The challenges of the Northern Sea Route

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Abstract. Global trade routes are undergoing a major restructuring driven by geopolitical crises and climate change, which is making navigation in the Arctic easier. This research focuses on the Northern Sea Route. Our aim is, based on a review of the literature, to highlight current opportunities and discuss the implications for the maritime transport market and the environment. The opportunities relate to the crises affecting other Asia-Europe corridors and the benefits this route offers to supply chains. For the maritime transport market, growing demand will shape an offer that must be considered through the prism of environmental challenges.

1 Introduction

As Rodrigue points out [1], the Arctic is crossed by four sea routes: the Arctic Bridge (from northern Scandinavia to Canada, passing north of Iceland), the Northwest Passage (in northern Canada), the Northern Sea Route (in northern Russia) and the Transpolar Sea Route *via* the Pole, although climatologists note that the latter is still hypothetical. Nevertheless, with global warming, all these routes will become increasingly navigable for long periods of the year [2]. In early 2026, President Trump's statements regarding his intention to annex Greenland, both for security reasons and, of course, for its natural resources, demonstrated just how much this region of the world was already a geopolitical and economic issue, a fact confirmed by the rise in academic publications on the subject [3]. According to Tsvetkova [4], these routes will impact logistics and supply chain strategies in the coming years.

As part of this research, we are examining the implications of the Northern Sea Route (NSR) for maritime transport. In late 2025, the Istanbul Bridge, a 4,843 TEU container ship operated by the Chinese company Sea Legend Shipping, reignited debate on this route by becoming the first vessel on a new regular service (the China Europe Arctic Express Line) serving the ports of Qingdao, Shanghai and Ningbo-Zhoushan in China, followed by those of Felixstowe, Rotterdam, Hamburg and Gdansk in Europe. According to Rodrigue [1], two German vessels were the first, in 2009, to complete a commercial voyage on this route, and in 2023, the Chinese company New Shipping Line was the first to launch a regular service (13 voyages completed) between Shanghai and Saint Petersburg.

Against the backdrop of the war in Ukraine, this inaugural voyage naturally sparked geopolitical debates; however, as is often the case, discussions regarding sustainable development were the most prevalent, highlighting the lack of port infrastructure to ensure

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safe navigation and local climate change with its impact on the permafrost. In this respect, they are entirely indicative of the academic literature, which focuses particularly on these environmental challenges of transport in the Arctic region, as well as on its feasibility and safety. However, in agreement with Tsvetkova and Timoshenko [5], we believe that the environmental aspect is only one of the three pillars of sustainable development and that it is also necessary to conduct socio-economic research on these routes, which will further connect these regions to the rest of the world economically and socio-culturally. In a region rich in resources (oil, gas…) that could become a major maritime transport corridor, whilst the population lacks essential infrastructure according to Høifødt et al. [6], the key challenge will lie in ensuring economic development that respects the inhabitants' way of life and their environment.

Our research is situated within this framework, focusing on issues related to maritime transport on the NSR. More specifically, our research question focuses on the factors that could increase transportation demand on this route and, at the same time, their impact on transportation services. We will base our analysis on a review of the literature to first the future growth in demand before identifying studies that have sought to model its impact on supply, considering the reduction in transit times associated with this maritime route. This paper is therefore structured in two parts. In the first, we present the current geopolitical context as conducive to the growth of the NSR, before, in the second part, discussing the structure of transportation services on this route as well as its implications for traditional routes.

2 A geopolitical context conducive to the development of the NSR

The aim of this first section is to show that the geopolitical context is potentially conducive to the growth of the NSR (2.1) and that it offers significant advantages today for the management of corporate supply chains (2.2).

2.1 Transport corridors under strain in the south

Since the war in Ukraine and the economic retaliatory measures against Russia – and without even revisiting the environmental concerns brandished as a moral barrier – the NSR, 80% of which lies within Russian territorial waters, appeared to be losing its appeal for Asia-Europe trade flows. However, for some time now, geopolitical developments have been changing this perception, given the wars or tensions affecting the corridors further south. A systematic examination of these corridors, from north to south, allows us to assess their current difficulties.

Since China launched its 'Belt and Road Initiative' in 2013, numerous Asia-Europe corridors have been proposed [7]. The most traditional is the Northern corridor, which runs from China to Europe *via* Mongolia and Russia. As the first to be affected by the war in Ukraine and economic retaliatory measures, although trains still run there, their numbers are significantly lower than initially hoped. The Southern Corridor, which starts in China and crosses Central Asia to reach Turkey and then Europe, was becoming an important alternative, but the current war in Iran makes its prospects highly uncertain in the short and medium term. China was particularly focused on its development, in conjunction with Iran, which joined the 'Belt and Road Initiative' in 2019, since the United States, as part of the peace agreement signed in 2025 with Armenia and Azerbaijan, acquired exclusive rights to develop the Zangezur Corridor, a strategic passage in the Middle Corridor. However, this is not China's sole motivation. Potential competition from the International North-South Transport Corridor, launched in 2002 by Russia, Iran and India—and affected by sanctions against Russia—is also a key factor in this decision. This is also justified by the potential competition from the IMEC (India Middle East Europe Economic Corridor) project, led by India, the United Arab Emirates, Saudi Arabia, France, Germany, Italy, the European Union and the United States. The literature shows that the latter is indeed perceived, particularly by researchers from China, Pakistan or other countries directly or indirectly affected by its development, as a direct competitor to the China–Pakistan corridor and the Middle Corridor [8]. Between the two corridors mentioned, North and South, the Middle Corridor (China–Kazakhstan–Azerbaijan–Armenia–Turkey), spearheaded by Turkey, presents itself as an alternative to overcome the difficulties encountered on the former. It is, however, itself beset by geopolitical tensions that are hampering its development despite substantial investment in port infrastructure on the Caspian Sea.

That leaves the maritime route, where the situation is also becoming more complicated. Iran's closure of the Strait of Hormuz certainly impacts energy flows (oil and gas), but also those of numerous industrial inputs (minerals, chemicals, fertilisers). In addition to this blockade, risks in the Red Sea are once again becoming significant. Shipping companies had begun to consider resuming traffic via Suez, but ultimately, they have no choice but to continue circumnavigating Africa *via* the Cape of Good Hope, which affects all Asia-Europe flows in terms of both cost and lead time.

These conflicts, which are emerging and blocking, here and there, the new global trade routes that states are seeking to establish, bear witness to the associated power struggles and, ultimately, to the 'war of the corridors' that is also being played out in this geopolitical space [9; 10]. In doing so, they also place at the forefront of concerns for businesses—which are directly affected—the issue of diversifying international routes to secure their supply chains and maintain their performance. From this perspective, the NSR represents a potentially attractive alternative, particularly in the medium and long term.

2.2 Opportunities for corporate supply chains

Since the Covid-19 crisis, global trade routes have become significant sources of risk for businesses. The simultaneous crisis in supply and demand has led to a deterioration in service levels provided by shipping companies (recurring delays, sudden changes to unloading ports) and ports (delays in unloading goods, terminal congestion requiring goods to be moved quickly amid a shortage of land transport, etc.). These market conditions have led, often amid criticism from shippers to a sharp rise in freight rates. Shippers then sought alternative solutions by managing their own maritime transport (chartering vessels, integrating their end-to-end international transport chain), by collaborating to improve their bargaining power vis-à-vis the major shipping lines, and by seeking to diversify the routes taken by their goods [11; 12].

Whilst the Northern rail corridor was able to (partially) alleviate the difficulties encountered up until the sanctions against Russia in 2022, the other corridors do not yet offer sufficient capacity, particularly given the unstable situation in the Middle East. Consequently, the maritime route remains the only solution. The current situation, with the conflict spreading across the Middle East following US and Israeli strikes on Iran, only exacerbates the difficulties that companies are struggling to manage to maintain the performance of their supply chains.

Whether upstream (supply of raw materials and components) or downstream (distribution of finished products), the NSR may therefore prove relevant in more ways than one. Given the context described, it already offers the possibility of reduced dependence on traditional international routes, particularly maritime ones, which, beyond the tensions mentioned that render them uncertain or even dangerous, have also reached saturation point [13]. By contributing to the development of alternative and additional capacities, this route has the potential to enhance the agility and resilience of supply chains (accelerating flows to keep pace with market demand, providing a back-up in case of problems on traditional maritime routes with reduced lead times and thus shorter response times) [14; 15]. Beyond the improvement in the supply chain's service level resulting from these capabilities to adjust more rapidly to changes in demand, the financial challenges associated with accelerating flows (more frequent rotations) have become essential. In an inflationary environment, the financial stakes involved in inventory management (reducing working capital requirements, cash flow management) are even more significant given that the need to secure supply chains has led to an upward trend in these areas.

The NSR also makes it possible to envisage the reconfiguration of supply chains, for example through the relocation of activities to countries where land and tax pressures, as well as labour costs, can also provide a competitive advantage. Serry's analysis of the development of the ports of Gdańsk and Gdynia [16], both linked by sea or rail (TEN-T corridors) to the major ports of the North Sea region and to the European market, is interesting in this regard. It highlights the ambition to make Poland the 'Japan of Europe'. In any case, analyses of the benefits of the NSR should incorporate the shippers' perspective with a view to the overall optimisation of their supply chain.

3 The NSR: what potential impact on transport provision and the environment?

The NSR has transformative potential in terms of containerised transport supply and the (re)structuring of maritime networks (3.1) and, as such, it warrants a more comprehensive approach to its environmental impacts than that generally adopted in research (3.2).

3.1 Potential impact on transport supply

Regarding the NSR's impact on transportation services, the literature can be structured around three main 'families' of theoretical frameworks, often combined within simulation models. The first relates to maritime economics and includes models of costs and revenues, speed–consumption trade-offs, economies of scale, and sustainability indicators. These approaches structure the assessment of the NSR's competitiveness relative to alternative routes by incorporating parameters such as fuel consumption and costs, tolls, and icebreaker escort fees, depending on seasonal navigability windows. The second falls within logistics and supply chain management, integrating issues related to the management of goods flows, such as lead time reduction, transport chain reliability, transit inventory costs, and potential network reconfiguration. The third 'family' relates to transport and international trade theories and models, including (i) route choice models describing potential stakeholder adoption and (ii) macro (general equilibrium) models linking lower transport costs to adjustments in trade flows. In this context, the NSR appears as a cost/time shock likely to marginally alter trade patterns, with heterogeneous and conditional effects depending on sectors, regions, capacity constraints, and climate policies.

The literature review by Theocharis et al. shows that analytical methods and transport cost models largely dominate comparative studies between the NSR and conventional routes, while seasonality, winter constraints, and navigational uncertainty limit the assumption of regular year-round service [17]. These simulation and modelling approaches can be grouped into five categories, each providing specific insights into transportation services. Techno-economic models calculate total costs (capex/opex, fuel, time, NSR fees), which are then compared with conventional routes. Key variables include fuel prices, vessel characteristics, seasonal escort costs, and environmental policies (e.g. the additional costs associated with low-sulphur fuels post-2020 and carbon taxation) [18]. Service optimisation and planning models, rooted in operational research, address routing, cargo allocation, and service design problems (e.g. time–space networks, mathematical formulations, Lagrangian decomposition/relaxation). They enable analysis of how the NSR—often seasonal—may alter network design, fleet rotation, and cost–service trade-offs. Importantly, they emphasise that the NSR is not merely a geographical shortcut but affects all route characteristics (frequency, vessel type, and service configuration), and thus the overall transport offering [19]. Route choice models and adoption scenarios, typically based on logit models (often using survey data), assess the impact of a wider opening of the NSR on route preferences and support the development of traffic transfer scenarios, particularly with respect to Suez transit [20]. Resilience and system dynamics models examine the operational resilience of shipping companies in the face of new corridors (including the NSR), capturing interdependencies between factors such as reliability, costs, and vulnerability through semi-quantitative frameworks (e.g. fuzzy cognitive maps). These models show that the introduction of new corridors reshapes operational trade-offs (robustness, vulnerability, performance) and allows comparisons between route architectures while accounting for systemic interdependencies [21]. Finally, macroeconomic models and trade–transport–emissions frameworks analyse the relationship between cost reductions associated with the NSR and their impact on international trade [22].

Other studies examine impacts on maritime transport supply and network configuration according to vessel type and cargo. In the bulk carrier segment, competitiveness is strongly influenced by market conditions (fuel prices, freight rates), explaining the persistent weakness of bulk transit despite distance savings. The advantages of the NSR do not always offset additional costs and risks (ice conditions, uncertainty, specific charges) [18]. For tankers, the literature proposes decision-making models incorporating monthly variations in navigational conditions and cost/time trade-offs between the NSR and traditional routes. Attractiveness varies by product type, vessel size, and assistance costs, and is particularly sensitive to assumptions regarding ice navigation speed and escort costs [23]. For container shipping, the NSR is currently not an economically viable alternative to Suez under realistic conditions. Distance savings do not necessarily translate into improved unit costs or profits due to route constraints (seasonality, speed limitations, specific costs, and service regularity requirements) [24]. Regarding energy transport, the NSR is analysed (i) as a corridor influencing oil supply costs and strategies, particularly for China's imports, and (ii) as a network variable affecting the economics of Asian LNG markets through scenarios involving new routes and network reconfiguration [25]. Finally, scenario-based approaches highlight that the future scale of the NSR depends on a complex interplay of geopolitics, technological developments, environmental policies, and economic dynamics. Possible futures range from a significant increase in transit traffic to continued dominance by resource exports with relatively low overall volumes [26].

This research provides valuable insights—particularly from the perspective of shipping companies—into how services may evolve with increased NSR usage. With smaller vessels than those deployed on traditional container routes and more frequent sailings, the NSR could meet demand from shippers seeking to secure and maintain supply chain performance. This could generate increasing demand, potentially fostering a more competitive transport offering, and thereby reviving environmental concerns.

3.2 Environmental impact

Environmental concerns are central to research on the NSR [5], particularly in modelling and simulation studies that assess the risks associated with increased traffic in the region.

While existing findings do not lead to an outright rejection of the NSR, they highlight the need for stronger regulatory frameworks to mitigate environmental impacts. The literature converges on a fundamental tension between reduced distances—which translate into lower fuel consumption and CO_2 emissions per voyage—and Arctic-specific externalities, but also systemic effects related to climate policies and route choices. For example, in the case of containerised freight, the trade-off depends on fuel types and regulatory contexts (e.g. environmental taxation), requiring the simultaneous consideration of private costs (for carriers and shippers) and societal costs [27].

Other studies, based on techno-economic models, incorporate environmental costs and decarbonisation pathways. They show that emission reduction strategies must be assessed at the level of the transport system rather than at the scale of individual voyages. In the context of the NSR, this implies alignment with policy instruments such as carbon taxation and emissions regulation [28]. The issue of black carbon—a highly potent pollutant—has received particular attention. Its impact is considered a major environmental concern in the Arctic, requiring not only technical and operational mitigation measures but also institutional and governance solutions at national and international levels to manage trade-offs between stakeholders and define appropriate regulatory pathways [29].

The risks of accidents and the potential impacts of oil spills have also been extensively examined in the context of increasing NSR traffic. Maritime operations in remote areas heighten exposure to risks (collisions, groundings, loss of propulsion), with potentially severe environmental consequences due to limited emergency response capacity. Bayesian models (e.g. SEMA) have been developed to estimate the socio-economic impacts of oil spills and to support the planning of optimal response strategies, highlighting the relevance of probabilistic approaches in assessing externalities [30, 31]. These approaches are increasingly complemented by data-driven research using machine learning models to predict incident types and identify key risk factors (e.g. weather and ice conditions, vessel characteristics). This reflects a broader shift toward large-scale data analysis, while also raising questions about model robustness [32].

Although valuable, much of this research remains focused on the Arctic region itself. While some studies compare alternative Arctic routes with differing environmental impacts, the primary focus remains on energy use (fossil fuels versus alternative energy sources). This body of work therefore highlights the importance of fleet evolution, both in terms of vessel size and the adoption of alternative energy technologies, in shaping future environmental outcomes.

4 Conclusion

The geopolitical context and global warming make the NSR a viable alternative for Asia-Europe trade routes. As noted, academic literature highlights the economic opportunities for shippers arising from reduced transit times, which not only lower transport costs but, above all, enable better alignment with market fluctuations. This anticipated growth in demand could impact transportation services, leading to increased competition between companies and fleet reallocations. In this context, environmental issues must be considered in a new light. Behind the initial desire to ban this route or limit its use as much as possible, research highlights the other pillars of sustainable development and calls for a more comprehensive consideration of environmental issues on the Asia-Europe routes ultimately. There is a genuine research agenda here that concerns tomorrow's supply chains, maritime transport and environmental issues from a broader perspective.

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