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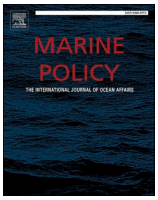

Arctic transshipment hub planning along the Northern Sea Route: A systematic literature review and policy implications of Arctic port infrastructure

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ABSTRACT

Previous research on the viability and challenges of commercial shipping along the Northern Sea Route (NSR) has thus far neglected to fully explain the connections between operational models for viable year-round commercial shipping along the NSR and port infrastructure services. In particular, little attention has been paid to the function of ports as transshipment hubs for emerging polar routes. The purpose of this paper is to synthetize the extant knowledge on the topic of Arctic ports and their function as transshipment hubs for polar routes. Following a systematic literature review methodology and using a configurative synthesis, This article analyzes a sample of 47 peer-reviewed articles indexed in high-quality academic databases to examine the extant research on transshipment hubs from a multi-dimensional perspective. The article proposes policy recommendations to address the identified gaps in the literature of transshipment hub functions for the NSR around the following axes: the operational and design features of transshipment terminals; the geopolitical and governance requirements of developing deep-water transshipment terminals; funding possibilities for the operation of transshipment terminals; and the development of a port system that is useful for the whole Arctic.

1. Introduction

Three transarctic shipping routes are widely studied in the literature [1,2]: the Northern Sea Route (NSR), which constitutes a part of the Northeast Passage (NEP); the Northwest Passage (NWP); and the Transpolar Sea Route (TSR). According to Russian law, the NSR stretches from Novaya Zemlya to the Bering Strait (crossing the Kara Sea, the Laptev Sea, the East Siberian Sea, and the Chukchi Sea) and it includes waters within a distance of 200 nautical miles from the Siberian coast [3]:

> "The area of the Northern Sea Route means a water area adjoining the northern coast of the Russian Federation, including internal sea waters, territorial sea, contiguous zone and exclusive economic zone of the Russian Federation, and limited in the East by the line delimitating the sea areas with the United States of America and by the parallel of the Dezhnev Cape in the Bering Strait; in the West, by the meridian of the Cape Zhelanie to the Novaya Zemlya archipelago, by the east coastal line of the Novaya Zemlya archipelago and the western limits of the Matochkin Shar, Kara Gates, Yugorski Shar Straits".

The NSR constitutes the main part of the NEP, which also includes the Barents Sea and connects the Atlantic and the Pacific Ocean by running along the northern coast of Eurasia [4]. The TSR is defined as a mid-ocean route across the North Pole, connecting ports in the Atlantic and the Pacific. However, the presence of sea ice on a large part of this route restricts navigation possibilities and prevents to determine a fixed navigational channel [4]. The NWP includes a set of marine routes between the Atlantic and the Pacific Ocean, along the Northern Canadian coast. This route stretches from the Davis Strait and the Baffin Bay in the east to the Beaufort Sea in the west and goes through the Canadian archipelago [4].

Research asserts that ship traffic along the NSR has the potential to increase significantly in the near future, given the geophysical, market potential, and connectivity factors at work in the region [5]. The NSR has gained attention from shipping companies by closely interrelated factors. It is important for climatic and logistical development as new

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transport routes between Europe and Asia via the NSR enable shorter transport distances and times (transit shipping), but it also represents an increase in destination shipping connected to resource exploitation [6]. For example, the NSR between NW Europe and NE Asia is 30–40% shorter in distance and potentially in time (during the summer-autumn season) than the Suez Route [7]. Ships navigating between Rotterdam – the busiest port in Europe in terms of the volume of containers transiting each year – and East Asian ports could therefore benefit from greater use of the NSR (see Fig. 1). It is also worth noting that East Asia, particularly China, contains a number of the busiest ports in the world, led by Shanghai. The logistical development goes interconnected to the reduction in summer sea-ice in the Arctic Ocean due to global warming, which has also led to increased natural resource exploitation in the Eurasian Arctic (along the NSR) [8]. This explains why several actors (including states, shipping companies, and export industries) show significant interest in the potential development of the NSR as a strategic corridor for international trade in the coming years.

Vessels' ice class and sea ice conditions decide whether ships are allowed to operate on the NSR independently. Transshipment onto ice-strengthened vessels may not be necessary when voyages take place in open water or in areas with light ice conditions. The Centre for High North Logistics (CHNL) observed that there were 9 non–ice class vessels operating on the NSR in the summer–autumn season of 2021, in which the first vessel entered the NSR on 10 August and left on 23 August, while the last vessel entered on 29 September and left on 7 October [9]. The Northern Sea Route Administration (NSRA) monitors ice conditions and updates hydrometeorological information on a daily basis. Before a ship enters into the NSR, the shipmaster must obtain permission from NSRA. This permission lists which areas the ship is allowed to operate with and without an ice-breaking navigation service. The organization of navigation of ships in the water area of the NSR is carried out by Rosatom, who develop routes for ship navigation and ensures icebreaker assistance [10]. If transshipment onto ice-class vessels is not considered, non–ice class vessels can navigate independently only in open water and when escorted by icebreaking navigation service in water with light ice conditions.

Shipping traffic along the NSR increased steadily during the past decade, from around 1.81 million tonnes (MT) in 2012–34.85 MT in 2021, with the largest increase in 2017 and 2018 [11,12]. Delivering exported oil and gas products makes up around two thirds of the total cargo flow. The remainder is mainly bulk and general cargo. In terms of transit traffic, CHNL recorded 86 transit voyages in 2021 [9]. As can be seen in Table 1, 72 voyages were international transit and 8 others were Russian domestic transport. In terms of the direction, 49 of them were eastward voyages and the remaining 37 were from east to west. In addition, 33 out of the 86 transit voyages had destinations in Russia, more than any other country. China is the second largest user of NSR, with 30 voyages having destinations in China in 2021. Other stakeholders include Denmark (7 voyages), Canada (6 voyages), Finland (5 voyages), Norway (2 voyages), South Korea (2 voyages), and the UK (1 voyage).

When it comes to the cargo type of transit voyages (Table 2), the largest category is dry bulk (mainly iron ore product), followed by general cargo. These two major categories account for more than 96% of cargo flow. The rest comprises liquid bulk, containers, and fish products.

Despite the potential of the NSR, research converges on the conclusion that container ship trading along the NSR is still far from becoming a real alternative to major transcontinental routes such as the Suez Canal [14,15]. Logistical concerns remain a critical issue for most operators, particularly given the remoteness of most NSR locations, a lack of roads, a harsh climate, unique logistics operations, and a need for available search-and-rescue (SAR) services [16], limitations in the draft of the vessels [17], poorly developed infrastructure (small-sized equipped ports) and seasonality of work of some ports in the water area of the NSR also limits commercial potential of the route [18].

The development of transshipment hubs constitutes a major step toward the greater utilization of the NSR as an intercontinental waterway, as the efficient use of vessels that can withstand the route's ice conditions requires the transshipment of goods from one ship to another on dedicated port infrastructure. Such infrastructure would, by necessity, become the main entry or exit on the NSR. While the significant transit costs on the NSR would obviously outstrip the benefits for most shipping companies, transshipment hubs located on both sides of this Arctic route and connected to each other with specific vessels used by specialized shipping operators could make the NSR a much more attractive transit route [19].

Hubs are often associated with the concept of *gateways* as both rely on the idea of flows converging on a particular location. However, while gateways have an intermodal function as points where passengers and goods transit from one transport mode to another, hubs instead have a transmodal function as points where transits occur between identical transport modes, like two airplanes at an airport hub [20]. Thus, hubs are described as nodes that are part of a network, with a particular location aiming to facilitate connectivity [21]. This provides undeniable advantages for transport operators in terms of scale economies as the establishment of hubs enables the concentration of flows on specific trunk routes, which can also lead to improved connections to and from less populated areas. In addition to logistical benefits, Arctic hubs improve connections to and from less populated areas and hence positively influence the demographic of the Arctic. Developing hubs implies developing numerous related activities in a single place. For example, this might include cruises, container management, raw materials shipments, and potentially inland infrastructure to connect the ports to the national network. Finally, Arctic hubs participate in shaping a port system to prove a safe and profitable navigation, and to reinforce the sovereignty of a state in a defined area. However, such a network structure favors congestion and generates a higher volume of pollution near the hubs because of a higher concentration of traffic, as observed in the case of air transport [22].

The prioritization of transshipment hubs as logistical infrastructure along the NSR stems from LNG exports and container shipping. According to the "Strategy for Developing the Russian Arctic Zone and Ensuring National Security until 2035"[1] (Arctic strategy up to 2035) [23], the total volume of the cargo shipping in the waters of the NSR is planned to increase to 90 MT in 2030 and 130 MT in 2035 (including LNG production to 64 MT tons and 91 MT and transit cargo shipping 2 MT and 10 MT correspondingly). To achieve some of the goals and objectives of outlined in the Decrees of the President of Russia such as 'Basic Principles of Russian Federation State Policy in the Arctic to 2035[2]', Rosatom initiated the project Northern Maritime Transit Corridor (NMTC) [24]. The main idea of the project is the creation of the logistical hubs, construction of the commercial fleet and the developing of the effective work of the transport system and the level of service provided for the participants of shipping market. These concrete plans and investments are in line with technical-economical analysis of container line in the frame of the NMTC project.

In terms of academic knowledge within Arctic transportation research, the extant literature has so far neglected a more concrete

[1] The Arctic Strategy up to 2035 is a strategic planning document on ensuring the national security of the Russian Federation, which was drafted to implement the Basic Principles of the Russian Federation State Policy in the Arctic to 2035. It determines the measures aimed at fulfilling the main tasks of developing the Arctic zone and ensuring national security, as well as the stages and expected results of carrying out these measures.

[2] The foundations of Russia's state policy in the Arctic constitute a strategic planning document aimed at ensuring national security and have been drafted to protect the country's national interests. The document establishes the goals, main areas, tasks and mechanisms of implementing Russia's state policy in the Arctic. In addition, the document lists the main challenges in ensuring national security in the Arctic [72].

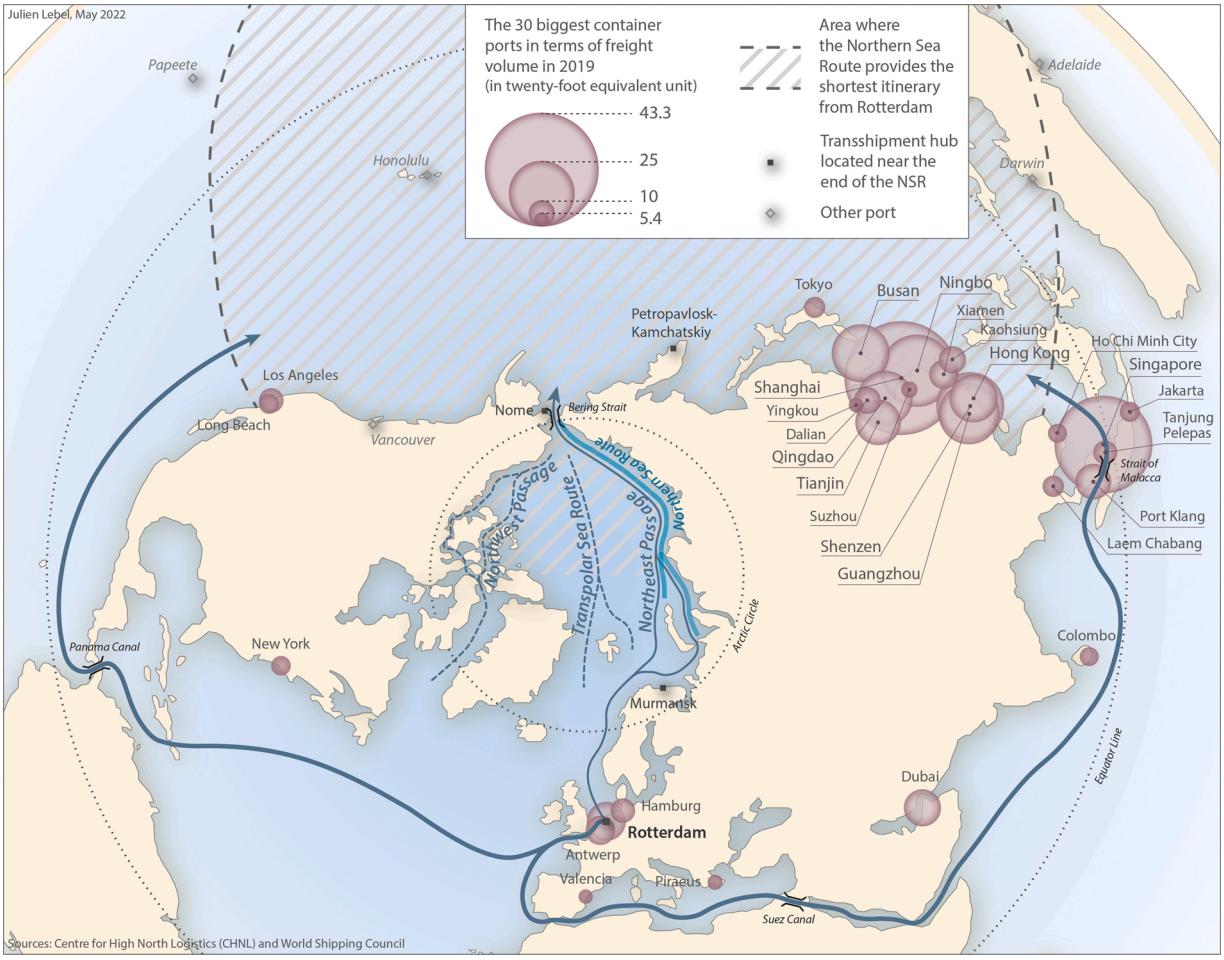

Fig. 1. This shows the 30 biggest container ports in the world and the major sea routes from Rotterdam to the Pacific area, using data from the Centre for High North Logistics (CHNL) and the World Shipping Council. The area where the Northern Sea Route provides the shortest itinerary from Rotterdam was calculated by comparing the distance when the ships travel via the Bering Strait, the Panama Canal, or the Suez Canal to reach ports located in the Pacific Ocean or in Southeast Asia. The map has an azimuthal equidistant projection centered on the North Pole, which creates distortions near the edges of the map.

Table 1
Transit voyages on NSR in 2021.

	Eastward Voyages	*Westward Voyages*	*Total*
International Transit	41	31	72
Russian Cabotage	8	6	14
Total	49	37	86

Source: [9].

Table 2
Cargo flow of transit voyages on NSR in 2021, by type cargo.

Cargo Types	*Cargo Volume (thousand metric tonnes)*	*Percentage*
Dry bulk	1580	77.96%
General cargo	374	18.45%
Liquid bulk	39	1.92%
Containers	30.8	1.52%
Fish products	3	0.15%

Source: [13].

analysis of the question concerning the development of deep-water ports and their function as transshipment hubs. Recent contributions call for further research to understand the context of transshipment hubs in Arctic shipping and the NSR [25,26]. In order to fill this gap, this paper's main objective is to address the following research question:

What are the key discussions and themes in regard to port planning in the Arctic and how do these discussions inform the role of transshipment hubs along the NSR?

This paper contributes to the literature on Arctic marine policy by problematizing the extant research on the operational models of the NSR and more concretely by delineating the role of ports as transshipment hubs. As a result, it fills in the existing gaps about ports' functions along the polar routes, specifically the NSR, vis-à-vis the combination of destination and transit shipping for commercially viable maritime logistics. In order to tackle the research question above, the authors proceed with a systematic literature review. Section 2 presents the sources and methods. Section 3 includes a thematic analysis of the selected literature. Section 4 discusses the results in light of the functions of transshipment hubs along the NSR and policy implications. Section 5 presents conclusions and implications for future research.

2. Materials and methods

This paper follows a systematic literature review (SLR) approach, taking as inspiration similar research in transportation research studies, e.g.,[27–29]. SLR is a research method aimed at answering a pre-defined research question and characterized by setting exclusion criteria for identifying relevant published or non-published scientific literature with the purpose of identifying research gaps, conceptual developments, or advances in the research field. Other SLR characteristics [30] are a

systematic assessment of the potential bias and quality of the individual articles in the sample, and the conclusions identifying potential gaps to advance the field.

In their methodological guidelines, Cardoso Ermel et al. [30] synthetize practices of SLR across different fields (engineering, business, medicine, natural sciences), outlining an overall set of steps for complying with the SLR quality criteria. The steps comprise setting a guiding research question, developing a list of search terms, searching the literature in academic databases, setting exclusion and inclusion criteria, selecting the final sample, and thematically analyzing the final sample [31].

The methodological approach as applied in this paper is outlined in Fig. 2.

2.1. Scope of the literature review

As the first step, the authors defined a guiding research question: *What are the key discussions and themes in regard to port planning in the Arctic, and how do these discussions inform the role of transshipment hubs along the NSR?*

This guiding research question allowed the authors to frame the key terms and concepts that should be included in the literature search (Table 3). These keywords are often referred to in SLRs about ports [32] and Arctic shipping [2]. As a result, a combination of search terms using these keywords was utilized. Similar combinations are adopted in SLR papers focused on Arctic shipping [33].

The next step involved setting up the inclusion criteria [30]. The

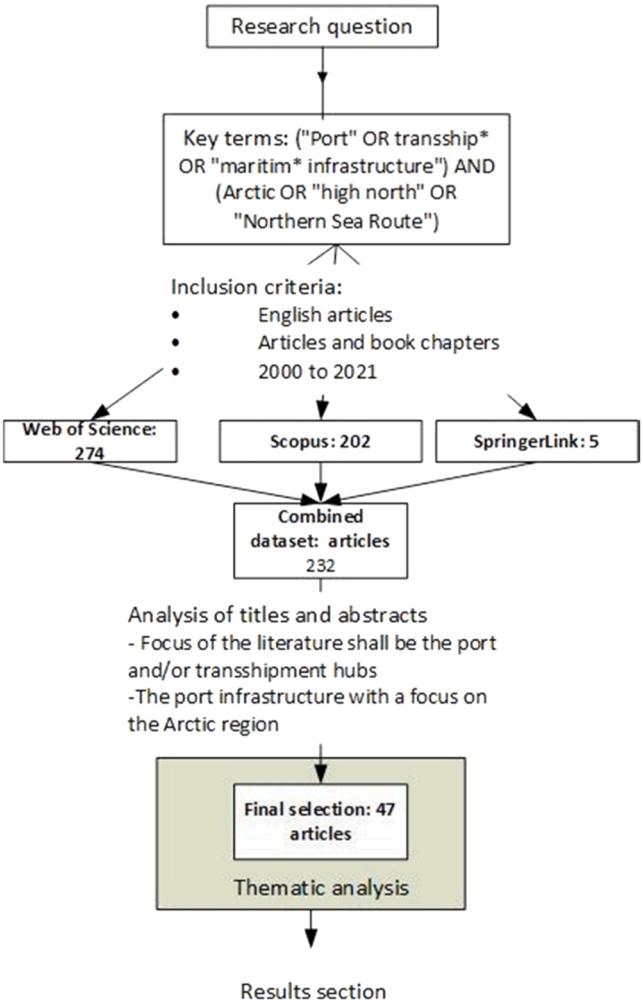

Fig. 2. Methodological approach for the SLR implemented in this paper.

Table 3
Keywords included in the database search.

Port	Arctic
Port OR transship* OR "maritim* infrastructure"	Arctic OR "high north" OR "Northern sea route" OR polar

authors included only peer-reviewed book chapters and journal articles published in the English language. These inclusion criteria echo conventional practices in the field [27], with a particular emphasis on the discussions emerging since the beginning of the 21st century.

2.2. Database search

Three databases were chosen to perform the systemic search: Web of Science, Scopus, and SpringerLink. The first two are considered the most comprehensive indexes of scientific literature, and as such are repositories of high-quality research. Therefore, most academic work takes both databases as a point of departure for research [30]. The search in Web of Science included the following sets: SCI-expanded, SSCI and ESCI, resulting in an initial search of 274 articles. The initial search in Scopus led to 202 articles. SpringerLink was included because Springer has published a number of edited books in the past decade with a focus on the NSR and Arctic shipping. The authors included the five edited books in the sample, even though each chapter in the books addressed different issues (See appendix A).

2.3. Article selection for thematic analysis

All the bibliographic information for each article (author, year, title, abstract, journal/ book name, number of citations and doi number) was exported into an Excel file for analysis. This first stage of analysis focused on a preliminary comparison of the titles and author information of each article to remove any duplicate articles from the dataset. The output of this stage was 232 unique articles from the three databases. The authors then proceeded to a close analysis of this sample, aiming to reduce the dataset to a critical number of articles providing in-depth information about the critical issues tackled by the research question [34]. Each article's title and abstract was read and decided to include in the final sample only those explicitly focused on port infrastructure in the Arctic region. This means that the authors excluded from further analysis those articles which only incidentally discussed port infrastructure development as part of other general aspects of Arctic shipping. Once this process was complete, the final list included 47 articles, which were read and analyzed thematically. Appendix A presents the list of selected articles.

2.4. Thematic analysis and synthesis

A thematic analysis was carried out with the final selection of 47 articles. For this analysis, four key aspects of each article were summarized (Table 4): 1) The article's general bibliographic information (including publication year and journal, but also focus country and methods); 2) the article's disciplinary approach to Arctic port and infrastructure development; 3) the port and transshipment hub issue(s) addressed in the Article; and 4) how the article addresses port development in the context of the NSR. Parts (1) and (2) address the descriptive aspects of the research question "What are the key discussions and themes in regard to port planning in the Arctic?" Parts (3) and (4) are directly connected to the reflective approach linked to the second part of the research question: "how do these discussions inform the role of transshipment hubs along the NSR?".

The synthesis steps of SLR involve not a simple summary of the identified literature, but combining insights from multiple studies to identify gaps or advances in the field through conceptual development [35]. This article follows a configurative synthesis approach with the

Table 4
Synthesis of the scientific literature included in the final sample.

Theme	Issues
I- Article information	• Publication • Country • Methods
II - Article content	• Specific Arctic route focus (if applicable) • Focus of the article (policy, geopolitics, economics, etc.) • Main issue of the paper • Type(s) of vessel mentioned in the article (if applicable)
III - Transshipment hub or port is included in the list of issues	• In what context are transshipment hubs mentioned? • Which products? • Which is the port mentioned in the article with potential transshipment hub functions? • What geographical entities/locations is the hub linking? • Which transportation modes are mentioned in relation to the transshipment hub? • Which infrastructure characteristics relevant to the Arctic environment are mentioned?
IV- Northern Sea Route	• What infrastructure considerations does the article address in relation to port development in the Arctic

integrative technique, commonly used in qualitative research, the purpose of which is to refine theories. This technique is appropriate when the overall objective is to identify gaps in the extant literature and propose a research agenda [35]; an integrative review thus reduces the primary research into codes that are subsequently organized into categories. In order to synthetize the literature, each article was coded according to the elements listed in Table 4. These relationships are summarized in Section 3.2. To increase the validity of the results, Section 3.3 contrasts the analysis of academic papers with the latest professional Arctic press articles and policy documents from the Russian government concerning transshipment hub developments. A similar approach is introduced in the SLR of Lavissière et al. [2]. After outlining the key categories in Section 3, the article includes an analytical map representing a spatial analysis of the key insights from the literature (Section 3.4).

The next section (Analysis) builds on two parts. First, it provides a description of the academic literature and the scientific state of the art regarding Arctic transshipment research. This synthesizes parts 1–2 of the articles' coding procedure. Second, the authors synthesize the main discussions within the themes described in parts 3–4 of the articles' coding procedure as described above.

3. Results

3.1. General overview of publications focused on Arctic port development

This section's descriptive analysis with frequency distributions technique aims to provide trends and insights to the audience relating to previous research on Arctic logistics hubs. This section demonstrates the frequency distribution of publications by year, popular journals, subject area, methodology, authors' location, and geographical focus. The analysis illustrates that the first literature of Arctic port development was introduced in 2000 and this topic has particularly attracted researchers' attention in the past six years. The most popular scientific publishing channels in this area are the *Journal of Transport Geography*, *Marine Policy*, *Maritime Policy & Management*, and *Polar Geography*. Logistics (38%) and planning (36%) are the two top subject areas when researchers discuss Arctic port development. Qualitative methodologies are the most commonly adopted research methodologies in reviewed articles. Norway, the US, Russia, and China are the major stakeholders of the Arctic sea routes, as evident in that almost 60% of articles (28 articles) are contributed by authors located in these four countries. In addition, likely due to the geographical advantage, Russia (19 articles, 40%) is the focus of the selected publications, followed by Norway (6 articles, 13%).

Fig. 3 illustrates the distribution of the selected articles based on their year of publication. There are only six publications in the first decade of the research period, and no more than one published in any single year. The number of publications from 2011 onwards fluctuates with an increasing trend. 60% of articles were published in the last six years.

Three types of sources are included in this sample: book chapters (10 sources, accounting for 21% of the sample), journal review articles (1 source, 2%) and journal articles (36 sources, 77%). Table 5 lists the journals with more published articles were, and shows that a wide variety of journals (27) published articles on the topic of Arctic logistic hubs. *Journal of Transport Geography, Marine Policy, Maritime Policy & Management*, and *Polar Geography* are the main sources for this topic (3 publications each), followed by *Journal of Maritime Research* and *Maritime Economics and Logistics* (2 each).

Fig. 4 illustrates the distribution of articles by subject area and year. Please note that some articles are placed in multiple categories. For example, Ragner [36] discussed both the logistics aspect and economic potential of the NSR, which means that the paper is included in both the "Economics" group and the "Logistics" group. Among the 47 reviewed articles, there are 7 on policy, 17 on planning, 7 on geopolitics, 8 on economics, 4 on engineering, 18 on logistics, and 3 on other subjects.

In terms of the research methodology adopted in the articles, 68.1% are based on qualitative methodologies, which of which 25% (8 articles) use a case study approach and the remaining 75% (24 articles) apply other qualitative approaches, e.g. report analysis [37], small-scale mapping [38], and business analytics [39]. 31.9% of articles (15 articles) use quantitative approaches, of which 33.3% (5 articles) adopt quantitative simulation, 6.7% (1 article) use quantitative regression, and the rest 60% (9 articles) use other quantitative approaches, e.g. graphical models for optimization problems [40], spatiotemporal mapping and shipping cost modelling [41], and quantitative case study [42]. (Fig. 5).

The vast majority of publications on the topic of Arctic logistics hubs (30 articles, accounting for 64% of overall publications) are by authors located in the six states surrounding the Arctic, namely Norway (9 articles), the United States (8 articles), Russia (7 articles), Canada (2 articles), Denmark (2 articles), and Iceland (2 articles). Other researchers contributing to this area come from regions which would see significant impact from the opening of the NSR: (1) major Asian exporting areas, including China, Malaysia, and Taiwan; (2) countries close to the NSR, including Poland, Finland, Sweden, Switzerland, the Netherlands, and Japan; and (3) Singapore, the major transshipment hub in the traditional Southern Sea Route (SSR) via the Suez Canal (Fig. 6).

In terms of the geographical focus of the selected publications, as illustrated in Fig. 7, the areas surrounding the Arctic also attract the most attention (33 articles, accounting for 57% of contributions). Other articles either focus on the seaports along the traditional SSR, discussing the impact of the NSR on them, or focus on the seaports close to the NSR, comparing shipping efficiency between the NSR and the SSR for selected origin-destination pairs.

3.2. Development of deep-water ports with transshipment functions in the NSR

3.2.1. Contexts, locations, and geographical entities linking in which transshipment hubs are mentioned

The port infrastructure along the NSR has historically evolved to align with shipping activities, and transition shipping of cargo with origins and destinations outside the Arctic has been an important driver of the growing demand; this incudes cargo for local communities, fishing, tourism and cruises, scientific expeditions, and resource extraction [43]. Few ports along the NSR can handle vessels with a draft between

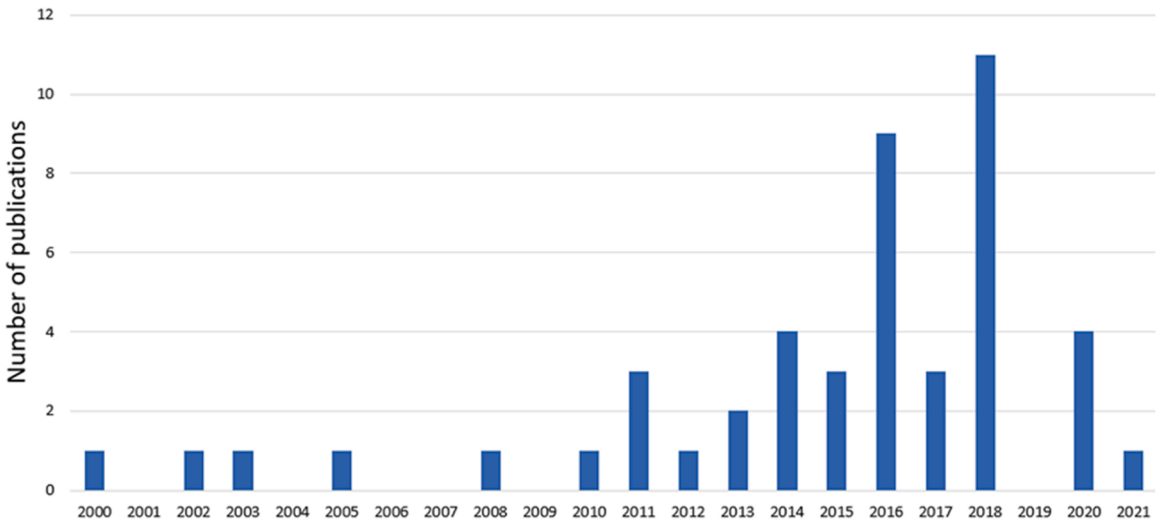

Fig. 3. Publications per year; only final sample of articles for detailed analysis.

Table 5
Distribution of papers across journals.

Journals	Number of papers
Journal of Transport Geography	3
Marine Policy	3
Maritime Policy & Management	3
Polar Geography	3
Journal of Maritime Research	2
Maritime Economics and Logistics	2
Applied Geography	1
Atomic Energy	1
Cold Regions Science and Technology	1
Futures	1
Geography and Natural Resources	1
Jati – Journal of Southeast Asian Studies	1
Journal of Siberian Federal University	1
Journal of the Geographical Institute "Jovan Cvijic" Sasa	1
Land Degradation & Development	1
Maritime Studies	1
Ocean and Coastal Management	1
Ocean Engineering	1
Ocean Yearbook	1
Polar Record	1
Post Soviet Geography and Economics	1
Regional Research of Russia	1
The Journal of Navigation	1
The Polar Journal	1
Tourism in Marine Environments	1
Transportation Research Part B	1
WMU Journal of Maritime Affairs	1

10 and 20 m. Most NSR ports are located in the Barents and Kara seas, locations which experience similar seasonal variations in port access due to ice. Several small ports have significance in supplying local communities but are not yet open to international shipping or do not have enough capacity to receive large vessels [16]. Our review of the literature identified a number of port activities and products closely connected to transshipment hub locations (Table 6). Analysis of the literature indicates that seven categories of transshipment infrastructure are often discussed in the publications (Fig. 8).

The extant literature centers around four aspects in relation to the context, locations, and geographical entities linking transshipment hubs. In our coding of the literature, the identified four aspects are: placement and design (8 mentions), Russian hinterland and infrastructure policy (7 mentions), contextualization of Arctic port development issues (5 mentions,) and impact on Asian ports (2 mentions).

The placement conditions for transshipment hubs often present an issue in the Arctic region. One factor for placement is environmental. In a study analyzing fuel consumption ratios when navigating the NSR, Chou et al. [54] concluded that the hub location influences how efficiently the NSR is used. With a starting point in the port of Rotterdam in Western Europe, the study quantifies carbon emissions by comparing potential hub locations in East Asia (Yokohama, Busan, Shanghai, Kaohsiung, Hong Kong, and Singapore), thus implying that environmental considerations should be accounted for when choosing the hub location and that there is a possibility to reduce greenhouse gas emissions if fuel efficiency is accounted for. Another factor for placement is how the potential location connects with routes other than the NSR. Sun and Zheng [55] develop a methodology to identify global hub locations, even in uncharted areas without ports. The study is illustrated with a case study of emerging Arctic routes. Sun and Zheng's study echoes the work of Dalaklis and Baxevani [46], whose main argument is that the economic viability of developing a hub rests on the possibility that it can connect with two or three maritime routes at the extreme of the Bering Strait, specifically the NWP or the TSR. A third factor is the logistical operational model. Milakovic et al. [22] propose, among six operational models, intermediate transshipment hubs at each end of the NSR, with ice-going cargo vessels sailing between the hubs in ice and feeders along the open-water sections of the route.

The literature also addresses design conditions from a critical perspective. Some authors are concerned with how to plan the exact capacity of transshipment hubs needed for an operational NSR as an international maritime route. Milaković et al. [26] also argument that it is difficult to plan the capacity of such ports as the actual capacity also depends on the shipping flows emerging from the endpoints of the NSR or NWP. Research attempting to determine optimal port capacity should account for both destination and transit ship traffic, along with factors such as how close ports are to other alternative industrial activities and human settlements [56]. A similar concern about capacity potential is highlighted by Pahl and Kaiser [57], who look into deep-water port design challenges and capacity. They define deep-water port infrastructure as infrastructure capable of accommodating large, heavily loaded ships (with a draft up to 12.04 m). However, the projections suggest that the anticipated traffic will not require such ports. Demands are rather emerging from local communities that have needs to solve, primarily those relating to resource extraction.

Another question impacting placement and design is whether potential transshipment hub locations are drivers of the development of industrial clusters. When discussing the development of an aqua-territorial production complex that includes marine ports (and possibly river ports that are available for ships), manufacturing firms,

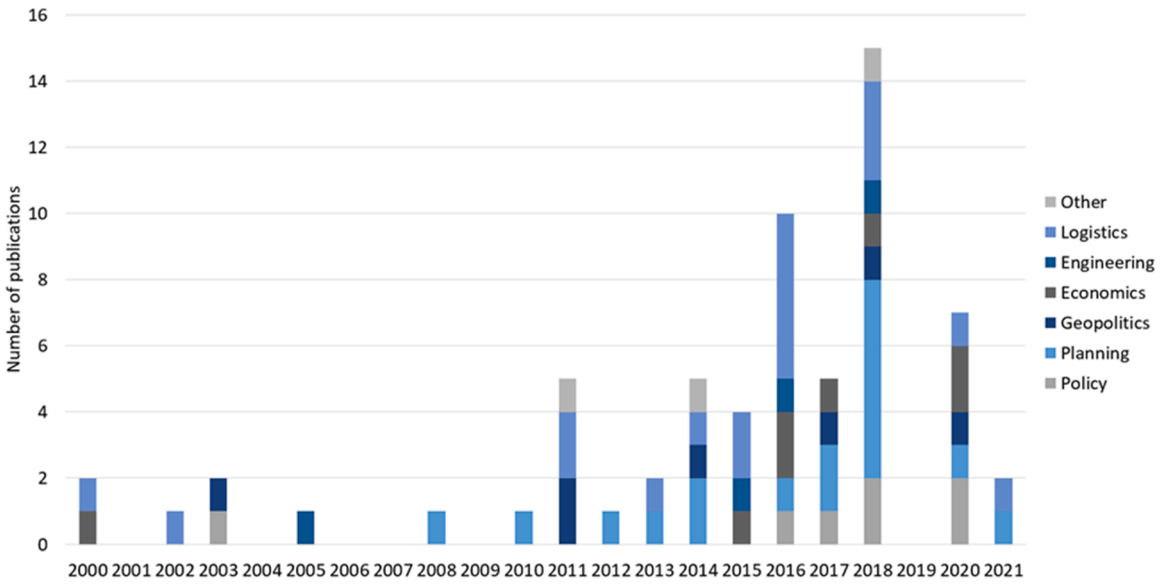

Fig. 4. Article distribution by subject area and publication year.

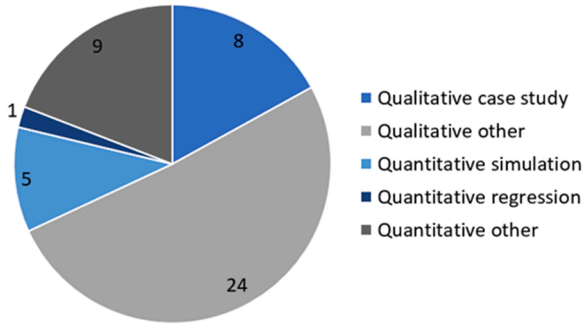

Fig. 5. Methodological approaches in the articles.

and coastal settlements, Malov and Tarasova [52] consider it advisable to start the industrial development process of the Russian part of the Arctic zone with the formation (or, in some places, restoration) of local port and industrial sites or centers [52].

The second broad focus of the literature on transshipment hubs along the NSR concerns Russian hinterland and infrastructure policy, which evolves from Russian Arctic policy. For instance, Liu et al. [49] analyze whether Russia's Arctic strategy promoted the development of ports along the NSR between 2003 and 2012. Sevastyanov and Kravchuk [53] discusses Russian policies on the development of the NSR as an international sea route in combination with domestic services for the Russian fleet, and the measures undertaken by Moscow to improve the navigation potential of the NSR.

As seen from these broader top-down policy approaches, there is a clear connection between the development status of ports along the NSR and broader hinterland development policies. Østreng et al. [44] introduce the discussion of transshipment hubs as part of each port description, whereby several of the ports located along the NSR can be seen as transshipment hubs at different scales, although not all of them are transshipment hubs for seagoing vessels. Their chapter also categorizes transshipment hubs according to port specializations. In a similar way, Pastusiak [16] also introduces the notion of transshipment hubs. but always in the sense of intra-Arctic shipping within Russia, assessing which types of products the key ports are handling. A concrete example of this connection between the NSR and the hinterland is the establishment of a diversified transregional transportation hub in the Ob River region and the supplementation of the Sabetta seaport capacities with riverways, railroads, and highways to improve the return on federal investment in the region and drive new business development,

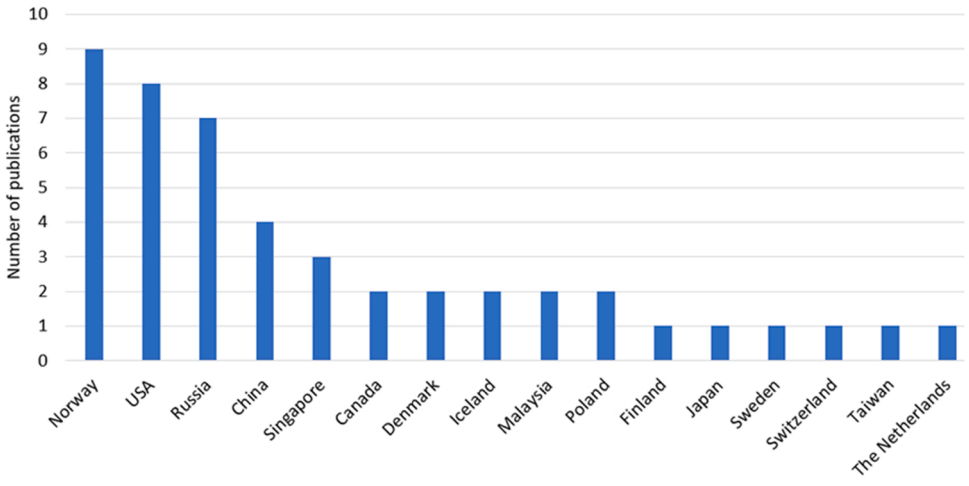

Fig. 6. Main authors' affiliation of the selected publication (region or country).

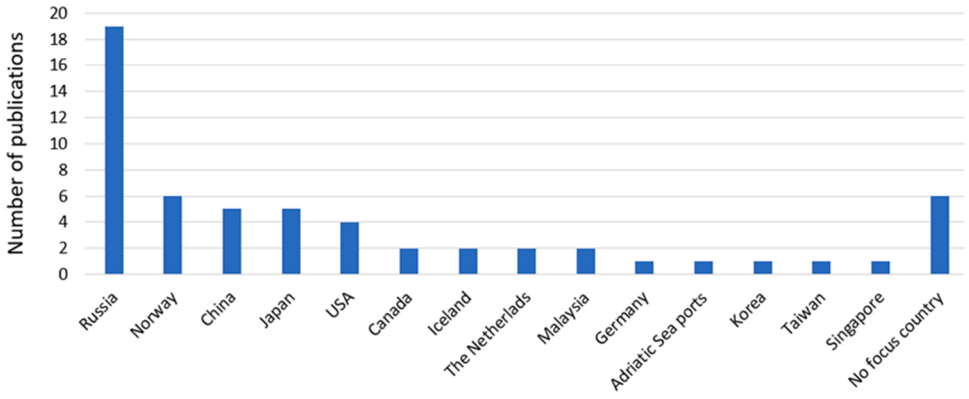

Fig. 7. Geographical focus of the selected publication (region or country).

Table 6
Overview of the port locations mentioned in the literature and connected activities.

COUNTRY	PORT	PORT ACTIVITY HIGHLIGHTED	REFERENCE
RUSSIA	Arkhangelsk	LNG, timber	[6,44]
	Cape Kamenny	Crude oil	[6]
	Dudinka	Non-ferrous metals, iron ore, nickel	[6,16]
	Igarka	Timber	[45]
	Kharasavey	Gas	[16]
	Murmansk	Passenger, ship repair, shipyard, Atomflot premises, LNG, food, equipment, general cargo, minerals, oil, gas, fishing supplies	[6,16,44, 46]
	Novy Port	Gas	[16]
	Ob Bay	Oil	[44]
	Sabetta	LNG, grain, metals coal and oil transport gas condensate, polyethylene, coal, grain wooed, engineering products	[46,47]
	Talagi	Oil	[44]
	Tiksi	Oil	[16,44]
	Vitino terminal	Oil	[16,44]
SVALBARD/ NORWAY	Longyearbyen	Tourist/cruise, oil and gas, products from fishing activity	[48]
CANADA	Port of Churchill	Fertilizers	[46]

Source: Own elaboration.

including commercial and industrial projects with substantial social and economic effects [40]. Ports with transshipment functions have a clear role in the analysis of the extractive industries in the Western Russian Arctic and the new development of mining and petroleum fields in East Siberia [50]. Similarly, Kaiser et al. [5] mention ports in general (though they do not use the term "transshipment hub"), and acknowledge that port development driven by resource extraction (oil and gas, fisheries) depends on international price fluctuations.

The review also identified a third broad category of research work which places the “transshipment hub” discussion within a broader Arctic context. One such study tackles the governance aspects of new projects involving transnational investment for the development of the port of Sabetta with the purpose of facilitating petroleum and gas extraction [47].

3.2.2. *Infrastructure characteristics relevant to the Arctic environment*

Due to the harsh climate conditions in the Arctic, navigational support equipment is needed, such as icebreaking, rescue, and auxiliary fleets. Our review revealed infrastructure characteristics relevant to three main issues of potential transshipment hubs: navigational concerns, port infrastructure, and access to the ports and surrounding communities. In terms of navigational concerns, the implementation of a transshipment system to allow year-round NSR transit should be coupled with environmental monitoring and forecasting services, the deployment of two marine rescue and coordination centers and three subcenters, six search and rescue stations, and the modernization of maritime awareness systems in the future once traffic has grown. Training is also key to producing experienced mariners [53,58].

Several ports along the NSR do not offer year-round access. Icebreakers are needed in Arkhangelsk and other ports covered by ice, and special equipment is required for loading and unloading cargo in ports partly covered by ice [16]. The current icebreaker fleet comprises 40 vessels, of which 4 are nuclear and will be decommissioned between 2023 and 2035 [53]. However, icebreakers are needed as the Ob River is only navigable from late May to late October. Currently, diesel icebreakers and one nuclear icebreaker are available to facilitate access to the Ob River, yet the restricted capacity is preventing traffic growth [47].

Port infrastructure is also affected by the complex geological climatic and hydrological conditions of the Arctic. 70 million tons have been dredged in shallower waters to accommodate ships with a draft up to 12 m. Similarly, inland infrastructure connections are poor in the eastern Russian section of the NSR. For instance, 175 km of railways to Bovanenkovo is needed to transform Sabetta from a specialized port into a multifunctional port [47].

3.2.3. *Issues of funding discussed in relation to transshipment hub and port infrastructure development*

The literature also provides background on the financial issues of port infrastructure in the Arctic context in general and concerning ports along the NSR in particular. The reviewed studies do not directly address planned deep-water transshipment hubs explicitly, but the aspects of infrastructure funding which are covered are worth considering for any future project in this domain.

One set of sources discusses whether state or market-based funding is able to drive potential port developments along the NSR. Malov and Tarasova [52] conclude that NSR-connected infrastructure, such as transshipment hubs, is subject to three plausible scenarios: the market scenario, whereby the Russian state could face challenges in funding all costs; the geopolitical scenario, whereby the state investments in infrastructure are primarily driven by a combination of support from the defense and extractive industries; and a defense scenario, whereby infrastructure development aims to fulfill the needs of defense. Overall, the market scenario seems to echo the findings of other researchers. However, the literature also portrays a rather negative assessment of the eastbound gas, petroleum, and mineral shipments. Political issues hinder Russia from accessing the international credit necessary to

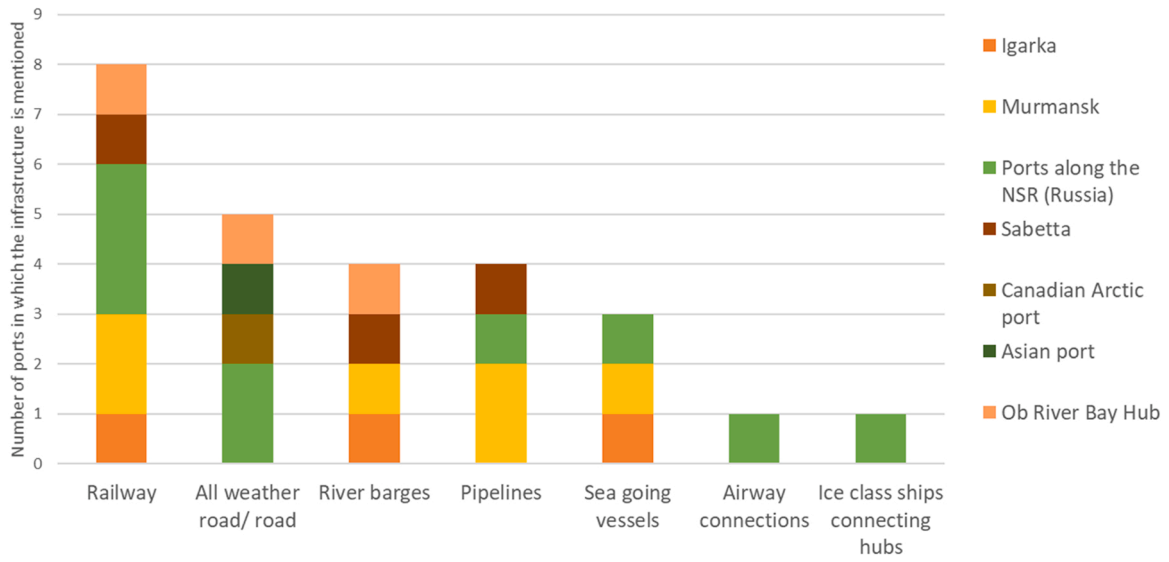

Fig. 8. Transshipment infrastructure connected to the port hubs. The y-axis represents the number of ports with which the infrastructure was associated in the reviewed articles.
Sources: [16,39,40,44,45,47,49–53].

develop the infrastructure in eastern parts of the NSR, in addition to climatic factors [50].

Gritsenko and Efimova [47] conclude that port duties and fees are not viable on Arctic routes, presenting the case of the port of Sabetta, where revenues from port activities are insufficient to repay capital investments. Here, public funding was needed as the port cost was 73.3 billion RUB (2.3 billion USD in 2013), of which the federal government was to cover 47.3 billion RUB. This increased to 69.6 billion RUB in summer 2014 due to dredging costs. Market-dependent mechanisms to fund infrastructure are also a risk for potential transshipment locations, as a historical analysis of the "ice dues." shows. This was a fee imposed by the Russian/Soviet government to cover icebreaker escorts. The fee was intended to cover the costs of the maintenance of the icebreaker, and represented an additional cost for companies involved in the resource exploitation of timber, which gradually made it unaffordable to use the NSR. This contributed to the degradation of Igarka as a transshipment hub and caused the companies involved in the timber business to use alternative routes [45].

Several articles focus on the Russian context and provide multiple examples of how state institutions at various levels are involved in co-financing port infrastructure expansion. Sevastyanov and Kravchuk [53] summarize the Russian institutional set-up that funds port development infrastructure in the Arctic, which results from the combination of complementary and sometimes overlapping responsibilities: NSR management is the responsibility of both the Ministry of Transport and Rosatom. the State Nuclear Energy Corporation (Law 27 December 2018). The Ministry of Transport is concerned with regulatory issues, safety, and navigational standards, while Rosatom the authority over the development and operational control of shipping and infrastructure along the NSR. In addition to these two institutions, oil and gas companies invest in port infrastructure development. The Rosneft Oil Company invested in the Taymyr peninsula with the purpose of expanding oil exploitation in the area. Rosneft is also mentioned in connection with its investments in the Talagi port terminal near Arkhangelsk. In 2007, Talagi exported 3.2 million tons of crude oil and petroleum products [44].

Novatek is also mentioned as a driver for the construction of LNG transshipment hubs in several locations along the NSR, including an LNG port on the Gydan peninsula with a capacity of 19.8 million tons of LNG per year [53]. Pastusiak [16] refers to both Novatek and Gazprom in the late 1990 s, under the Yamal LNG project. [16] mentions the expansion of oil and gas terminals of Novy Port- Mys Kamennyi- Yamburg, as well as building the LNG terminals Tambey-Sabetta. As part of the expansion activity, these terminals expanded its handling capacity from 0.6 million tons in 2010–3 million tons by 2017 and will further increase it to 50 million tons by 2030 [16]. Similar investments in LNG transshipment installations are mentioned in Kamchatka, specifically at Petropavlovs-Kamtachtsky port, where the local government has implemented a new preferential regional regime for taxes and investments to fund the port expansion. With strategic interest in the Asia-Pacific market, Novatek, in collaboration with the government of the Kamchatka region, agreed to construct a floating terminal for LNG transshipment with support from TASED (21.7 million tons per year) [53].

Other companies involved in port infrastructure development include the Sevneft company and Norilsk Nickel. Sevneft was involved as a project designer in the port of Murmansk expansion in the early 2000 s, which scaled up that port's capacity to 200 million tons per year. The Murmansk government funded the project with 150 billion RUB (3.4 billion Euro at 2008 exchange rates) [44]. At the port of Dudinka, Norilsk Nickel has started the construction of 15 Arctic container carriers for unassisted navigation on ice up to 1.5 m thick [16].

3.3. Prerequisites and assumptions behind LNG transshipment hubs and container transshipment

As a complement to the academic publications, this section presents the state of the infrastructure developments concerning transshipment hubs covered by Arctic professional press and Russian public authorities documentation on the NSR. The Arctic strategy up to 2035 [23] includes gradual implementation phases. In the phase comprising the years 2025–2030, the activities prioritize the development of mineral resource centers and the realization of economic and/or infrastructure projects in the Arctic. In concrete terms, logistics is mentioned as the provision of year-round navigation throughout the NSR, the construction of one additional universal atomic icebreaker (project 22220) and two icebreakers (project "Leader") and starting the construction of ports—hubs for the transshipment of international container cargo. Between 2031 and 2035, the goals are to establish a competitive world-class national transport communication system on the basis of the NSR, to continue the construction of harbors for the transshipment of international container cargo and commissioning an additional icebreaker of the "Leader"

project [23]. Following the Arctic Strategy up to 2035, in 2022, the Russian Government approved the Development Plan for the Infrastructure of the Northern Sea Route for the period until 2035 [59]. This plan comprises a creation of logistics and transshipment hubs in Murmansk, Petropavlovsk-Kamchatsky and Vladivostok in the period 2022 until 2026 for maintenance international (including transit) transportation in the waters of the NSR [59].

These governmental plans are driven by the gas production developments, in particular in Yamal peninsula (Yamal LNG) and the field in construction Arctic LNG-2 in Gydan peninsula. In this business, funding for logistics infrastructure is connected to Novatek and the Russian shipping operator Sovcomflot. The gas field location at the western flank of the NSR calls for a logistics system for year-round transportation of natural gas to European and Asian markets by sea through specialized ice-class Arc-7 class vessels with a capacity of 17 million tons per year to be shipped through the NSR [60]. Novatek has begun construction of the port's largest LNG transshipment complex (41.4 MT capacity), which is planned to be launched in 2023 in Ura Bay, close to Murmansk. The project was approved by the Russian Government in July 2019. The total investment is estimated at 70 billion RUB [61]. The terminal for container cargo is being built by LLC Rusatom Cargo in the Murmansk region. The company aims to transport up to 800 thousand containers per year along the NSR in the pilot version, and with full-scale operation of the transport artery - more than 4 million containers. Construction of the container terminal project in Murmansk started in 2021 while pilot operation is planned to begin in 2024 [61].

In the eastern flank of the NSR, another Novatek project is the construction of an LNG transshipment complex in the port of Petropavlovsk-Kamchatsky in Bechevinskaya Bay. Its capacity will be 22 million tons per year. Although the terminal was planned to be built by the end of 2022, the project has been delayed [61]. The infrastructure includes an LNG transshipment terminal, with floating gas storage facilities and safe navigational equipment [62]. In the same port of Petropavlovsk-Kamchatsky, in Avacha Bay, the Seroglazka Terminal company will create a complex for servicing fishing vessels and transshipment of refrigerated and container cargo. The terminal is designed to handle up to 1 million tons of cargo per year. Construction is expected to start in 2024 and it is planned to be built by 2027 [61]. In 2021, DP World, an Emirates-based company, expressed interested to build a container terminal in Vladivostok to tackle growing demand for container shipping along the NSR. The envisioned intermodal terminal, besides offering transshipment to ice-class vessels towards the NSR, was expected to offer railway connections for the hinterland in Asia (China) [59].

3.4. Geospatial framework of transshipment hubs along the NSR

Russia is undoubtedly a major player in the development of the NSR due to the length of its coastline along the route and the need for ships travelling along the NSR to navigate extensively through its territorial waters. By promoting a greater utilization of the NSR as an intercontinental trade way, the Russian government has set the ambitious goal of reaching 30 million tons of transit shipments by 2030, against 1.3 million tons in 2020. Such a strategy aligns with the emergence of transshipment hubs dedicated to the shipping of goods via this waterway, while the increased export of hydrocarbon products from Arctic oil and gas fields is also a major factor for the future of the NSR. As the current network of pipelines from the Yamal peninsula – a region with large hydrocarbon reserves – is mostly directed towards Europe, the wider opening of the NSR could correspond with the will of the Russian authorities to boost oil and gas exports to East Asia.

The development of local communities in the Arctic is also expected as a result of the growing traffic volume, coupled with the upgrading or building of infrastructure along the northern coasts. Fig. 9 underlines the diversity of existing infrastructure along the NSR, but also showcases their unequal distribution. While the literature highlights the lack of attention given thus far to the social, environmental, and local impacts of the increased shipping in the region [8], a wider development of the NSR would have obvious consequences for local communities and their surroundings. Those include the opportunity to strengthen regional integration and upgrade transport infrastructures between the Northern coasts and the Russian hinterland, especially in Eastern Siberia.

Although the railways in Eastern Siberia are not as developed as those in Western Russia, it is interesting to consider the role of the Yenisey and Lena rivers, which offer possibilities for connecting some ports on the NSR to larger urban centers served by rail, especially Krasnoyarsk and Yakutsk. Thanks to these waterways, ports like Dudinka and Tiksi emerge as strategic *gateways* between the NSR and the Russian hinterland. At the western end of the NSR, Murmansk and Arkhangelsk constitute obvious entry/exit points, benefitting from good connections towards Moscow and St. Petersburg, while Murmansk also has the advantage of offering ice-free port infrastructures all year round. On the eastern end, Petropavlosk-Kamchatskiy appears to be an attractive transshipment hub, even though the city lacks land connections towards other regions as it exclusively relies on air transport, unlike Vladivostok. In the Chukotka region, Anadyr and Provideniya additionally have strategic positions at the entrance to the Bering Strait. In such communities coping with poor land connections, the increasing utilization of the NSR would offer the opportunity to strengthen connectivity and stimulate local activities.

The development of the NSR may thus affect a much wider area than the Arctic coastline because of the upgrading of infrastructure which would likely take place in connection with the increasing volume of traffic. Even though the literature highlights the multiple obstacles linked to navigation on the NSR, which is still considered "hazardous" [1], when considering the development of Arctic communities this must be balanced against other challenges regarding the Russian hinterland, whether about environmental concerns (especially with regard to permafrost) or about the lack of efficient and reliable transport links. These elements also have to be taken into consideration in the discussion about the emergence of intermodal nodes along the Arctic coast, in order to develop the NSR not only as a transcontinental corridor but also as a tool to improve connectivity and regional integration, without neglecting the environmental impacts.

4. Discussion

The findings advance the state of research in this area in several ways. First by describing the state of the art by reviewing published studies outlining NSR ports' status in terms of intermodal connections, infrastructure expansion funding, environmental considerations, and port hub functionalities. The findings indicate a shift from the current emphasis in the field on the historical development of the port infrastructure along the NSR to a new framework focusing on port hub functions with connections to the NSR [66]. Second, the results indicate a key gap in research knowledge on Arctic port strategies and industrial clusters, emerging topics which require further theoretical investigation, and in particular attention to how feeder routes relate to other infrastructure such as railroads, barges, and dry ports. Such a need is highlighted by Lavissière et al. [2], who provide a general overview of the wider research topics on Arctic maritime operations (i.e., tourism, ports, and shipping) in both the NSR and the NWP [2].

During the course of the preparation of this manuscript, the geopolitical turns resulting from the Russian-Ukrainian international armed conflict led to sanctions against the Russian State and private businesses, as well as interruption of Western investments in the Russian Federation. This change in international relations also impacts the Arctic space within the sovereignty of Russia, which includes part of the NSR [67]. Historically, Russia has claimed rights of regulating navigation of parts of the NSR not part of its territorial waters citing the UNCLOS art. 234 which allows coastal states of ice-infected waters to issue and enforce regulations to prevent pollution and avoid hazards of ships navigating in

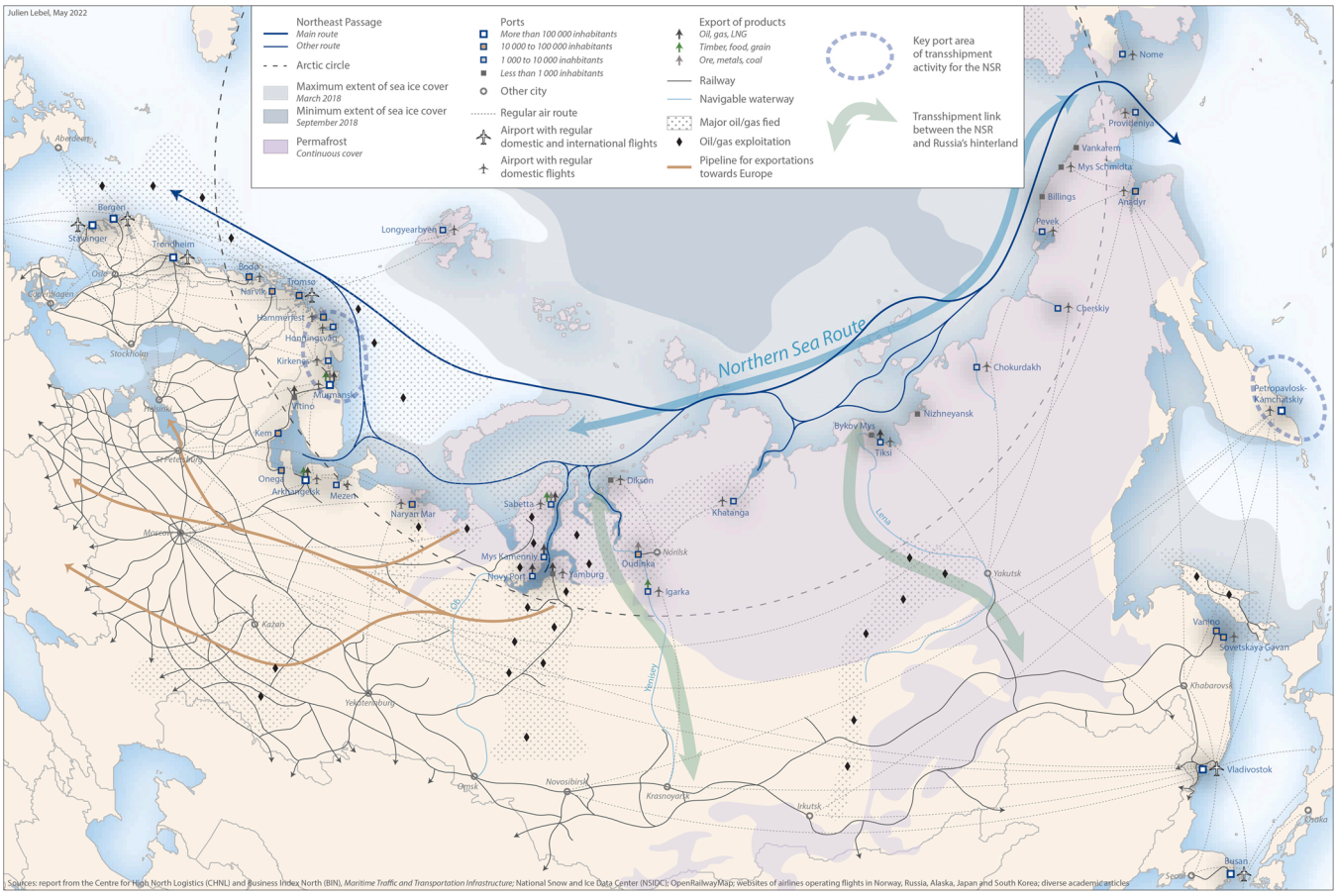

Fig. 9. The Northern Sea Route as a transcontinental waterway in a wider network of transport infrastructures: Local development opportunities, alternative shipping routes, and environmental challenges.
Sources include the following academic articles: [63–65].

ice-infected waters [67]. However, the question of internationalizing polar routes, and in concrete the NSR has often been aired in in international spheres thus causing strong opposition from the Russian government [67]. As highlighted by the findings of the SLR and the comparison with Arctic professional press and Russian policy documents, the LNG shipments from the Arctic are a key driver for transshipment hub investments. Ongoing LNG projects are already taking direct impact from the sanctions [68]. However, concrete data or projections into the specific transshipment hub infrastructure investments is lacking and any inference about their future can only be based on assumptions at this stage. Risks are however high in connection to further conflict escalation, which can lead to further sanctions or boycotts.

Navigational data will be needed to be able to delineate effects of the sanctions and international tensions. For instance, a further expected consequence is the reduction of transit shipping traffic use of the NSR by shipping companies based in the West, given their reluctance to face legal consequences of trading with Russian-state owned companies. However, specific transit of gas products may continue to be a major use of the route. The latest shipping transit data from the NSR information office indicates that as of April 2022, LNG tankers still navigated in the western flank of the NSR with destinations of several ports in Western Europe. This data does not indicate shipments toward Chinese/Asian ports [69]. Given the embargo of ships under Russian flags in European harbors it is thus even more critical to discuss the implications of transshipment hubs with shipments heading for Western European ports. It is, however, expected that the larger markets of China and India will provide a future demand for oil and gas products from Russia—as neither country is taking active part in the current sanctions against Russia. Amid the geopolitical developments, Arctic port infrastructure along the NSR will continue to play a role for destination traffic and the natural resource exploitation in the area, which is shown in the analysis of this paper. In all, this gives further importance to a research agenda to better understand the Arctic port system, as pointed out by Panahi et al. [70] is an under-researched topic.

Having considered the extant research, as well as recent developments, our review indicates several areas which require policy attention but closely match gaps in the current research. The first centers on the definitions of transshipment hubs in the Arctic context and in the NSR in particular. Required policy in this area should clearly define the parameters for large deep-water international transshipment hub terminals servicing transpolar routes. Although the extant research defined here identified major key hubs along the NSR at both its western and eastern ends, the question of potential transshipment terminals at the eastern end of the NSR is not yet defined with the aim of unveiling current and planned potential transshipment terminals. Research in this area should identify the services and design features needed in such a transshipment terminal, including land-based and floating facilities, structural components, and intermodal requirements.

The second area of inquiry highlighted in our analysis is the context of locations and geographical entities in which transshipment hubs are discussed in the literature. The purpose of such research would be to identify all Arctic transshipment hub infrastructure development projects (with special emphasis on the NSR) and to create a comprehensive GIS database comprising the ports' geophysical and market information to provide insights into the current status of investment, expansion, and market context of each particular port. This detailed geographical information should then be combined with qualitative research focused on understanding the institutional dynamics behind the hub port

development projects. Policy should provide insights into the interactions between national interest and international interests underlying port development mechanisms by highlighting the financial, local governance, and geopolitical implications of the potential transshipment infrastructure for commercially viable Arctic shipping along the NSR.

Another are of research opportunity closely linked to the previous point is that of funding possibilities for the operational costs of transshipment terminals within the NSR. Although our review identified critical issues concerning the public-private partnerships underpinning the financing of expansion projects along the NSR, and more recent publications describe a theoretical basis for this [71], less empirical evidence is concretely connected to the function of NSR ports as international transshipment terminals. Public policy shall be oriented towards financing possibilities can also determine the potential demand for these hubs and other supporting ports. Further research oriented to this policy objective can take the following approaches: first, by interviewing existing NSR shipping operators to understand the decision variables behind their choice of hub operations; second, by conducting a survey to explore the likely risk-reward trade-offs; and lastly, by surveying shipping operators without active routes in the NSR to determine the primary factors they would consider before entering this market.

Finally, there is a need to develop a better understanding of the implications of transshipment hubs for polar routes other than the NSR, aiming for the development of a port system that is valid for the whole Arctic. Although Ng et al. [8] provide a good overview of the existing ice and climate models and their relation to future prospects of polar shipping, routes, the results indicate serious gaps in research analyzing the interlinks between future climatological and ice conditions and the future-oriented operational models of Arctic port systems. Research into this area could investigate the impact of different ice scenarios and conditions on operations and regulations. For example, one possibility would be to conduct a scenario analysis on international trade as well as regional and local communities. These scenarios might be based on yearly ship traffic analysis and integrate simulation methods, such as Agent-Based modeling, to understand how the creation of hubs can increase or decrease ship traffic according to a set of conditions. For example, what might be the consequences of retreating ice for the role of transshipment hubs or even for ice-strengthened tankers? Alternatively, scenarios can be discussed with focus groups, comprising local or regional level planners at locations where there is potential for transshipment hub creation.

5. Conclusion

Through a systematic literature review, this paper problematized the concept of transshipment hubs in the Arctic through a detailed thematic analysis of multiple dimensions of the topic, including the underlying assumptions about port infrastructure functions along the NSR. This article identifies four key areas of policy development in relation to Arctic transshipment hubs: First, the operational and design features of transshipment terminals focused on the NSR. Second, the geopolitical and governance requirements of developing deep-water transshipment terminals as an operational model for the NSR. Third, funding possibilities for the operation of transshipment terminals within the NSR. And fourth, the implications of transshipment hubs for polar routes other than the NSR towards the development of a port system valid for the whole Arctic. Amid ongoing geopolitical developments as a result of the Russian-Ukrainian armed conflict, increasing sanctions toward Russian gas investments in the Arctic are expected. These might have serious implications in transshipment hubs plans, at least in the short and medium term.

CRediT authorship contribution statement

Roberto Rivas Hermann: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Ning Lin:** Data curation, Writing – original draft, Methodology, Visualization. **Julien Lebel:** Writing – original draft, Writing – review & editing, Visualization. **Alina Kovalenko:** Writing - original draft, Writing - review & editing.

Data Availability

Data is available as supplementary files.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2022.105275.

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Glossary

LNG: Liquefied natural gas
MT: Million tons following the metric convention system (1 ton equals to 1000 kg)
NSR: Northern Sea Route
NWP: Northwest Passage
RUB: Russian ruble
SLR: Systematic Literature Review
TSR: Transpolar Sea Route
UNCLOS: The United Nations Convention on the Law of the Sea