

# Approaches of the profitability of Arctic shipping in the literature<sup>1</sup>

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## 1. Introduction

The future use of the so-called Arctic routes could reshape maritime transport geography. This includes development of new trade routes for bulk and specialised shipping as well as possible reconfigurations of liner shipping networks or the launch of new ones, between origin-destinations (OD) in Northwest Europe, the Baltic and the Arctic to Northeast Asia and North America. Recent studies project future accessibility of both the Northern Sea Route (NSR) and the Northwest Passage (NWP) by 2050 for non-ice class vessels. Polar Class 6 type (PC6) vessels will also be able to operate through the Transpolar Sea Route (TSR) (Smith & Stephenson, 2013, Melia, Haines & Hawkins 2016), whilst there is also a high possibility for non-ice class vessels to use the TSR (Melia et al., 2016) by that time. Opportunities for more frequent use of polar routes could be facilitated by the gradual change in Arctic sea ice conditions. The implications could be lower fuel costs, greenhouse gas (GHG) and non-GHG emissions, shorter transit times, improved network connectivity, and lower overall transport costs.

Comparative studies between Arctic and traditional routes have grown considerably during the last ten years. Lasserre (2014, 2015) and Meng, Zhang and Xu (2016) reviewed 26 and 25 studies respectively, whilst Theocharis, Pettit, Rodrigues and Haider (2018) systematically reviewed 33 peer-reviewed studies concerning both research and methodological considerations. This chapter offers an updated review of the literature based on Theocharis et al. (2018) with a particular focus at the micro-economic level. The economic feasibility (costs, profits) and environmental assessment (emissions, environmental costs) of Arctic routes are reviewed by including studies that were published during 2018<sup>2</sup>.

## 2. Review methodology

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. Various approaches are used to synthesise findings in order to identify emerging themes, key results or any links to theory or concepts (Tranfield, Denyer & Smart, 2003). Traditional routes and oceanic canals dominate bulk shipping and determine connectivity in global liner networks. However, the emergence of new hubs, future canal development or expansion (Rodrigue & Ashar, 2016, Yip & Wong, 2016, Martinez, Steven & Dresner, 2016) and the potential opening of polar routes (Notteboom, 2012) could redefine the maritime transport geography landscape and increase network diversity (Ducruet, 2013). Generally, 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, Wang & Winebrake, 2009, Notteboom & Vernimmen, 2009), scheduling optimisation (Lam, 2010), expansion of existing canals (De Marucci, 2012) or new ship designs, technologies and fuels

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(Lindstad, Jullumstrø & Sandaas, 2013, Lindstad & Bø, 2018). 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, Lee & Aluko, 2015). All else being equal, the comparative advantage of Arctic routes stems from the fact that shorter geographical distances could mean shorter transit times and lower transport costs, higher service frequency, and potentially lower fuel consumption, which in turn means lower GHG and non-GHG emissions.

## 2.1 Search strategy

According to the research scope of this review, only papers reporting original results on cost and emissions assessments of Arctic routes at the micro-economic level were included. Quality control is increased only by restricting the searches to journal papers (David & Han, 2004). Studies dealing with shifts in global trade flows or other macro-economic variables and future emissions inventories in the Arctic based on traffic assessments are beyond the scope of this review and therefore excluded. Major shipping canals and maritime routes were used as keywords in Scopus and Web of Science, as well as variations of terms that have similar meanings. A total of 35 unique papers were retrieved and analysed based on their research and methodological considerations regarding only cost and emissions assessments.

## 3. Results

### 3.1 General statistics

Only 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 35 papers reviewed, two were published in the 1990s, seven between 2001 and 2010 and 26 between 2011 and 2018. This increasing trend in publications appears to be consistent with the view that scholarly research followed developments in narratives about the potential use of Arctic routes, and regarding the actual utilisation of Arctic routes. For instance, it was only from 2011 onwards that an increasing number of non-Russian flagged vessels started to use the NSR (CHNL, 2018). The 35 papers selected for this review were published in 22 journals. *Maritime Policy & Management* and *Transportation Research Part A: Policy and Practice* have the most frequent publications followed by the *Journal of Transport Geography*, whereas the remaining journals each published one paper between 1992 and 2018 (Table 1).

Table 1. Number of articles published per academic journal

Country	No. of Articles
Maritime Policy & Management	5
Transportation Research Part A: Policy and Practice	5
Journal of Transport Geography	4
Maritime Economics & Logistics	2
International Journal of Production Economics	1
Transportation Research Part E: Logistics and Transportation Review	1
Climatic Change	1
International Journal of e-Navigation and Maritime Economy	1
International Journal of Geographical Information Science	1
Journal of Ship Production and Design	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
Izvestiya, Atmospheric and Oceanic Physics	1
Journal of Nuclear Science and Technology	1
Sustainability	1

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Thirteen countries have contributed to Arctic shipping research concerning cost and emissions assessments of Arctic routes. The selection of countries was based on the country of affiliation of the first author of each paper. China and Canada have the biggest contributions whereas South Korea, Germany, Singapore, Australia and Finland have the lowest rate of contribution with one paper each.

### 3.2 Methodological considerations

The categorisation extended to include the methodological characteristics of the reviewed papers. Only research methods and data analysis techniques employed on cost and emissions assessments are reported.

#### 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 29 papers, whereas empirical statistical and case studies were found in four and two papers respectively (Table 2).

Analytical modelling and simulation are used with the aim of developing mathematical relationships to explain the behaviour of real-world systems by investigating the performance of dependent variables or models under different conditions (Meredith, Raturi, Amoako-Gyampah & Kapplan, 1989). Papers that used transport cost models, optimisation or mathematical simulation techniques through case examples 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 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

Optimisation models were reported in four papers. Regression, Monte Carlo simulation and GIS simulation are reported in three, two and one papers respectively. On the other hand, 26 studies report general scenario-based transport cost models. The preference for general cost models and optimisation techniques, to a lesser extent, could be attributed to the fact that researchers focus on route-specific economic characteristics and their overall competitiveness from a shipowner/charterer's perspective. 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.

Table 2. Methodological considerations of the reviewed articles

Methodological Characteristics	Categories	No. of articles
<b>Research Methods</b>	Analytical Mathematical	29
	Empirical Statistical	4
	Empirical Case Study	2
<b>Data Analysis Techniques</b>	Transport cost model	26
	Optimisation model	4
	Regression analysis	3
	Monte Carlo simulation	2
	GIS simulation	1
	None	2
	Other	3

### 3.3 Research considerations

#### 3.3.1 Routes, transport systems and OD pairs

The majority of reviewed papers assessed the NSR (23), four studies chose the NWP, three assessed both routes and one addressed the feasibility of both the NSR and the TSR. Ten studies included emissions assessments or environmental costs. Most of them juxtaposed Arctic routes with the Suez Canal route (30), four of them chose the route via the Panama Canal and two considered the route via the Cape of Good Hope amongst others. Two papers reported all-rail routes, two an all-air route, one paper included intermodal routes (sea-air) as alternatives, whereas five 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 (21 studies), six studies selected dry bulk segments, four studies examined oil tanker segments, three 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, whilst some others opted for ports in Russia, USA, Mexico and Canada.

#### 3.3.2 Cost and emissions assessments

Overall, Arctic routes were found to be either cost-competitive or profitable in 13 of 35 studies, and unprofitable or not cost-competitive in eight. 10 studies suggest that they are competitive under specific scenarios and certain trade routes. The remaining two papers project that Arctic routes would become cost-effective in the long-term. Of the ten studies that appraised emissions, two concluded that Arctic routes are either less energy efficient than the traditional

ones or incur increased environmental costs when using region-specific Global Warming Potential (GWP) factors. Figure 1 shows that Arctic routes tend to be either uncompetitive or demonstrate mixed results in most of the studies which assume an annual operating period, especially for liner shipping (e.g. Verny & Grigentin, 2009, Liu & Kronbak, 2010, Lasserre, 2015, Zhao, Hua & Lin 2016, Xu, Yang & Weng, 2018). The picture is similar regarding seasonal sailings, where four studies report mixed results (Lasserre 2014, 2015, Shibasaki, Usami, Furuichi, Teranishi & Kato, 2018, Wan, Ge & Chen, 2018). In contrast, they were found competitive in most of the studies that assumed round or single voyages mainly for bulk or specialised shipping (e.g. Wergeland, 1992, Schøyen & Bråthen, 2011, Raza & Schøyen, 2014, Lu, Park, Choi & Oh, 2014, Cariou & Faury, 2015). Finally, the competitiveness of these routes increases for year-round liner shipping operations only in the long-term (Khon & Mokhov, 2010, Khon, Mokhov, Latif, Semenov & Park, 2010).

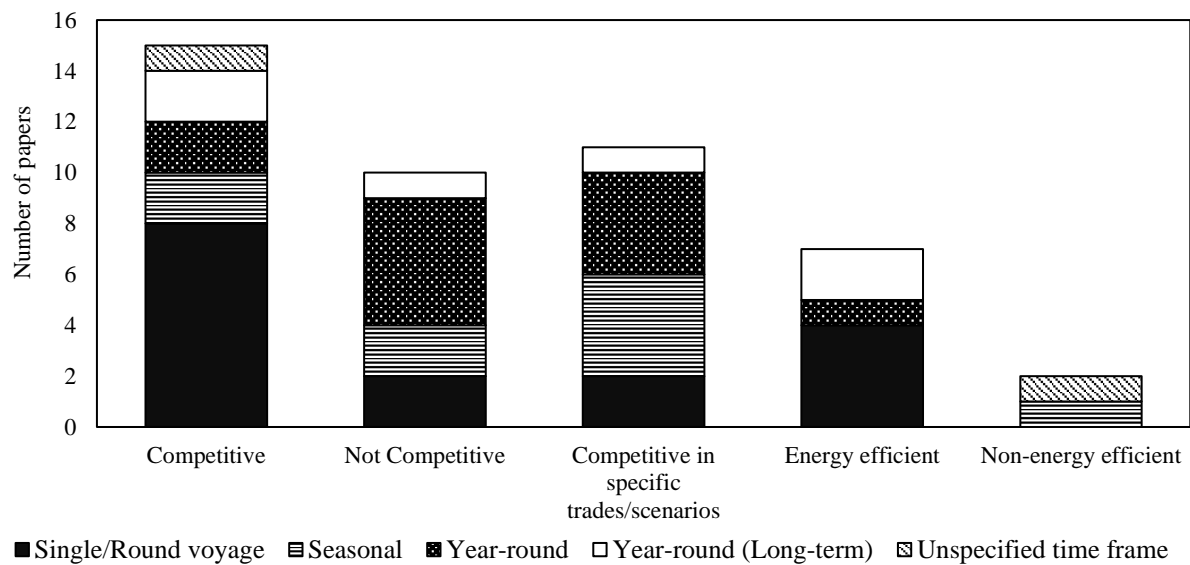


Figure 1. Cost and emissions assessment results based on the time frame of operations.

#### 4. Discussion and future directions

##### 4.1 Research insights

The number of influential factors, which determine route choice, extend to include navigational, revenue, operational and cost factors amongst others. Important variables are discussed below 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 NSR is identified as the most preferable route in the literature, probably due to currently more favourable sea ice conditions compared to the other Arctic routes, and recent infrastructure and project developments. However, studies 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, whilst in Khon, Mokhov & Semenov (2017) the season for NSR is 4-6.5 months regarding low ice class ships by late-century. Stephenson, Smith, Brigham & Agnew (2013) projected the NSR navigation

season to be approximately 103, 113 and 120 days for non-ice class, PC6 and PC3 ships respectively by the end of 21st century.

Stephenson, Brigham & Smith (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, Howell & Kushner (2016) found both the NWP and TSR to be ice-covered beyond mid-century, whilst Pizzolato, Howell, Dawson, Laliberté & Copland (2016) and Liu, Ma, Wang, Wang & Wang (2017) also concluded that multi-year ice in the NWP poses significant obstacles 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, Popova, Yool, Nurser, Williams, Bertino & Bergh (2017) identified sea ice extent and thickness as the most determining factors for shipping in the Arctic until 2030-50, 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) (Notteboom, 2012, Yip & Wong, 2016, Martinez et al., 2016, Zeng, Wang, Qu & Li, 2017, Shibasaki et al., 2018).

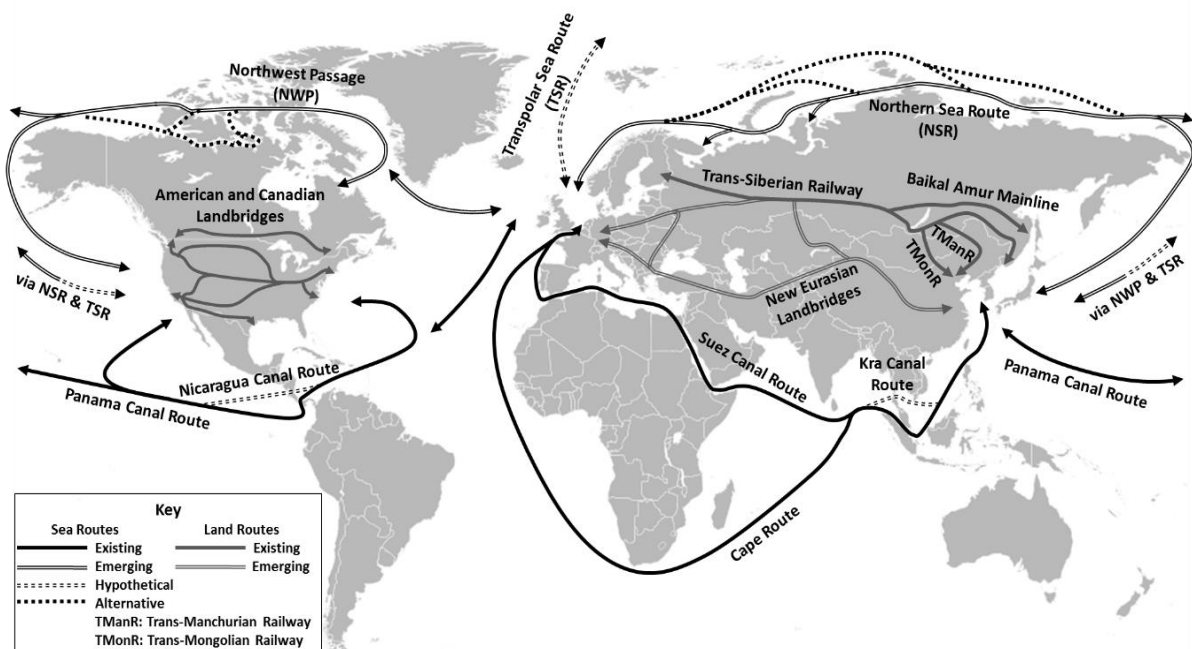


Figure 2. Alternative sea and land routes between Eurasia and North America

(Source: Theocharis et al., 2018)

#### 4.1.2 Cost, operational, and navigational variables

A wide variety of navigational, operational, and cost factors were identified. The assumed period of operations was identified to be a crucial factor across all reviewed papers. Under the current winter navigational and climatic conditions, Arctic routes could serve as seasonal alternatives during the summer/autumn season, mainly for bulkers and tankers rather than offering regular access to ships on an annual basis. An extended navigation season with low ice-breaking fees and high fuel prices increases significantly the competitiveness of Arctic routes (Liu & Kronbak, 2010, Lasserre 2014, 2015, Zhao et al., 2016, Lin & Chang, 2018, Xu et al., 2018, Wan et al., 2018) and even when assuming the use of larger vessels on the traditional routes (Furuichi & Otsuka, 2015). However, any fuel cost savings could be offset by the need to deploy additional ships on a NSR/SCR combined liner network when assuming very high fuel prices (Xu et al., 2018). Further, increased load factors and high average speeds, which implies high frequencies, could improve profitability, especially for liner shipping (Wergeland, 1992, Guy, 2006, Lasserre, 2014, 2015, Zhu, Fu, Ng, Luo & Ge, 2018, Wan et al., 2018).

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, Flynn & Szymanski, 2007, 2009, Liu & Kronbak, 2010, Xu et al., 2018, Wan et al., 2018). 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. 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.

Insurance costs are usually high for ice-class vessels operating in the Arctic. Generally, a common denominator is difficult to find since each voyage in Arctic waters is evaluated individually. Sarrabezoles, Lasserre and Hagouagn'rin (2016) report H&M and cargo insurance premiums up to 50%, and P&I premiums up to 25% in most of the cases. Yet, safety factors are considered very important from the shipping industry as well as from the underwriters' point of view. This implies that insurance premiums are still assessed on a case-by-case basis regardless of the fact that the Polar Code aimed at addressing these issues amongst others (Shyu & Ding, 2016, Tseng & Cullinane, 2018, Fedi, Faury & Gritsenko, 2018).

The ice breaking fees assumed in the reviewed papers either refer to the official NSRA fees or to discounts offered in particular cases from time to time. This discrepancy stems from the fact that transit fees have been subject to the practice of negotiated tariffs (Gritsenko & Kiiski, 2016). Yet, independent navigation is allowed depending on certain conditions since 2012, and the official NSRA 2014 tariffs have improved the fees structure, especially with respect to economies of scale (Gritsenko & Kiiski, 2016). It was found that substantially reduced fees lower the optimal range of fuel prices for a competitive NSR/SCR liner network (Xu et al., 2018), whilst the sensitivity of ice breaking fees becomes more pronounced than that of fuel prices when taking into account the ruble/US dollar exchange rates (Shibasaki et al., 2018).

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. According to transit data, the average speed recorded in 2010-13 is around 10 kts (CHNL, 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.

Increased fuel consumption is also assumed in some studies due to greater engine power required on ice water and the additional weight of an ice class vessel. Whilst the use of 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. Solakivi, Kiiski & Ojala (2017, 2018) estimate on average 10% and 30% additional fuel consumption for the current fleet of ice class containerships, and dry bulk and tankers respectively.

The fuel types to be used in the Arctic or elsewhere may also affect the economics of alternative routes in the future due to either future environmental regulations or the use of special fuels in the Arctic or the possibility of fuel taxation globally (Lasserre 2014, 2015, Schøyen & Bråthen, 2014, Cariou & Faury, 2015, Wan et al., 2018). Moreover, alternative approaches of estimating the environmental impact of maritime operations on different regions may give different results (Lindstad et al., 2016, Zhu et al., 2018).

#### 4.1.3 Revenue and market factors

Optimal operating speeds are adjusted depending on the prevailing market conditions and fuel prices amongst others. Low freight rates and/or high fuel prices impose speed reductions which favour slow steaming and vice versa (Notteboom & Vernimmen, 2009, Devanney, 2010). Various combinations of freight rates and fuel prices may favour one route over the others and this largely depends on other cost factors, such as insurance premiums, and more importantly, transit fees. Route choice also depends on the transport system in question, fleet supply and geopolitics amongst others. Generally, shorter routes are preferred in a high fuel price environment, which is also confirmed by the literature. Low freight rates may favour longer routes, but scheduled services require short transit times due to capacity requirements that have to be met at certain periods of time.

Low load factors, high ice breaking fees, potential delays and uncertainty when it comes to liner shipping favour the classical routes, even under high fuel prices (Liu & Kronbak, 2010, Lasserre, 2014, 2015, Zhang et al., 2016, Xu et al., 2018, Zhu et al., 2018). Low dwt utilisation and small ship sizes were also found to favour traditional routes for bulk shipping even under high fuel prices (Zhang et al., 2016). Other factors, such as cargo value, in-transit inventory and operating cost premiums also affect the relationship between speed, freight rates and fuel prices. 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. In addition, alternative ship sizes and ice class designs are also important factors, which could be further investigated in the future.

#### 4.1.4 Maritime transport systems

Liner shipping is mostly investigated in the literature, although this transport system does not seem to be feasible in the short to medium-term. A number of factors contributing to this are: potential delays and schedule unreliability due to prevailing sea ice conditions, limited navigation season, remoteness of Arctic ports, lack of proximity to markets and access to hinterlands, regional bottlenecks and poor port infrastructure and services amongst others (Lasserre & Pelletier, 2011, Lasserre et al., 2016, Beveridge et al., 2016). Some of the reviewed papers partly tackle these issues by incorporating either lower load factors or smaller vessels on Arctic routes. Some studies report a network structure in the literature (Xu et al., 2011, Zhao et al., 2016, Lin & Chang, 2018, Xu et al., 2018, Wan et al., 2018). Further research could shed light on network structure and the feasibility of liner operations from this perspective.



On the other hand, both bulk and specialised shipping are less studied, although these systems are the most feasible for Arctic operations due to their nature. Besides, bulk shipping (e.g. oil products, LNG, iron ore, coal and other minerals, frozen fish) dominate transit records during 2011-16 (CHNL, 2018). Recent surveys also report that bulk and specialised shipping fit better with the Arctic environment than liner shipping (Lasserre & Pelletier, 2011, Lee & Kim, 2015, Beveridge et al., 2016, Lasserre et al., 2016).

## 4.2 Methodological characteristics

### 4.2.1 Operational research and cost models

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 number of parameters by considering several alternative options related to fleet size, route choice, the number of voyages and networks. Examples are the comparative studies of Zhao et al. (2016) and Lin and Chang (2018). Speed adjustments to minimise fuel consumption and/or costs or to maximise profits in both liner and tramp shipping are very relevant (Psaraftis & 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.

Scenario-based transport cost models could be developed further to include more assumptions considering not only operational and cost factors but also environmental factors. Studies 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, Reimer & Jochmann, 2017). On the other hand, more diversity is needed in terms of scenarios and assumptions so as to provide fruitful insights and counter-arguments.

### 4.2.2 Empirical case studies

Lasserre (2014, 2015) mentions the discrepancies in hypotheses and assumptions made in the literature regarding operational and cost factors as well as market conditions. 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 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 & Schøyen, 2014, Zhao & Hu, 2016). This type of research could help increase the understanding of Arctic maritime operations.

### 4.2.3 Regression analysis and other techniques

Lu et al. (2014) use regression analysis in order to investigate the cost determinants on both the NSR and the Suez Canal route. Other techniques such as discrete choice and Multi-Criteria Decision-Making (MCDM) models could aid model-based research by investigating stakeholders' perspectives regarding influential decision-making factors and the potential of Arctic shipping amongst others (e.g. Moon, Kim & Lee, 2015, Shyu & Ding, 2016, Benedyk & Peeta, 2016, Wang, Zhang & Meng, 2018, Tseng & Cullinane, 2018).

## 5. Conclusion

The results of this updated review generally confirm those of Theocharis et al. (2018) regarding the economic potential of Arctic routes. These are considered more competitive than traditional routes in 13 of the 35 papers that evaluated their economic potential, less competitive in eight papers whereas ten report mixed results. Two papers project that they will become competitive in the long-term, especially for liner shipping. Whilst eight out of ten studies find the Arctic routes more energy efficient than their traditional rivals, two conclude that the use of the former could increase GHG and non-GHG emissions and environmental costs. 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 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.

Further research is required to investigate the potential of all Arctic routes. 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 Arctic routes. Ice conditions as well as other physical constraints 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. More model-based research with robust sensitivity analyses is needed in order to overcome discrepancies in the assumptions regarding operational and cost factors as well as to shed light on interrelations between various variables. Future research could also take into account insights from studies assessing the future accessibility of Arctic routes. As regards the environmental aspects of Arctic shipping, future research could focus on alternative fuels and new technologies. The study of future Arctic sea ice regimes along with trade and traffic flows could further improve our understanding regarding the environmental impact of shipping activities in the Arctic.

The literature focuses mainly on liner shipping and to a lesser extent on bulk shipping. However, bulk and specialised shipping will mostly benefit from Arctic routes in the short to medium-term. 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, regression analysis as well as discrete choice and MCDM techniques amongst others. Finally, this review limited its scope to studies reporting on cost and emissions assessment of Arctic routes at the micro-level. A broader review of the literature could include conceptual and descriptive studies, surveys and studies focusing on time/distance effects, shifts in trade flows, ice class ship evaluation or on the environmental impact and other economic factors at a macro-level.

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