inter-annual variability of the NSR navigation season taking into account sea ice and bathymetry from 2013-2027. Further, Stephenson and Smith (2015) identified a gradual increase in the number of voyages through the TSR for PC6 vessels by mid-century whilst the possibilities of utilising the NWP rise by 2060. In contrast, Laliberté et al. (2016) found both the NWP and TSR to be ice-covered beyond mid-century whereas regions along the NSR and Arctic Bridge are projected to be more accessible for non-ice class vessels. Their results are in line with Pizzolato et al. (2016) and Liu et al. (2017) who concluded that multi-year ice in the northern sub-route of the NWP to be a significant obstacle for shipping activities in the medium-term. According to Melia et al. (2016), the TSR is projected to become available for non-ice class ships by mid-century whilst voyages from Europe to the Far East will take 17 days by late-century. Aksenov et al. (2017) identified sea ice extent and thickness as the most determining factors for shipping in the Arctic until 2030-2050, whereas other ice properties (e.g. ice ridging, drift ice, and internal pressure), ocean circulation, winds, currents and waves will mostly affect navigation beyond that period.

Taking into account these findings, future research should also pay attention to the TSR as an alternative route. In addition, more focus is needed in simulating the NWP, and alternative sub-routes of the NSR, as these could enable the employment of larger vessels. Moreover, the possible opening of the Nicaragua and Kra Canals, the expansion of both Panama and Suez Canals as well as alternative land-based (e.g. Tran-Siberian Railway, New Eurasian Land Bridges) and other established trade routes will also have an impact to their northern rivals (Fig. 3) (Tavasszy et al., 2011, Yip and Wong, 2016; Martinez et al., 2016; Zeng et al., 2017).

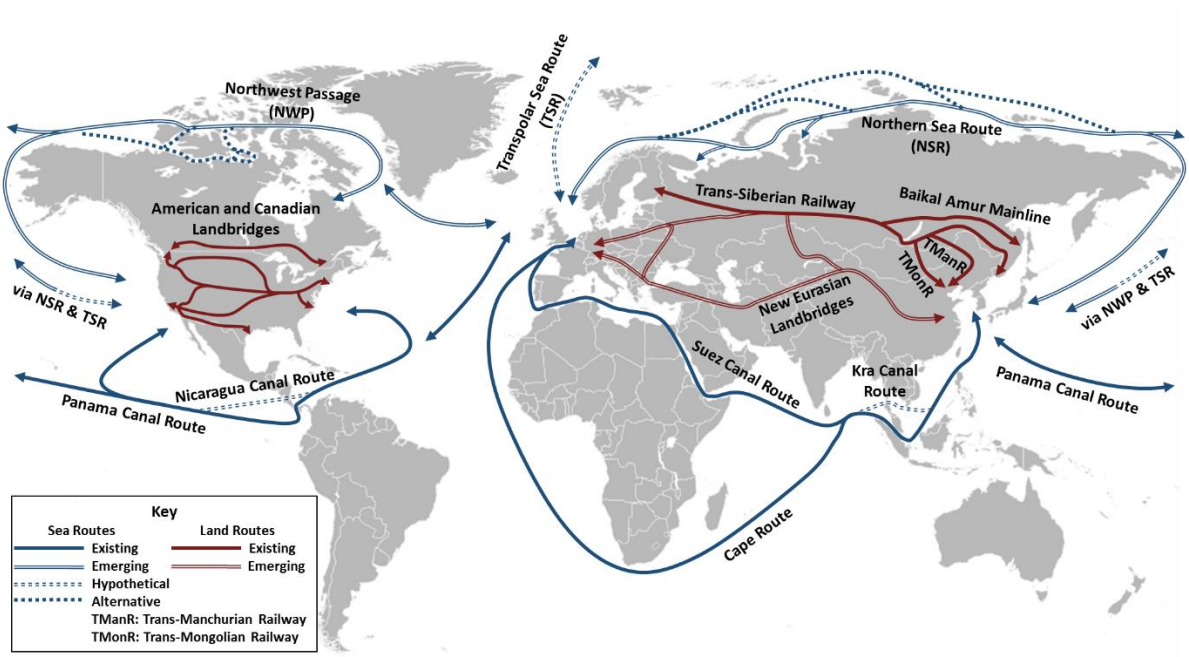

Fig.3. Alternative sea and land routes between Eurasia and North America

(Authors, based on Rodrigue et al., 2017 and MERICS Research, 2017)

4.1.2 Cost, operational, and navigational variables

A wide variety of cost, operational, and navigational variables were identified. This is in line with the findings of Lasserre (2014). The differences extend to include not only the unit of cost and emissions measurement but also operational and market factors as well.

To begin with, the assumed sailing season affects the route comparison and the results across the models. This implies that under the current winter navigational and climatic conditions they could serve as seasonal alternatives for a limited period of about five months (summer season) mainly for bulkers and tankers rather than offering regular access to ships on an annual basis. It was identified that a combination of an extended sailing season with low ice-breaking fees increases significantly the competitiveness of the Arctic routes even under high fuel prices (Liu and Kronbak, 2010, Lasserre 2014, 2015, Zhao et al., 2016) and use of larger vessels on the traditional routes (Furuichi and Otsuka, 2015). Further, increased load factors and high average speeds that enable many rotations through the Arctic routes, could improve profitability, especially for liner shipping operations (Wergeland, 1992, Guy, 2006, Lasserre, 2014, 2015).

The capital cost premium is in the order of 20-30% in most cases and was identified as an important cost factor amongst others (Somanathan et al., 2007, 2009, Liu and Kronbak, 2010). The importance of an extended sailing season is crucial in order to exploit the advantages of operating on shorter routes by utilising ice class vessels, which entail increased capital costs. Besides, operators may seek opportunities to use ice class tonnage in other ice bound regions with easier ice conditions during the winter season (e.g. Baltic Sea, Sea of Okhotsk), depending on the ice class and vessel characteristics.

In most of the cases, crew costs were assumed to be 10% higher when operating in the Arctic routes whilst in Song and Zhang (2013) they were 28% higher than in the southern routes.

According to Somanathan et al. (2007), a well-trained crew is required for Arctic operations whilst additional costs occur when ice navigators or additional crew are included as well.

Furthermore, it is widely accepted that insurance costs are higher for ice-class vessels operating in the Arctic. However, a common denominator is difficult to find since each voyage in Arctic waters is evaluated individually. According to a recent survey by Sarrabezoles et al. (2016), most of the insurers stated that H&M premiums range between 25 and 50%, others estimated them between 0 and 25%, whereas only one assumed rates between 50 and 75%. As regards the P&I and cargo insurance premiums, these range from 0 to 25% most of the times whilst an almost equal number of respondents estimated cargo insurance premiums around 25-50%.

The ice breaking fees assumed in the reviewed papers can be distinguished in two broad categories. Those, which refer to the official NSRA fees, and those, which refer to discounts, offered in particular cases from time to time. This discrepancy stems from the fact that transit fees have been subject to fluctuations related to financial and geostrategic reasons rather than a well-targeted policy during the period 1991-2013 (Gritsenko and Kiiski, 2016). Several studies emphasise the importance of relatively low ice breaking fees in order for the Arctic routes to be viable (Liu and Kronbak, 2010, Zhao et al., 2016, Lasserre, 2014, 2015, Furuichi and Otsuka, 2015). On the other hand, the fact that ice-breaking assistance is not compulsory since 2012 and the recent improvements on navigational rules implemented in 2014 are remedies to the aforementioned obstacles (Gritsenko and Kiiski, 2016).

The average speed used in the models also differs widely. The operating speed depends on the speed realised on ice waters since the speed in open waters will be the same as in classical routes (Faury and Cariou, 2016). This variability in sailing speeds stemming from the uncertainty of ice and weather conditions underline that there are no standards and every case is unique. According to the NSRA data, the average speed recorded between 2011-2014 is around 10 kts (NSRIO, 2018), which is in line with the operating speeds realised in first-year sea ice in the Bay of Bothnia during the ice season. However, it can be easily reduced to 5-6 kts or even to zero depending on the ice and local climatic conditions.

Some of the studies assume increased fuel consumption in their scenarios due to greater engine power required in the icy parts of the route and the additional weight of an ice class vessel. Whilst the use of the shorter Arctic routes imply lower fuel costs, this largely depends on transit times and possible delays due to deviation of a vessel from its predefined navigational route in order to avoid difficult ice conditions. Pruyn (2016) suggest that fuel consumption of an unescorted vessel should be equal to that at design speed regardless of the speed realised on ice. Further research could shed light on the fuel consumption of an ice class vessel in both open water and ice to refine cost simulations with respect to overall fuel costs when comparing ice-infested and traditional routes.

As regards the types of fuel used by ships in the Arctic routes, Lasserre (2014; 2015) claimed that IFO 380 fuel may not be appropriate during winter navigation. The picture becomes more blurred if possible taxation on fuel is assumed (Schøyen and Bråthen, 2014), future emissions surcharges (Carriou and Faury, 2015), the use of alternative fuels in the Arctic or the extension of a recent IMO policy that requires vessels to use fuels containing less than 0.1% sulphur in ECAs such as the North and Baltic seas to the Polar Circle (Lindstad et al., 2016). Moreover, alternative approaches of estimating the environmental impact of maritime operations on different regions my give different results. Lindstad et al (2016) challenged the assessment of CO_2 emissions that rely merely on fuel consumption conversion to CO_2 amounts when considering the Arctic region. They claimed that, if region-specific Global Warming Potential

(GWP) factors are applied, then the NSR generates higher kg-CO_2-eq/t than the Suez Canal route even if LNG is used as a fuel.

4.1.3 Revenue and market factors

The literature focuses mainly on cost and navigational factors, whilst revenue factors have been overlooked in most cases. Shipowners adjust the operating speed according to the prevailing market conditions and fuel prices amongst others. Thus, a combination of low freight rates and high bunker prices impose speed reductions which favour slow steaming and vice versa (Notteboom and Vernimmen, 2009, Devanney, 2010). The reduction in voyage costs in this case is very small and other factors such as low load factors, high ice breaking fees or potential delays and uncertainty when it comes to liner shipping, favour the classical routes (Liu and Kronbak, 2010, Lasserre, 2014, 2015, Zhang et al., 2016). Further, the relationship between speed, freight rates and fuel prices is not often straightforward if other factors such as cargo value, in-transit inventory and operating costs are included amongst others. The net effect of these factors upon the route choice depends critically on the logistical context of the calculations. Commodity prices and proximity to the markets play an important role too. Differences in the distances explain some of the differences in freight rates and regional commodity prices amongst others (Laulajainen, 2007, Maxwell and Zhu, 2011). Economies of scale and different ship sizes and ice class designs are also important factors, which have not been investigated thoroughly in the literature.

4.1.4 Maritime transport systems

Whilst 20 studies assessed the Arctic routes against liner shipping, this system seems to be the most uneconomical and unfeasible to date. Thus, a number of criteria are not satisfied when it comes to carrier's port selection: remote geographical location of Arctic ports, lack of proximity to markets and access to hinterlands, regional bottlenecks and port infrastructure and service (Lirn et al., 2004; Song and Yeo, 2004). Other factors are high uncertainty related to ice and climatic conditions in the Arctic that may result in delays, schedule unreliability and longer transit times (Zohil and Prijon, 1999; Notteboom, 2006).

Some of the reviewed papers partly tackle these issues by incorporating lower load factors to both eastbound and westbound cargoes. Although Arctic routes do not provide for sufficient port calling, they can serve as shorter routes in the long-term, allowing liner operators to either reconfigure their networks or establish separate services through the Arctic. The global geographical focus of liner networks as well as the inherent trend of expansion in secondary markets (Guy, 2003; Baird, 2006) will possibly trigger the interest of operators possessing large capacity to extend their network in the Arctic by establishing seasonal transits in the short-term and forming regular networks in the long-term (Lee and Kim, 2015). Few studies report a network structure in the literature (Xu et al., 2011, Tavasszy et al., 2011, Fan et al., 2012, 2015, Zhao et al., 2016). Further research could shed light on network structure and the feasibility of liner operations from this perspective.

It is evident from this review that bulk and specialised shipping are both overlooked in most of the papers (11 of 33). This neglects the possibility for the Arctic routes to emerge as an alternative option for liquid and dry bulk trades and other cargoes, especially oil, gas condensate, naphtha, LNG and to a lesser extent iron ore and other minerals (Jørgensen-Dahl and Wergeland, 2013; Bambulyak et al., 2015). The potential of bulk and specialised shipping was also reported in recent surveys (Lasserre and Pelletier, 2011; Lee and Kim, 2015; Beveridge et al., 2016; Lasserre et al., 2016). The reefer segment is also largely neglected in

the literature. However, the NSRA statistics show that there are a considerable number of reefer vessels transporting frozen fish via the NSR (NSRIO, 2018). Thus, economies of short distances offered by the NSR could be materialised concerning locations between North Europe and Northeast Asia as regards reefer vessels.

4.2 Methodological insights

The methods and data analysis techniques identified in the literature are discussed in this section to provide insights on how these could be developed in the future. Techniques that could aid modelling in this area are also presented, although other techniques could be appropriate. As a relatively new topic in maritime transport area, Arctic shipping, could be addressed by many methods and techniques used in social sciences.

4.2.1 Operational research and cost modelling approaches

Arctic shipping could be a fertile ground for operational research techniques. Examples are the comparative study of Zhao et al. (2016) who bring together the areas of liner network design and Arctic shipping, and Fan et al. (2012; 2015) where linear programming and stochastic network models were employed to minimise costs and assess risk uncertainties with respect to future container flows. Most of the papers reviewed in this systematic review consider the assignment of one vessel in single or annual voyages. Operational research methods could increase the parameters of the models by considering several alternative options related to fleet size, route choice, the number of voyages and networks (Fan et al. 2012; 2015). Contemporary operational tactics such as sailing speed adjustments adopted to minimise fuel consumption and/or costs or to maximise profits in both liner and tramp shipping are very relevant (Psaraftis and Kontovas, 2013). Environmental sustainability is also addressed through multi-objective optimisation techniques (Mansouri et al., 2015). Thus, modelling could be informed from all the aforementioned techniques to address operational, economic and environmental aspects. As Zhao et al. (2016) mentioned, the majority of operational research studies in shipping rely on the established routes and networks and do not consider new routes and their impact on maritime operations.

Given that scenario-based transport cost models reported in the literature are likely to remain the prevalent technique, they could be developed further to include more assumptions considering not only operational and cost factors but also environmental factors. Of the 33 studies reviewed, only eight report the estimation of emissions based on various formulas. Studies within climate science evaluating future accessibility in the Arctic could also aid the modelling approaches with respect to navigation season, sea ice conditions and transit times so as to better quantify these factors. Global climate models projecting ice and weather conditions under different emissions scenarios could be used as inputs to simulations (Schröder et al., 2017). On the other hand, more diversity is needed in terms of scenarios and assumptions so as to provide fruitful insights and counter-arguments. Arctic maritime operations require cost analysis methods that can deal with the structure and complexity of the issues being involved.

4.2.2 Empirical case studies

Many authors mention the discrepancies in hypotheses and assumptions made in the literature regarding operational and cost variables as well as market conditions (Lasserre, 2014; Cariou and Faury, 2015). This is a result of the infancy of Arctic maritime operations, which in turn leads to the lack of relevant data and statistics. Empirical case studies with a focus on the examination of the Arctic routes and interviews with key stakeholders can complement the data reported in databases and other publicly available sources to further refine any modelling

approach where there is no, insufficient, or inaccurate statistical data. The identified case studies report empirical data obtained through interviews and records from real voyages occurred in the NSR (Raza and Schøyen, 2014, Zhao and Hu, 2016). This type of research could help increase the understanding of Arctic maritime operations. As Wacker (1998) pointed out, empirical research offers verification of model-based research amongst others. In particular, case studies provide a deeper understanding of the usually complex operational processes in the real world.

4.2.3 Econometric modelling, regression, panel data analysis and other techniques

Structural econometric modelling, regression and panel data analysis have been widely used in maritime research (Glen, 2006; Heaver, 2012; Xu and Yip, 2012). All these techniques could be employed in order to develop models that test various explanatory variables with respect to the determination of costs, profits and emissions when utilising maritime routes. For instance, Lu et al (2014) use explanatory variables such as freight rates, distance, time, transit fees, fuel consumption and vessel size in order to investigate the cost determinants on both the NSR and the Suez Canal route. Pruyn (2016) uses a sophisticated structural model including macroeconomic data from sixteen countries, vessel sizes, fleet age, freight rates and transport costs to explore the feasibility of the NSR. Other techniques such as discrete choice and MCDM models could aid model-based research by investigating stakeholders' perspectives regarding influential decision-making factors and the potential of Arctic shipping amongst others (Moon et al., 2015, Shyu and Ding, 2016, Benedyk and Peeta, 2016, Wang et al., 2018).

5. Conclusion

The literature on comparative studies between Arctic and traditional routes has grown considerably during the last ten years. Whilst there have been attempts to identify, survey (Lasserre, 2014; 2015) and review the extant literature (Meng et al., 2016), to date there have been no systematic reviews. This study therefore contributes to Arctic shipping research by providing the first such systematic review of the literature between 1980 and 2017.

In doing so, both economic issues and environmental assessment of the Arctic routes were taken into account. Further, the methodological characteristics of the reviewed studies were identified and analysed. In addition, important decision-making factors were pointed out and discussed, such as cost (capital cost premiums, ice breaking fees, fuel costs, operating costs, in-transit inventory costs), operational (speed, fuel types), navigational (alternative routes, sea ice conditions) and revenue and market factors (freight rates, commodity prices, cargo value). This review serves as the starting point of developing a conceptual framework of route choice decision-making factors within the context of Arctic shipping which could be used in future research.

The results of this review suggest that Arctic routes are considered more competitive than their traditional rivals in 13 of the 31 papers that evaluated their economic potential. On the other hand, they were found to be less competitive in six papers whereas seven reported mixed results. Five papers project that they will become competitive in the long-term. Only eight studies assessed emissions comparing the Arctic with traditional routes, with seven out of eight studies concluding that Arctic shipping routes are more energy efficient than their traditional rivals. The competitiveness of these routes decreases as we move towards year-round operations. This means that under the current winter navigational and climatic conditions they could serve mainly as seasonal alternatives for a limited period of about five months rather than offering regular access to ships on an annual basis. Consequently, Arctic routes appear to be

more suitable for bulk rather than liner shipping in the short to medium-term. The findings serve as evidence to inform transport practitioners who operate or willing to operate in the Arctic regarding cost, revenue, operational and navigational factors. Moreover, they provide an initial understanding of what factors promote or hinder the cost-competitiveness and/or profitability of the Arctic routes, why and how.

This review identified several issues that need to be addressed in future research. These relate to both research and methodological aspects of the reviewed papers. Further research is required in terms of the NWP, the TSR and variations of the NSR. Attention should be paid to revenue attributes, commodity and fuel prices, and how these factors along with Arctic sea ice conditions determine the competitiveness of the Arctic routes. More model-based research with robust sensitivity analyses is needed in order to overcome discrepancies in the assumptions regarding cost and operational variables. With respect to the navigational factors, future research could take into account studies related to climate change models and variations in the Arctic sea ice. Ice conditions as well as other physical constraints (e.g. regional bottlenecks) are critical factors that affect the operating speed or the size of the vessels used in Arctic waters, which in turn affect the revenue, transit time, operating and voyage costs.

The literature focuses mainly on liner shipping and to a lesser extent on bulk shipping. However, bulk (Liquid, Dry) and specialised shipping (LNG, Reefer) will mostly benefit from Arctic routes in the short to medium-term. For liner shipping, more emphasis could be given to network structure/configuration and/or reconfiguration of the existing networks as part of scenario-based simulations. Analytical mathematical methods were found to be prevalent in the literature with empirical statistical and case study research being used in a lesser extent. With regards to data analysis techniques found during the review, the literature shows a particular preference for scenario-based transport cost models. When it comes to the methodological aspects, this study suggests that as a relatively new topic in maritime transport area, Arctic shipping could be addressed by many methodologies and techniques used in social sciences, namely, operational research, case studies, econometric modelling, regression and panel data analysis as well as discrete choice and MCDM techniques amongst others. Finally, this review limited its scope to studies reporting on cost/emissions assessment of Arctic routes. However, the Arctic shipping literature spans several research areas and topics. A broader review of the literature could include conceptual and descriptive studies, surveys and studies focusing on factors other than costs/profits (e.g. time/distance effects or ice class ship evaluation) or on the overall environmental impact of future shipping traffic volumes in the Arctic.

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Appendix. Factors affecting ship revenues and costs[1]

Author(s) and year	Crew premium	Insurance premium	Transit fees	Fuel consumption rate	Speed	Capital Cost Premium
Wergeland (1991)	+17.3%	+25%, Cargo insurance: 0.2% per voyage	Official NSRA fees	N.A.	NSR: 12 kts, Suez & Panama Canal: 13.5 kts	+35%
Kondo and Takamasa (1999)[2]	+147%	+183.7% +936,000 US$ nuclear energy insurance/year	N.A.	N.A.	NSR: 20 kts Suez Canal: 25,30 & 34.2 kts	+134.4%
Guy (2006)	+15-200% premium incl. in Trip Charter costs	+15-200% premium incl. in Trip Charter costs	Hypothetical	N.A.	Optimistic Scenario: 22 kts, Pessimistic Scenario: 6 kts on ice	+15-200% premium incl. in Trip Charter costs
Somanathan et al. (2007)	+565 US$/day	+50-51.4%	No fees	Same SFOC but higher engine power	NWP & Panama Canal: 11 & 20 kts	+30%
Somanathan et al. (2009)	+21.2%	+50%	No fees	New York-Yokohama: +50%, St Johns, Newfoundland-Yokohama: +58%	New York/ St. Johns - Yokohama: NWP: 18.4 kts (September) 18.2 kts (February), Panama Canal: 20 kts	+30%
Verny and Grigentin (2009)	N.A.	N.A.	Official NSRA fees	N.A.	NSR: 17 kts on ice & 24 kts on open water, SCR: 24 kts	N.A.
Liu and Kronbak (2010)	+10%	+62.5%	Official NSRA fees & three variant scenarios	SCR: 0.3 t/nm NSR (on ice): 0.5 t/nm = nautical mile	NSR: 10 kts on ice water & 18 kts on open water, SCR: 18 kts	+20%
Schøyen and Bråthen (2011)	+20% premium incl. in Operating Costs	+125,000 US$/trip for both H&M and P&I	Official NSRA fees	Porsgrunn-Shekou (NSR): 49% and 78% lower than SCR and Cape respectively, Narvik – Qingdao (NSR): 84% lower than NSR	Porsgrunn-Shekou: NSR: 11.5 & 8.7 kts, SCR & Cape: 14.4 kts Narvik-Qingdao: NSR: 8.3 kts, SCR: 14.4 kts	+20%
Xu et al. (2011)	N.A.	N.A.	No fees	N.A.	N.A.	No premium
Fan et al. (2012)	N.A.	N.A.	N.A.	N.A.	3-4 kts on ice water (around 1000 n.m.)	N.A.
Song and Zhang (2013)	+28%	+5%	N.A.	+7%	NSR: Based on AIRSS rules, SCR: 14.5 kts	+5%

[1] Studies in which these factors could not be discerned are not included in the Appendix.

[2] The factors reported in this table refer to the benchmark scenario of a 6,000 TEU diesel ship (20-year life & speed = 30 kts) compared to a cassette-type MRX ice-breaking 1,400 TEU ship (40-year life)

Author(s) and year	Crew premium	Insurance premium	Transit fees	Fuel consumption rate	Speed	Capital Cost Premium
Lasserre (2014)	+10%	NSR: +50% NWP: +65%	NSR: 7.44 US$/t NWP: No fees	**Rotterdam-Shanghai:** NSR and NWP: 21% lower than SCR **Rotterdam-Yokohama:** NSR and NWP: 24-25% lower than SCR	**Rotterdam-Shanghai:** NSR: 17.71 kts, SCR: 20 kts, NWP: 16.94 kts **Rotterdam Yokohama:** NSR: 16.95 kts, SCR: 20kts, NWP: 16.6 kts	+25%
Raza and Schøyen (2014)	N.A.	H&M premium: +281,250 US$/round voyage, Increased Values: +20,250 US$/round voyage	NSR: 6.8 US$/t laden, 3 US$/t ballast; SCR: 158,294US$/round voyage (piracy premium)	N.A.	NSR: 12 kts on ice & 19.5 kts on open water SCR: 19.5 kts	No premium
Lu et al. (2014)	N.A.	N.A.	5 US$/t	N.A.	NWP: 10 kts on ice	N.A.
Lasserre (2015)	+10% in six-month scenario +15% in year-round scenario	**Summer season:** NSR: +50% NWP: +65% **Year-round:** NSR: +65% NWP: +80%	NSR: 1. Official Tariffs 2. Variant Scenario: 8.2 US$/t NWP: No fees	**Summer Season:** Rotterdam-Shanghai: NSR and NWP: 21% lower than SCR respectively; Rotterdam-Yokohama: NSR: 25% and NWP: 24% lower than SCR **Year-round Scenario[3]**	**Summer Season:** Rotterdam-Shanghai: NSR: 17.7 kts, SCR: 20 kts, NWP: 16.9 kts Rotterdam-Yokohama: NSR: 16.9 kts, SCR: 20kts, NWP: 16.6 kts **Year-round Scenario[4]**	**Summer Season:** NSR & NWP: +20% (1AS Ice-class) **Year-round Scenario:** NWP: +30% (PC4 Ice-class), NSR: +20% (1AS Ice-class)
Furuichi and Otsuka (2015)	N.A.	10 US$/GT/year Piracy Premium (SCR): 40 US$/TEU	5 US$/GT	+10% SFOC for an ice-class vessel (additional weight)	NSR: 13-14 on ice, 20 kts on open water	+10%
Chou et al. (2015)	N.A.	N.A.	N.A.	N.A.	12 kts in all routes and cases	N.A.
Chang et al. (2015)	N.A.	N.A.	Official NSRA fees?	NSR 26% lower than SCR on average	NSR: 14 kts on open water, 6-12 kts on ice	N.A.
Cariou and Faury (2015)	+9.5% premium incl. in Operating Costs	+62.5%	Official NSRA fees	+5%	NSR: 6.4-12.8 kts SCR: 8-16 kts	N.A.
Lindstad et al. (2016)	N.A.	N.A.	N.A.	N.A.	NSR & SCR: 10-11 kts	N.A.

[3] **NWP:** 26% higher (winter) and 19% lower (summer) than SCR; **NSR:** 32% (winter) and 25% (summer) both lower than SCR

[4] Rotterdam-Yokohama: NWP: 11.7 kts (winter), NSR: 11.2 kts (winter); summer speeds at both routes are the same as in summer season scenarios

Author(s) and year	Crew premium	Insurance premium	Transit fees	Fuel consumption rate	Speed	Capital Cost Premium
Pruyn (2016)	N.A.	P&I: +100% H&M: +200% Piracy Premium: 18 US$/GT	Five scenarios[5]	NSR: Ice 0,1,2: +5% Reg-1, Reg-2: same as SCR	NSR: Ice 0: 14.3 kts, Ice 1,2: 11 kts, Reg-1,2: 9 kts, SCR: 14.3 kts	Ice 0,1,2: +5%, Reg-1,2: same as a non-ice class vessel
Zhao et al. (2016)	+10%	H&M : +100% P&I: +25%	Three hypothetical scenarios based on historical data	SCR: 0.3 t/nm NSR (ice water): 0.5 t/nm	N.A.	+20%
Zhao and Hu (2016)	+14% premium incl. in Operating Costs	+14% premium incl. in Operating Costs	Official NSRA fees	Same in both NSR & SCR	NSR & SCR: 12.5 kts	N.A.
Zhang et al. (2016)	**Containerships:** +10% **Oil Tankers:** +20% premium incl. in Operating Costs	**Containerships:** H&M: 50%, P&I: 25% **Oil Tankers:** +20% premium incl. in Operating Costs	5 US$/GT	+30% for both Containerships and Oil Tankers	**Containerships:** NSR: 12 kts on ice SCR: 14.4-17.7 kts **Tankers:** NSR: 9.4 kts on ice SCR: 15-15.5 kts	+30% for both Containerships and Oil Tankers
Faury and Cariou (2016)	+20% premium incl. in Operating Costs	+20% premium incl. in Operating Costs	Official NSRA fees[6]	+5.1%	SCR: 14.5 kts; NSR (Depending on the month and zone)	N.A.
Chou et al. (2017)	N.A.	N.A.	N.A.	N.A.	NSR: 17.71 kts SCR: 20 kts	N.A.
Schröder et al. (2017)	N.A.	N.A.	N.A.	N.A.	Oil Tanker: 16 kts, LNG Tanker: 20 kts on open water, 8 &7 kts on ice respectively	N.A.

[5] Ice 0: No fees, Ice 1,2: 4 US$/t, Reg-1: 5 US$/t, Reg-2: 19 US$/t below 40,000 DWT & 16 US$/t above 40,000 DWT

[6] Independent navigation during September, October & November

Author(s) and year	Maintenance premium	Load Factor	Type of vessel	Ice Class	Transport Costs[7]	Impact of Ice on Fuel Consumption
Wergeland (1991)	+23.6%	75% in all scenarios	20,000 DWT Norilsk type Multi-purpose vessel	ULA (PC4/PC5, IACS Classification)[8]	Shipowner's & Cargo Owner's perspective	•
Kondo and Takamasa (1999)	+50.3% (Periodic Maintenance)	100% in all scenarios	1,400 TEU Nuclear-powered Containership	Cassette-type MRX Nuclear-powered Ice-breaking ship	Shipowner's & Shipper's perspective	N.A.
Guy (2006)	+15-200% premium incl. in Trip Charter costs	N.A.	Panamax Containership & Panamax Bulker	N.A.	Shipowner's & Charterer's perspective	N.A.
Somanathan et al. (2007)	+ US$ 650/day +150% (Periodic Maintenance)	100% in all scenarios	4,500 TEU Containership	CAC 3 (PC3, IACS Classification)	Shipowner's perspective	•
Somanathan et al. (2009)	+150% (Periodic Maintenance)	100% in all scenarios	N.A.	Same as above	Shipowner's perspective	•
Verny and Grigentin (2009)	+100%	Westbound: 100% Eastbound: 30%	4,000 TEU Containership	N.A.	Shipowner's perspective	N.A.
Liu and Kronbak (2010)	+100%	60% in all scenarios	4,300 TEU Containership	1B (IB)	Shipowner's perspective	•
Khon and Mokhov (2010)	N.A.	N.A.	N.A.	N.A.	Charterer's perspective	N.A.
Khon et al. (2010)	N.A.	N.A.	Bulk/Containership	"Light ice-class"	Charterer's perspective	N.A.
Schøyen and Bråthen (2011)	+20% incl. in Operating Costs	100% in all scenarios	40,000 DWT Handymax & 50-68,000 DWT bulk carriers	GL E3 (IA)	Charterer's perspective	N.A.
Xu et al. (2011)	N.A.	N.A.	10,000 TEU Containership	No ice-class	Shipowner's perspective	N.A.
Fan et al. (2012)	N.A.	100%?	4,400 -12,000 TEU Containerships	N.A.	Shipper's Perspective	N.A.
Song and Zhang (2013)	+26%	100%	120,000 DWT Aframax tanker	1A (IA)	Shipowner's perspective	•
Lasserre (2014)	+20% (Periodic Maintenance)	Shanghai-Yokohama[9]	4,500 TEU Containership	1AS (IAS)	Shipowner's perspective	•

[7] Transport costs are distinguished between "Shipowner's" and "Charterer's" unless otherwise stated.

[8] The ice class in the parenthesis is the Finnish-Swedish equivalent where applicable. IACS classification is used otherwise.

[9] **NSR**: Westbound: NSR: 70%, SCR: 87%, Eastbound: NSR: 45%, SCR: 60%, **NWP**: Westbound: NWP: 45%, SCR: 87%, Eastbound: NWP: 70%, SCR: 60%

Author(s) and year	Maintenance premium	Load Factor	Type of vessel	Ice Class	Transport Costs	Impact of Ice on Fuel Consumption
Raza and Schøyen (2014)	N.A.	Eastbound: NSR & SCR: 90%	150,000 cm/84,682 DWT LNG Tanker	Lloyd's 1A (IA)	Charterer's Perspective	N.A.
Lu et al. (2014)	N.A.	100% in all scenarios?	4,500 –15,000 TEU Containership	N.A.	Charterer's Perspective	N.A.
Lasserre (2015)	**Summer Season & Year-round**[10]	**In all scenarios**[11]	4,500 TEU Containership	1AS (IA) & PC4	Shipowner's Perspective	N.A.
Furuichi and Otsuka (2015)	N.A.	Eastbound and Westbound: 70%	4,000 TEU – 15,000 TEU Containership	N.A.	Shipowner's Perspective	•
Fan et al. (2015)	N.A.	100%	1000 -14,000 TEU Containerships	N.A.	Shipper's Perspective	N.A.
Chou et al. (2015)	N.A.	N.A.	60,000 DWT Panamax Bulk Carrier	N.A.	Charterer's Perspective	N.A.
Chang et al. (2015)	N.A.	N.A.	N.A.	N.A.	Charterer's Perspective	N.A.
Cariou and Faury (2015)	+9.5% premium incl. in Operating Costs	80% in both the NSR and SCR	40,000 DWT Handymax Bulk Carrier	1A (IAS)	Shipowner's Perspective	•
Lindstad et al. (2016)	N.A.	100%?	Capesize and Panamax Bulk Carriers	N.A.	Charterer's Perspective	•
Pruyn (2016)	N.A.	100%?	11 Bulk Carrier sizes (17,000-289,000 DWT)	Ice 0, 1, 2, Reg-1, 2 (Hypothetical)	Shipowner's & Charterer's perspective	•
Zhao et al. (2016)	+100%	Real data based on COSCO's Asia-N. Europe Service	4,800 TEU Containership	IA?	Shipowner's Perspective	•
Zhao and Hu (2016)	+14% premium incl. in Operating Costs	N.A.	19,461 DWT Multi-purpose/general cargo vessel	1A (IA)	Shipowner's Perspective	N.A.
Zhang et al. (2016)	**Containerships:** +20%, **Oil Tankers:** +20% premium incl. in Operating Costs	Different levels of demand (TEUs) on each port, 100% for oil tankers	New Panamax & Panamax, Containerships VLCC & Aframax Oil Tankers	1A (IA)?	Shipowner's Perspective	•
Faury and Cariou (2016)	+20% premium incl. in Operating Costs	100%	74,997 DWT Panamax Oil Tanker	1A (IA)	Shipowner's Perspective	•
Chou et al. (2017)	N.A.	100%	5,551 TEU Containership	N.A.	N.A.	N.A.
Schröder et al. (2017)	N.A.	N.A.	102,000 DWT Oil Tanker 115,500 LNG Tanker	1A (IA) & Arc7 (PC3)	N.A.	•

[10] **Summer Season:** NSR & NWP: +20%, **Year-round:** NWP: +150%, NSR: +25%, (both Periodic Maintenance)

[11] Westbound: NSR & NWP: 70%, SCR: 85%, Eastbound: NSR & NWP: 50%, SCR: 75%