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Cold Calculations: Economic Prospects for Arctic Shipping Routes

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Abstract

With Arctic seas becoming increasingly navigable due to global warming and declining levels of sea ice, shipping routes in the region, such as the Northern Sea Route (NSR), Northwest Passage (NWP), and speculative Transpolar Sea Route (TSR), are gaining attention as potential alternatives. This analysis explores the economic advantages and challenges of these Arctic routes, including reduced operating costs, transit times, and the unique requirements of operating in the region. A comparative economic analysis examines these recent and emerging routes alongside the traditional maritime chokepoints of the Suez and Panama Canals. Additionally, potential economic complications related to geopolitics and the environment are considered. All elements indicate that, with the current trajectory of Arctic melt, these routes will become increasingly viable and could challenge more traditional shipping paths in the very near future.

The global shipping industry is an indispensable element of international trade playing a significant role in the movement of physical goods around the globe. Container ships alone are estimated to transport 80% to 90% of global trade by volume and over 70% by value (UNCTAD, 2023). Despite the temporary slowdown caused by the recent pandemic, this method of transit remains on an upward trajectory and is expected to grow another 2% between 2024 and 2028 (UNCTAD, 2023). Maintaining the efficiency of the maritime shipping industry is a necessity, as any disruption can have widespread repercussions on related supply chains and economic stability worldwide.

Traditional shipping routes, particularly the Suez and Panama Canals, which handle transit between continents, have historically played an important and newsworthy role in this trade. The Suez Canal alone handles about 12% of global maritime trade and 25% of the total containerized trade annually, translating into significant economic throughput (SCA - Adm. Rabiee, 2024). Similarly important, the Panama Canal supports approximately 2-3% of global trade each year, predominantly in manufactured goods from Asia to American markets (Dierker et al., 2024).

These canal chokepoints, however, are increasingly fraught with challenges. The Suez Canal, for instance, witnessed a major disruption in March 2021 when the Ever Given container ship became lodged, blocking the canal for six days and causing global trade delays that cost the shipping industry approximately $400 million per hour in terms of cargo value (Vlamis, 2021). More recently, in 2024, transit has again been disrupted due to regional hostilities that are directly impacting this trade route ("How Viable is Arctic Shipping?", 2024). Though not plagued by violence and unrest, the Panama Canal has seen a decline of approximately 36% due to its own issues derived from climate change (AP News, 2024). The resulting droughts and drops in water levels negatively impact the lock system that allows for transit through the canal halting or severely limiting traffic (AP News, 2024).

It is hardly surprising that the search for alternatives has turned attention to the Arctic. Shipping routes such as the Northern Sea Route (NSR), Northwest Passage (NWP), and the anticipated Transpolar Sea Route (TSR) are potential opportunities to adjust global transit routes. The unfortunate reality of climate change has made these routes increasingly realistic options and could lead to a noticeable shift in maritime navigation. Current studies predict we will see significantly more navigable days in the region with each season, due to reduced ice levels, that will further result in completely new paths opening by mid-century (Smith and Stephenson, 2023). While these routes may become physically viable, their economic viability remains in question. The shorter distances may reduce fuel consumption and transit times, but they will also entail unique challenges of their own.

Traditional Shipping Routes

The Suez and Panama Canals serve as essential conduits for major global maritime trade lanes. Their economic impact is substantial, profoundly influencing the logistics and operations of international shipping networks and the broader landscape of global commerce.

Suez Canal

As one of the world's busiest maritime passages, the Suez Canal facilitates the movement of global trade between Europe and Asia, avoiding the longer and more hazardous route around the Cape of Good Hope. In 2022, over 23,000 ships passed through the canal, carrying about 1.41 billion tons of cargo ("How Viable Is Arctic Shipping?," 2024; Presse, 2023). The economic significance of the canal is demonstrated by its substantial revenue contributions, which are integral to Egypt's economy. In 2022 the canal recorded record high earnings in transit fees of $8 billion, 25% higher than the previous year (Presse, 2023).

The Suez Canal's strategic location, while well placed to facilitate intercontinental trade, makes it highly susceptible to regional instabilities. The attacks on commercial vessels by the Houthis this year, a Yemeni rebel group, demonstrate the ongoing fragility. These attacks have resulted in seven of the world's ten biggest shipping companies needing to suspend transit through the Red Sea ("How Viable Is Arctic Shipping?," 2024). Geopolitical problems surrounding the Suez Canal have economic repercussions in more than just lost revenue in tolls. Using the example of the effects on one commodity, in December of 2023 the industry recorded a decrease of 24% in globally traded liquefied natural gas (LNG), compared with the rest of 2023, all of which was attributed to the rebel attacks which began just one month prior (Eiermann, 2024).

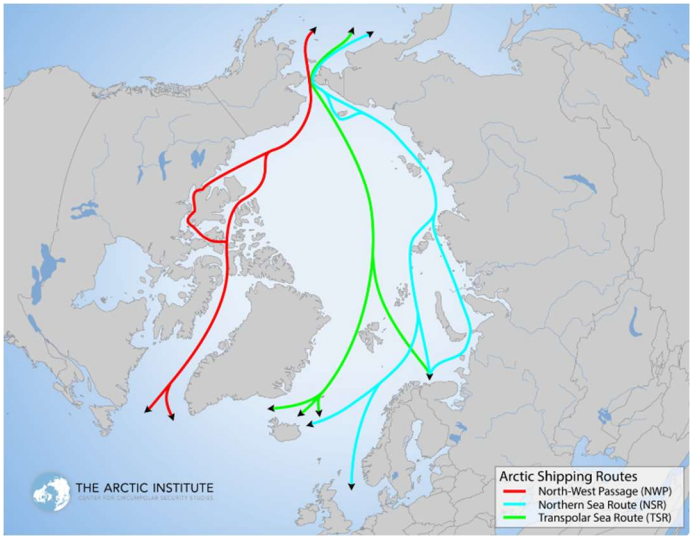
Panama Canal

As the link between the Atlantic and Pacific oceans, the Panama Canal plays a similarly important role to the Suez Canal. Approximately 13,000 to 14,000 ships per year utilize this 50-mile isthmus, which is a vital shortcut for maritime vessels and drastically reduces transit time when compared to navigating the additional 8,000 nautical miles to route around South America (Panama Canal Authority, 2023). Toll revenue in this canal is also a substantial contribution to the Panamanian economy. In 2023 the canal generated $3.46 billion in toll fees, which represents a 3.1% contribution to the GDP of Panama (Panama Canal Authority, 2023).

Environmental concerns in the Panama Canal, however, impact the usability of this route and result in economic costs to global trade. As a primary route for US agriculture trade with Asia, the current drought is expected to severely impact this sector throughout 2024, and possibly longer if the agriculture shipments are forced to continue taking longer routes (Agricultural Marketing Service USDA, 2023). Grain exports showed a decrease in transit through the Panama Canal from 2 million metric tons in October 2022 to 200,000 metric tons in October 2023 due to the canal restrictions and limitation attributed to the unprecedented drought (Agricultural Marketing Service USDA, 2023). As greater amounts of this commodity are forced to find alternative routes the longer shipping times will result in higher costs for producers. These higher costs will eventually be passed on to consumers causing escalated food prices. Given these challenges and threats to the economic costs associated with traditional routes, the Arctic presents a compelling alternative.

Emergence and Development of Arctic Shipping Routes

The Arctic routes, still in relatively early stages of development, offer intriguing opportunities for shorter, and possibly more secure, pathways for maritime traffic. As global temperatures rise and Arctic ice recedes, the new maritime routes such as the Northern Sea Route (NSR), the Northwest Passage (NWP), are becoming increasingly navigable, while the impending existence of the Transpolar Route (TSR) is now seen as an inevitability. This section will examine the development, potential, and challenges of these routes and the associated economic implications.



Arctic Shipping Routes, The Arctic Institute (Humpert, 2021)

Northern Sea Route (NSR)

Shorter Transit Distances and Cost Savings

The Northern Sea Route provides a significantly shorter path between East Asia and Europe, reducing the voyage distance by approximately 30% to 40% compared to the traditional Suez Canal route ("How Viable Is Arctic Shipping?," 2024; Melia et al., 2016). This reduction in distance translates directly into decreased fuel consumption, one of the largest components of a ship's operational costs. For example, a voyage from Shanghai to Rotterdam via the NSR can cut the sailing distance from 21,000 kilometers, when traveling via the Suez Canal, to roughly 14,000 kilometers which translates to substantial fuel savings and reduced transit time by up to 10 days (Liu, 2010).

These savings on fuel and time not only reduce direct operating costs but could also enhance the turnover rate for these shipping vessels, allowing them to complete more voyages within the same timeframe and assist in maximizing their revenue potential. This economic efficiency would be particularly advantageous for shipping high-value or time-sensitive goods, where faster delivery is a necessity and could command premium charges.

Analysis of Transit Fees and Operational Costs

The NSR is a reduction in distance, however, it incurs specific costs unique to Arctic operations. The Russian government mandates the use of Russian icebreaker escorts for traversing the NSR, which introduces transit fees that vary based on the ice conditions, the size of the vessel, and the extent of icebreaker support required (Drewniak et al., 2018). According to a study by Zhou et al. (2023), the average cost for icebreaker assistance can range from $100,000 to $300,000 per voyage, which has a notable impact on the total operational costs of the journey (Zhou et al., 2023).

Furthermore, operational costs on the NSR include higher insurance premiums due to the perceived higher risks associated with ice navigation and the remote nature of the Arctic environment

(Milaković et al., 2018). As of 2001, these insurance costs were up to three times higher than those for more conventional routes like the Suez Canal (Liu et al., 2021). These additional costs associated with Arctic travel can negate some of the savings gained from reduced fuel consumption and shorter transit times.

Northwest Passage (NWP)

Economic Implications of Less Frequent Usage

Another prospective option is the Northwest Passage (NWP) which is made up of a series of sea routes, approximately 900 to 1,500 nautical miles, connecting the Atlantic and Pacific Oceans through the Arctic Ocean along the northern coast of North America (Encyclopedia Brittanica, 2024). Threading through the Canadian Arctic Archipelago, this route remains less frequented compared to more established maritime routes and its counterpart, the Northern Sea Route (Mudryk et al., 2021). The infrequent usage is primarily due to the greater navigational challenges posed by dense ice conditions and the lack of supporting maritime infrastructure, which is somewhat more developed along the NSR (Mudryk et al., 2021). Despite navigational challenges, the NWP holds considerable potential economic benefits due to its potential to shorten the distance between East Asia and North America's east coast significantly.

A study by Boylan (2021) assesses these potential benefits, noting that while the route can reduce the transit distance by up to 17% compared to the Panama Canal, the current unpredictable ice conditions and the need for icebreaker escorts increase the overall operational costs making it a less efficient option (Boylan, 2021). Similarly to the NSR, costs associated with current Arctic travel can offset some, if not all, of the time and distance-related savings.

Seasonal Limitations and Their Economic Impact

Evaluating the route under recent conditions, the seasonal limitations of the NWP are profound, with this route typically only navigable during the late summer months (Encyclopedia Brittanica, 2024). This restrictiveness affects scheduling and operational planning for shipping companies, making the route less attractive for regular commercial use (Dal, 2023). Dal's research provides an economic analysis of these operational challenges, concluding that while the potential for cost savings exists during optimal conditions, the reality of extended periods of inaccessibility and the high cost of ice navigation can reduce the route's reliability and, therefore, overall economic viability (Dal, 2023). However, if the greatest economic hurdle faced is accessibility, this obstacle may very soon be a thing of the past.

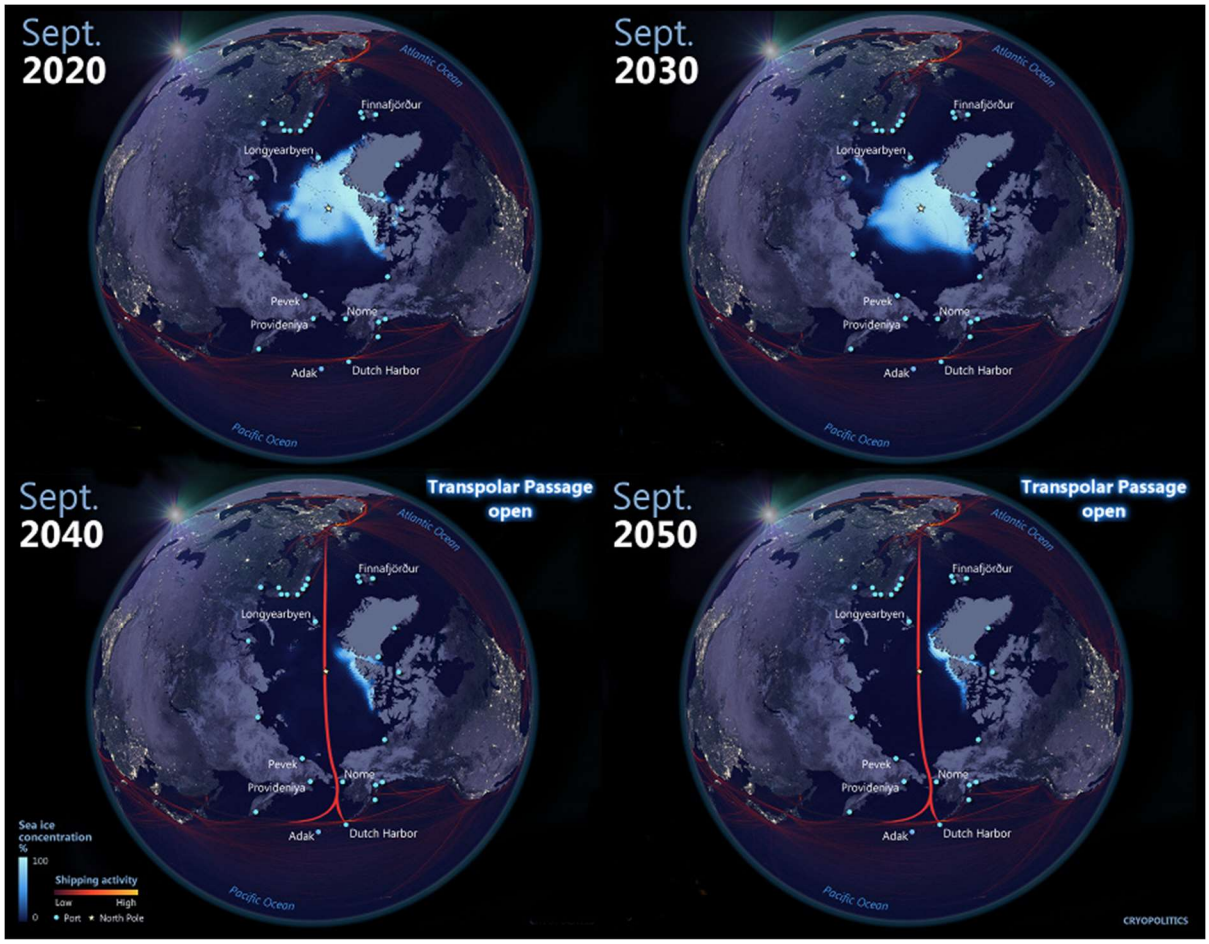
Transpolar Sea Route (TSR)

Speculative Development

The Transpolar Route (TSR), will be the most direct route of the three, passing approximately over the North Pole connecting the Atlantic and Pacific oceans. As the TSR is not currently in existence, evaluation of this Arctic route remains largely hypothetical. Consideration of

this polar route is contingent upon significant reductions in summer ice levels, which most climate models predict will occur by 2050 (Kaur and Mooney, 2023).

If realized, the TSR could revolutionize maritime trade by providing the shortest possible route between Europe, Asia, and North America. This direct route offers an even shorter transit time than the NSR (approximately reduction of 20%), which would translate into economic benefits if the geopolitical environment remained stable and cooperative (Kavirathna et al., 2021). However, initial costs are expected to be high due to the initial need for advanced ice-class vessels and potential regulatory developments (Munim et al. 2022).



Arctic Ice Coverage Projections (Bennett, 2019)

Governance & Infrastructure

While all polar routes are expected to increase navigability by mid-century, the TSR is expected to become 56% more accessible relative to early 21st-century conditions, a more dramatic change than either the NWP (30% more accessible) of the NSR (16% more accessible) (Bennett et al., 2023). More access inevitably leads to the question of governance. The TSR presents complex challenges that involve a mix of international law, national interests, and the strategic objectives of key Arctic and non-Arctic nations. Reinforced by the Ilulissat Declaration, which reaffirmed the

authority over these routes by existing international maritime law, the Arctic Council will undoubtedly play an important role in the question of governance and emphasize their sovereign rights over Arctic waters (Spohr et al., 2021). However, the increased involvement of non-Arctic nations in Arctic development, notably China, which has positioned itself as a 'near-Arctic' state, introduces additional layers of diplomatic and economic complications and negotiations (Bennett et al., 2020).

An added consideration in the development of the TSR as a viable shipping lane is a need for substantial infrastructure advancements, primarily in the realm of port development and icebreaker services, for at least the initial stages (Lui, 2010). The Russian Arctic plays a role here, with numerous ports along the NSR serving as logistical hubs and bases for resource export that could also serve the TSR (Liu, 2010). These central Arctic ports would not only need to support traditional shipping operations but also cater to the emergent needs of the TSR, such as search and rescue services (Liu, 2010). Traditionally, Russia has significantly invested in the economic development of the region, with China rapidly advancing its own efforts in Arctic development (Conley, 2017). he necessary funding for infrastructure, therefore, not only supports logistical needs but may also implicitly influence sovereignty claims in the region.

Comparative Analysis

It is evident that polar and traditional shipping routes both face significant potential challenges and lucrative economic benefits. For the Arctic routes, container ships face restrictions of ice cover, a lack of established port infrastructure, and a lack of search and rescue services. In traditional canal shipping, container ships face extremely long wait times, existing geopolitical disruptions, and environmental instabilities. While these challenges in canal routes may currently equal those in the Arctic, they appear to be increasing while becoming less of an impediment in Arctic routes.

Northern Sea Route (NSR) vs Suez Canal Route (SCR)

In a focused comparison of the Suez Canal Route (SCR) and the Northern Sea Route (NSR), based on actual cost figures derived from studies by Wu et al., Koçak and Yercan, and Liu et al., we can examine the viability of these routes through both current and projected scenarios.

According to Wu et al. (2021), a 4000 TEU (Twenty-foot Equivalent Unit) traversing the NSR during the summer months currently incurs costs of $349.32 per TEU based on ice navigation requirements and the need for icebreaker assistance. In contrast, a similar voyage through the SCR costs $286.28 per TEU, due to the absence of ice-related challenges and lower operational risks. The operational challenges of the NSR intensify during winter, leading to a cost of $587.06 per TEU, significantly higher than the summer months and more than double the cost of transiting through the SCR under similar conditions. Furthermore, for ships traversing the NSR, the insurance premiums can be approximately 0.5% of the hull value, notably higher than for more temperate routes such as the Suez (Milaković et al., 2018). This higher rate is attributable to the increased risk of ice damage and the remote location, which complicates rescue and salvage operations (Milaković et al., 2018).

Global warming is expected to continue decreasing ice levels, potentially extending the navigable period of the NSR and reducing or even eliminating ice navigation costs during the summer. However, despite the potential advantages of reduced transit times and lower costs in favorable conditions, comprehensive year-round analyses such as those by Wu et al. (2021) still favor the Suez Canal Route (SCR) for its lower and more predictable costs. Koçak and Yercan (2021) echo this finding, noting that the NSR's higher operational costs related to ice navigation generally render it less economically viable compared to the SCR.

In contrast to the finding of Wu et al. and Koçak and Yercan in 2021, a study performed two years later in 2023 by Li et al. comes to a different conclusion. Using high-fidelity simulation methods for sea ice calculations and fuel consumption, traveling via the NSR saves between 17% and 33% of the total cost when compared to the route utilizing the Suez Canal (Li et al., 2023). They further enumerate their calculations by pointing out that this equates to a single trip savings of $250,000 USD (Li et al., 2023). The findings of this more recent study illustrate how the significant reduction in sea ice and the resulting increase in navigability substantially affect the economic viability of Arctic transit routes.

Northwest Passage (NWP) vs Panama Canal

In comparing the Northwest Passage (NWP) with the Panama Canal it is important to account for the most recent increases in costs for the canal. As of 2023, the Panama Canal Authority implemented a new toll structure, aiming to simplify and streamline the costs associated with transit (Panama Canal Authority, 2023). According to the PCA, the tolls are now based on a value-based pricing system that reflects the actual value of the service the canal provides to maritime operations. As of this revision, the base toll for container ships passing through the Panama Canal is approximately $90 per TEU for loaded containers and $45 per TEU for empty containers (Panama Canal Authority, 2023). This new fee structure equates to approximately $237,000 for a fully loaded 2500 TEU container ship or $327,000 for a 350 TEU Panamax Class 1 container ship (Waypoint Port Service, 2024).

Comparatively, the NWP does not have a structured toll system like the Panama Canal due to its different governance and the variable ice conditions that do not always require icebreaker services (Smith & McCarthy, 2021). The greatest costs associated with the NWP are primarily driven by the seasonal need for icebreaker support and the higher insurance premiums associated with navigational risks in Arctic waters (Smith & McCarthy, 2021). These insurance fees are even greater than those in the NSR and can reach up to 1% of the hull value depending on the ship's ice class and the season of transit (Cheaitou et al., 2020). Using the data provided by Koçak and Yercan, we can extrapolate further estimated costs for a direct comparison of these two routes.

Considering elements of fuel, operational costs, and transit fees, the NWP would come out the winner in a summer, or other non-icebreaker required scenario, for a trip from Shanghai to Rotterdam (Koçak and Yercan, 2021). As the Arctic route is more direct, and approximately 13 days shorter, the fuel savings alone amount to approximately $300,000 (Koçak and Yercan, 2021). Considering the added benefit of the absence of tolls, it would appear that operational costs on the NWP are significantly lower than those of the Panama Canal (Koçak and Yercan, 2021). This calculation, however, does not account for the more difficult to quantify dangers of navigability and

lack of support and ports along a majority of this route, which are still significant considerations. Much like the NSR though, the dangers of sea ice and harsh Arctic conditions are less and less of a cost consideration as the years progress.

Transpolar Route (TSR) Estimates

The prospect of traversing directly across the North Pole through the central Arctic Ocean is an intriguing potential option presented by the Transpolar Route (TSR). All figures for this comparison are estimates based on expectations and considered costs of existing Arctic routes. It is largely expected that the first true operational voyages will be feasible by 2050 and studies predict that the route will be navigable for 6-7 months of the year once it is open (Melia et al., 2016; Stephenson & Smith, 2015).

Based on this date, the route has been coined the CAO2050 route by certain studies and, with all cost considerations accounted for, it is expected to be the most economically efficient route as soon as it is possible to be used (Koçak and Yercan, 2021). Along with the NWP route, these Arctic routes that do not require transit and toll fees become increasingly more appealing, particularly when icebreaker services are no longer a consideration. In the same comparison of the Shanghai to Rotterdam route, the TSR could reduce the transit time by an additional 20% over that of the reductions already seen with the NSR (Kavirathna, 2020). These progressively shorter transit times have an additional benefit beyond the straightforward advantages of fuel and time savings. A route such as the TSR would allow shipping companies to increase the frequency of their trips, and potentially their overall capacity as vessels would be tied up in transit for shorter periods.

Other Economic Considerations

Fuel, tolls, services and other hard costs of operating container ships are important considerations for freight companies and for global trade. Though the focus of this research is on the economic feasibility of Arctic shipping routes, it would be remiss not to acknowledge some additional factors affecting this proposition, particularly as they are not independent of economic considerations. Two of the most important factors include elements of geopolitics and the environment.

Economics of Geopolitics

Historically, Russia has prioritized the economic development of the Arctic, a focus that has gained renewed vigor and resources under the ambitious leadership of President Putin, even despite broader national economic challenges (Conley, 2017). Meanwhile, China, though relatively new to the region, has quickly become a dynamic player in Arctic economics, diplomacy, and science (Bennett et al., 2020). The collaboration between Russia and China, exemplified by their joint ventures in the Yamal Peninsula, may spearhead the creation of an Arctic connectivity corridor linking Asia and Europe, termed the Northern Arctic Belt, Road, and Circle (Conley, 2017). The success of these initiatives would certainly stake a claim on Artic navigation.

The economic impact of Russia in Arctic shipping is evident in the cost of icebreaker escorts required year-round. The requirement for icebreaker escorts throughout the year increases the cost of transits and Russia charges substantial fees for these services, which can range from $100,000 to over $300,000 (Drewniak et al., 2018). While ice remains a challenge, these costs, and the provider of these services, cannot be ignored. While geopolitical tensions have not escalated to open conflict around the NSR, the potential for violence remains as real in the Arctic as it has proven to be in the Red Sea.

Environment and Maritime Trade

Hostility between nations may pale in comparison to the hostile nature of the environment in this region of the world. There is a reason that insurance rates are so high in the Artic, the unforgiving nature of the region involves very serious risks to both successful completion of transit and to human safety (Milaković et al., 2018). Opponents of Arctic shipping conversely point to humanity as the greater threat to the environment rather than the other way around. Environmental concerns surrounding the exacerbation of climate change, black carbon outputs and destruction of valuable ecosystems are frequently cited when disputing these routes as viable options (McVeigh, 2022).

This extensive criticism, however, does not consider the true requirements of traveling via Arctic routes which inherently involve more environmentally sound practices than those required for temperate sea routes. Slow steaming, the practice of operating container ships at significantly reduced speeds, is an increasingly adopted strategy to lower fuel consumption and shipping costs, thereby reducing emissions (Pelić et al., 2023). Conditions in the Arctic require slower speeds than traditional canal routes and typically do not exceed 12.7 knots, even in the best conditions (Liu, 2007). This speed is the same threshold used in studies of slow steaming to reach a reduction in fuel consumption of 72.36% to 76.25% (Pelić et al., 2023). The end result of inherent slow steaming implies that Arctic travel could potentially be more environmentally friendly than traditional maritime routes, as well as offer the financial benefits associated with reduced distances and fuel consumption.

Conclusion

The contemporary landscape of global maritime logistics is influenced by a dynamic array of economic factors poised to shape its future trajectory. The increasing viability of Arctic routes—such as the Northern Sea Route, Northwest Passage, and Transpolar Sea Route—presents potentially advantageous alternatives to the Suez and Panama Canals. These northern passages, offering reduced transit times, could profoundly reshape the logistics of international shipping. However, the benefits are currently counterbalanced by the unique challenges of Arctic navigation, such as the need for icebreaker escorts, higher insurance premiums, and the lack of established port infrastructure and search and rescue services. As conditions in the Arctic evolve, so too will the associated cost considerations.

The comparison with traditional routes outlines both the potential and the challenges of Arctic shipping. While the Suez and Panama Canals have been reliable and vital arteries of global trade, they are increasingly compromised by challenges such as geopolitical instability, climate change-induced disruptions, and capacity constraints, all leading to rising costs. The Ever Given incident, recent attacks in the Red Sea, and drought issues in the Panama Canal exemplify the vulnerabilities of these chokepoints. Although Arctic routes are promising, they are still emerging and face their own challenges. These routes will require significant investments in infrastructure and regulatory frameworks to become fully viable and will certainly require further study and history of use to determine the validity of today's latest projections.

Looking ahead, projections suggest that Arctic shipping routes may become economically superior within the next 15 years, contingent upon continued reductions in ice levels and technological advancements in maritime infrastructure. The potential economic benefits, including shorter transit times and reduced operational costs, are significant. In contrast, traditional canal routes are facing increased restrictions, disruptions, and rising fees. While current seasonal limitations may render Arctic shipping less efficient today, all indications from this research suggest that by 2050, Arctic shipping could become a realistic, viable, and economically advantageous alternative to traditional canals, potentially reshaping global maritime trade.

As we advance, it will be necessary for stakeholders and policymakers to monitor these developments closely, develop responsible strategies to adapt to environmental changes, and invest in sustainable infrastructure to support the future of Arctic maritime navigation. It will require continued research and concerted efforts to fully understand and harness the potential of these emerging routes, ensuring their positive contribution to global trade dynamics.

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