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Climate Change and Global Sea Routes: Implications for the Arctic and Suez Canal Corridors

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ABSTRACT

Climate change has begun to impact global maritime trade by shifting traditional sea routes and affecting the operational efficiency, safety, and economics of shipping. Extreme weather events, changes in wind patterns, rising sea levels, and the melting of polar ice caps are restructuring major maritime corridors and their dependencies. The objective of the study is to examine the effects of climate change on sea routes, particularly those in the Arctic and the Suez Canal. Using a qualitative approach with data from articles, peer-reviewed journals, and reports from international organisations, a SWOT analysis was conducted. The findings reveal interruptions in maritime trade due to accessibility issues during extreme weather, increased fuel costs, insurance challenges, and emerging geopolitical competition over Arctic routes. While melting Arctic Sea ice offers shorter passages between Europe and Asia, it presents navigational and environmental challenges. Extreme weather conditions threaten global supply chains by causing delays and infrastructure damage. The study recommends adaptive and practical maritime policies, such as enhanced international cooperation, revised maritime laws and regulations, and investment in infrastructure.

Key Words: Maritime trade, Suez Canal route, Arctic trade route, climate change, maritime challenges, environmental threats, maritime corridors

INTRODUCTION

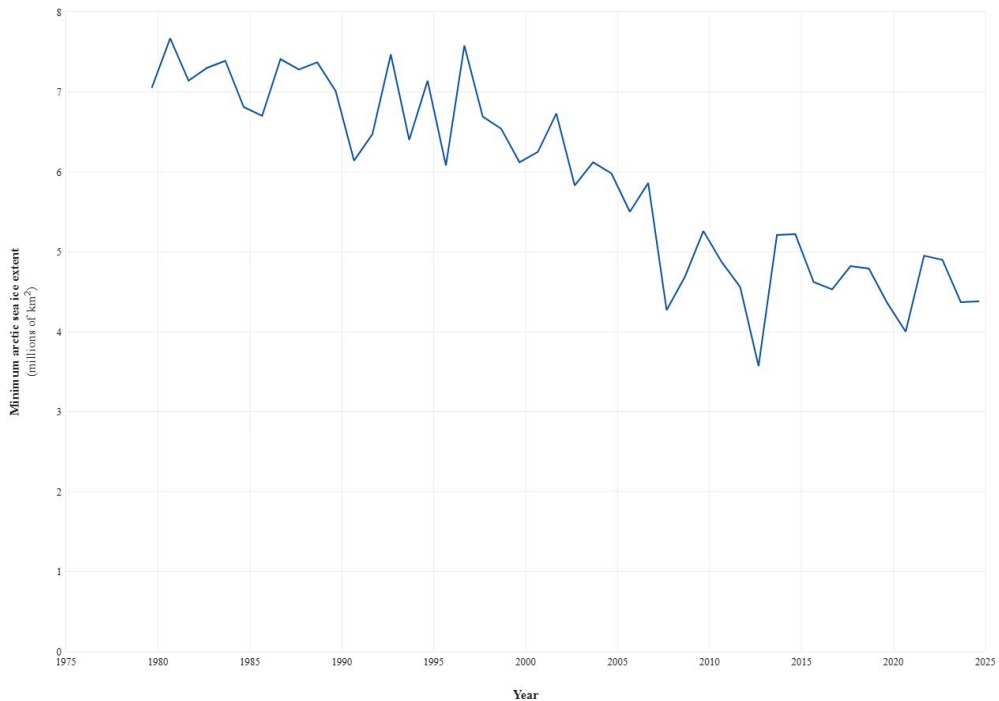
Climate change poses a significant threat to port operations and maritime trade, compromising maritime stability and the efficiency of international trade services. Climate impacts like the rise in Sea level, frequent shifts in weather patterns, extreme weather events and intense storms damage the infrastructure of coasts, disrupt major shipping routes, causing delays, increasing costs, and economic instability. The coasts' vulnerability to climate change impacts demands attention, as ports play a vital role in the international supply chain. It is essential to comprehend these climate-driven challenges and threats to develop adaptive strategies that enhance the resilience of maritime infrastructure and safeguard trade flows in times of environmental uncertainty (UNCTAD, 2023).

Recent disruptions at seaports highlight the significance of addressing these challenges. Taking an example of the Panama Canal, in 2013, experienced the worst drought in the last seven decades, which decreased its vessel capacity from 36 to 22 ships per day. South Africa's port of Durban in 2022 was severely affected by intense floods due to the heaviest rainfall in over 6 decades. Hurricane Harvey flooded the port of Houston in 2017, suspending operations for two weeks and causing huge economic losses across the U.S. Gulf Coast (Ship Technology, 2024).

Carbon emissions from the burning of fossil fuels are causing a temperature rise, resulting in changes to the global environment and maritime conditions. An unexpected consequence of global warming is the melting of Arctic ice, allowing access to new commercial sea routes. Energy resources like oil and natural gas are primarily transported by sea. Liquefied Natural Gas (LNG) transport depends on maritime corridors connecting major global gas markets to North America, Asia Pacific and Europe. The Suez Canal is used for LNG shipments connecting the Middle East and South Asia with the Asia Pacific and Europe. However, new polar routes like the Northeast Passage (NEP) are reshaping the dynamics due to the shift of energy geopolitics and environmental change. The Panama Canal Route (PCR) connects America to the Pacific region. The conventional maritime routes, such as the Suez Canal, the Panama Canal and the Strait of Malacca, are narrow, congested Passages that can disturb global shipping trade. These chokepoints can cause logistical disruptions due to capacity constraints and accidental blockage.

The Arctic Ocean is the world's smallest Ocean, covering an area of approximately 14.6 million km² from the North coast of America to Eurasia. It was considered remote and mostly uninhabited due to its closeness to the North Pole mainly covered with ice most of the year. Climate change has accelerated the melting of the ice of the Arctic Ocean, resulting in several ice-free regions during summer (Kayode-Edwards et al., 2024).

ARCTIC SEA ICE YEARLY MINIMUM



Source: <https://www.climate.gov/climatedashboard>

The Arctic Ocean is becoming the centre of attention as a potential maritime trade corridor. The melting of sea ice is making the Arctic Ocean a getaway by opening up inaccessible Northern Sea Route (NSR), a previously inaccessible shipping route which can reduce travel time by up to 40% between Asia and Europe (UNCTAD, 2023). This route has economic and logistical advantages, but also poses new challenges, including geopolitical tensions, limited infrastructure and environmental risks. This region needs strong governance, international cooperation, and infrastructure due to its fragile ecosystem, lack of search and rescue capabilities and navigational infrastructure.

The Suez Canal is one of the busiest trade routes between Europe and Asia, controlling 12% of global trade and handling 30% of maritime container traffic, a vital transit route for oil and LNG, and about 8-10% of maritime oil shipping. It generates \$8 billion in revenue for Egypt annually, making it a vital economic and geopolitical hub (UNCTAD, 2021; Suez Canal Authority, 2023). In March 2021, a container ship got stuck in the Suez Canal Channel, blocking maritime traffic for nearly a week. Similarly, the Strait of Malacca is strategically vulnerable for China and East Asia Countries as they rely on this passage. Therefore, the Northeast Passage (NEP) is a potential alternative route offering a less congested and shorter route with less fuel consumption.

The Arctic Ocean is highly affected by climate change and warms faster than the global average, a climate phenomenon known as Arctic amplification (Serreze & Barry, 2011). The satellite observation started in 1970, and since then, the Arctic has been melting on an average of 3000 km³ of ice per decade (Kwok & Rothrock, 2009). The melting rate is faster than projected, causing debate over whether the high loss

of ice results from a temporary climate fluctuation or will continue (Notz & Stroeve, 2016). Although the Suez Canal route is followed for Shipping routes from East Asia to Europe, the Panama Canal is used for the U.S. Atlantic Coast. But Arctic routes such as the Northern Sea Route (NSR) have economic potential, which is 40% shorter, reducing fuel consumption, travel time, and costs (Mudryk *et al.*, 2018). These incentives attracted major shipping states such as Japan, China, South Korea and Singapore, which gained observer status in 2013 in the Arctic Council despite their lack of arctic territory (Lasserre, 2018). There is a potential to increase trans-Arctic shipping, but a major obstacle is sea ice coverage, and climate models predict that it will continue to decline, leading to long navigable seasons (Smith & Stephenson, 2013). These projections offer opportunities for Arctic shipping, posing challenges to geopolitical disputes, infrastructure and insurance costs. These opportunities and challenges will impact the adoption of these routes (Dawson *et al.*, 2018).

Currently, Arctic shipping is dominated by destination shipping. Automatic ship tracking data of 2014 revealed 11,066 vessels in the Arctic, 9.3% of global shipping. Most of the ships were specialised for research or survey, followed by cargo, tankers, fishing, and cruise ships (Eguíluz *et al.*, 2016). The Barents Sea is reported to be the largest share of Arctic traffic due to its proximity to major European ports and ice-free nature. The Arctic shipping takes place in September due to the suitable conditions, as sea ice is at its lowest level (Smith & Stephenson, 2013). A longer ice-free season is required for commercial shipping and to achieve economic viability. Climate models predict the expansion of the arctic shipping season by one month per decade (Mudryk *et al.*, 2018). According to the Paris Agreement scenario, by 2050, the navigable days will be 2.5 times more than in the early 21st Century, in contrast, according to the business-as-usual scenario, the navigable days will increase by 3.5 times, giving 40% more shipping opportunities compared to the Paris Scenario (Barnhart *et al.*, 2016). Theoretically, Ice-strengthened vessels would enable year-round transits, while open-water (OW) ships would remain restricted to seasonal operations due to ice risks (Dawson *et al.*, 2018). This means that despite extended accessibility, shipping companies must still account for unpredictable ice conditions in route planning.

Therefore, this study aims to explore how climate change impacts major global maritime trade routes, with a focus on the Arctic and the Suez Canal. It also examines the opportunities and challenges presented by the existing Suez Canal and new Arctic shipping routes due to climate change, and provides recommendations for adaptive maritime policies to manage climate-related risks in global shipping.

LITERATURE REVIEW

Impact of Rising Sea Levels and Extreme Weather Events on Global Maritime Routes

Climate change impacts global maritime routes, and the transport system has been debated over the last decade. The research investigated the impact of climate

change has redefined maritime geopolitics, route dependency, the need for new routes and redefined navigation in the Suez Canal and Arctic routes. The Arctic Sea ice is melting, increasing the opportunity of seasonal navigation of the Northern Sea Route (NSR), an alternate route for the Suez Canal offering 40% less travel time between Asia and Europe, a cost-effective option with less fuel consumption and less carbon emissions (Bennett & Lasserre, 2021). But unpredictable ice coverage and extreme weather due to climate change pose significant challenges and threats to emerging Arctic maritime routes (Mudryk et al., 2018). By 2100, under a high-emission scenario, most of the Arctic Ocean will be ice-free for half a year (Laliberté et al., 2016). However, annual variation will continue as some years still experience high ice concentrations (Notz, 2015; Swart et al., 2015). But unpredictable ice coverage and extreme weather due to climate change pose significant challenges and threats to emerging Arctic maritime routes (Mudryk et al., 2018). Maksimenko (2023) explained the risks in Arctic routes' operational uncertainty, instead of expanding the summer window, as advanced technologies for ice forecasting and insurance adaptations are required.

Sea level rise and extreme weather are the prominent impacts of climate change on maritime trade. Rising sea levels are accelerating due to climate change and will continue to have the potential to disrupt ship lanes and seaport infrastructure (IPCC, 2019). Coastal areas such as the Suez Canal and other significant chokepoints are vulnerable to floods with infrastructural damage, operational disruptions in shipping schedules, and increased trade costs, as emphasised by UNFCCC. The blockage of the Suez Canal in 2021 by Ever Given, a huge container ship, highlighted how vulnerable the Suez Canal is, with just a single disruption resulting in billions of dollars in loss to trade and global supply chains (UNFCCC, 2021). Hurricanes, floods and storms are intense and frequent due to the rise in global temperature. Significant increases in storms in the North Atlantic are a critical threat to shipping routes in the Gulf of Mexico and the Caribbean, which disrupts regular maritime trade and re-routing of ships with increasing transit time and costs (World Meteorological Organization, 2020).

Melting of Polar Ice and Opening of the Arctic Shipping Routes

Polar Ice is melting due to climate change, impacting global maritime routes. New maritime trade routes are becoming accessible, opening new opportunities with shorter and cost-effective routes between Europe, Asia, and North America. The IPCC (2014) reports a 40% decrease in Arctic Sea ice since 1970. The melting of ice opens new Arctic shipping routes, the Northern Sea Route (NSR) and the Northwest Passage (NWP) are more navigable for longer seasons (Arctic Council, 2020). These new shipping routes offer economic opportunities as NSR can reduce shipping travel time and fuel consumption between Europe and Asia by 40% compared to the Suez Canal (Karamperidis & Valantasis-Kanellos, 2022).

Increased shipping in the Arctic region poses environmental and political challenges, such as environmental protection, resource extraction and territorial conflicts. The Arctic Council (2020) warns about the damage to the maritime

ecosystem, indigenous communities and conventional livelihoods due to increased maritime traffic and the risk of oil spills. Sea ice melting can also change ocean currents, further exacerbating global weather patterns that affect shipping routes in other regions (IPCC, 2014).

Risks to the Suez Canal

The Suez Canal is one of the most significant global maritime routes between Europe and Asia, connecting the Mediterranean Sea to the Red Sea. UNCLOS (1982) highlights the significance of maintaining the free maritime trade routes through the Suez Canal, but climate impacts can disrupt this principle. The rising sea level in the Red Sea and Mediterranean can affect the Canal's capacity and infrastructure to manage global trade volume due to increased flood risks (World Bank, 2020).

Despite being an old maritime route Suez Canal is vulnerable to climate-induced threats. Eldeeb and Elemam, (2023) identified the impacts of rising sea levels, rise in temperature, and extreme heat events on port infrastructure in the Red Sea and Eastern Mediterranean regions. Events like the 2021 *Ever Given* blockage, although it was not climate-induced but show how one failure can cause massive global impacts. Variation in climate can increase vulnerabilities, causing increased congestion, grounding of ships and delays (Lee & Wong, 2021). Li et al. (2023) examine trade simulation models to analyse the potential diversion of Suez Canal Asia-Europe shipping passage towards the Arctic route under favourable conditions. These maritime route shifts have risks too due to seasonal variations, infrastructure development and Political Cooperation. According to a report from the Suez Canal Authority (2021) report says that the canal has been undergoing important upgrades to increase its capacity, but climate change challenges will need more investment to build resilient infrastructure.

Climate Change's Strategic Implications

The opening of the Arctic passage has increased commercial, military, and scientific interest of major powers like Russia, the United States and China (Puranen & Kopra, 2023). As maritime trade and traffic increase, there is a need for multilateral governance policies to ensure security and equitable access. The Arctic Council and UNCLOS-based policy frameworks should encourage strong enforcement mechanisms and sustainability standards (Buixadé Farré *et al.*, 2014). Maritime Policy experts highlight the need for defensive governance. The traditional and emerging sea routes need adaptive policy frameworks to counter climatic risks. Heininen (2024) recommended increasing maritime safety regulations, expansion of icebreaking and search and rescue operation capabilities in the Arctic region, and international cooperation is essential to promote shared benefits and to avoid conflicts in new maritime zones.

RESEARCH METHODOLOGY

To explore climate-induced changes impacting significant maritime routes with a major focus on Arctic Ocean routes, the research adopts a qualitative research design. The objective is to analyse how climate change, through the melting of sea

ice, extreme weather events, and rising sea levels, is redesigning global maritime trade, navigation, and geopolitical dynamics.

The study relies on Secondary data sources, including academic journals, government reports, and international organisation publications such as UNCTAD and the Arctic Council, policy papers, and most relevant data from environmental science and maritime transport studies, were included. The selection of these sources is based on their relevance, credibility, and peer-reviewed nature. The secondary data approach has provided room for a comprehensive synthesis of existing literature and knowledge and served as a foundation for the policy framework.

The data was collected systematically, ensuring its relevance to climate impacts and maritime trade. This data was then analysed thematically to identify emerging patterns, trends and critical risks in climate-induced maritime trade transformation. The thematic analysis provides a comprehensive understanding of important factors that are changing the dynamics of maritime shipping. Major themes include

- Seasonal accessibility and operational feasibility of Arctic Sea routes,
- Vulnerability and disturbances in the Suez Canal due to climate change
- Geopolitical impacts of emerging maritime routes.

To ensure rigorous analysis, the research integrates a SWOT analysis (strengths, weaknesses, opportunities and threats) to evaluate the Suez Canal and the Arctic maritime Corridor. The SWOT analysis identifies key factors such as environmental vulnerability, strategic strength, economic feasibility and governance. The study explores how climate change affects these routes and redefines maritime trade routes and reframes maritime policies. The study focuses on comparative analysis of the Suez Canal and the Arctic trade routes while considering strategic strengths and climate vulnerabilities, as well as economic feasibility and governance of both routes to manage these policies

Two maritime shipping routes were used as key case studies to explain in-depth analysis, the 2021 Suez Canal blockage and the Northeast passage since 2007. These case studies explain how climate impacts reshape maritime trade patterns and reframe maritime policies due to the disruption caused by climate change, and why alternative routes are important. Using the SWOT analysis, the study explains how climate change plays its role in reshaping maritime trade routes and reframing maritime policy. The study aims to offer a feasible and practical framework for maritime decision-making by identifying areas for international collaboration, policy innovation, and maritime trade risk mitigation. The study can guide future policy making to address climate-induced risks for global maritime trade and shipping and to ensure the resilience of key maritime routes.

RESULTS AND DISCUSSION (SWOT Analysis of Suez Canal and Arctic Corridors)

The research provides a comprehensive *SWOT* analysis to examine the strategic dynamics of two major maritime trade routes, the Suez Canal and the Arctic Sea routes (NSR and NWP). Climate change impacts have increased the

transformation of global maritime trade routes, so this analysis provides an understanding of internal and external factors determining the feasibility, practicality and strategic importance of the Suez Canal and Arctic routes.

Suez Canal Route

The Suez Canal has been an important maritime route for decades, connecting the Mediterranean Sea to the Red Sea, connecting Europe and Asia and serving as a significant maritime trade route, managing almost 12% of global maritime trade. This route is central, with strong infrastructure for international shipping. Therefore, this route holds a strong position and is considered one of the busiest and vital global maritime trade routes. Despite being an old maritime route, the Suez Canal is vulnerable to climate-induced threats. Eldeeb & Elemam (2023) identified the impacts of rising sea levels, rising temperatures, and extreme heat events on port infrastructure in the Red Sea and Eastern Mediterranean regions. Events like the 2021 *Ever Given* blockage show how one failure can cause massive global impacts. Variation in climate can increase vulnerabilities, causing increased congestion, grounding of ships and delays (Lee & Wong, 2021).

The 2021 *Ever Given* blockage is a critical incident, when a large container ship was stuck in the Suez Canal due to climate change impacts. On 23rd March, a 400-meter-long container ship, *Ever Given*, operated by Taiwan's private company Evergreen Maritime Corp, became stuck in the Suez Canal due to harsh weather, and the vessel's bow crashed into the Suez Canal eastern bank (Port Economics, Management and Policy, 2023). This ship can transport goods equal to 200 trains at once and can transport them from China to Europe in a single journey. It blocked the route for six days, blocking more than 300 ships carrying oil, gas, food items and manufactured goods on both sides of the canal. Its economic impact was huge, with an estimated \$9–10 billion per day (Harper, 2021), shipping delays in Europe and Asia disturbing global supply chains. Another weakness is its narrow passage, which limits the route options for ultra-large ships. The Suez Canal is also vulnerable to regional political conflicts, due to its proximity to the Middle East's conflicting regions, which can cause instability in the Red Sea region.

The Suez Canal can improve global maritime traffic flow, increase climate resilience, and accommodate the flow of large ships through modern technologies, expansion and digitisation. It can integrate the Suez Canal into green shipping and smart logistics systems with the growth of global maritime trade. The Canal route has significant threats. These climate change impacts can challenge its long-term significance and functionality. The melting of sea ice from the Arctic routes is a dominant challenge to the Suez Canal route, as Arctic Sea ice melting is increasing the chances of access to Arctic routes. Political instability in Egypt and other Middle East political conflicts can impact the Suez Canal's global trade.

Arctic Sea Routes (NSR and NWP)

The Arctic Sea routes, Northern Sea Route (NSR) along the coast of Russia and Northwest Passage (NWP) along Canadian waters offer significant strengths due to the geographic potential. These maritime trade routes are the shortest routes

between Europe and Asia, reducing travel time by 40% compared to the Suez Canal, with significant savings in time, fuel and shipping costs. Arctic maritime trade passages also have the potential of direct and less conflicting maritime passages, as these passages avoid narrow paths and have no politically sensitive regions. The Arctic Sea ice is melting, increasing the opportunity of seasonal navigation of the Northern Sea Route (NSR), an alternate route for the Suez Canal offering 40% less travel time between Asia and Europe, a cost-effective option with less fuel consumption and less carbon emissions (Buixadé Farré et al., 2014). But unpredictable ice coverage and extreme weather due to climate change pose significant challenges and threats to emerging Arctic maritime routes (Mudryk et al., 2021).

Lee et al. (2024) examine the trade potential diversion of Suez Canal Asia-Europe shipping passage towards the Arctic route under favourable conditions. These maritime route shifts have risks too due to seasonal variations, infrastructure development and Political Cooperation. Heininen (2024) recommended increasing maritime safety regulations, expansion of icebreaking and search and rescue operation capabilities in the Arctic region, and international cooperation is essential to promote shared benefits and avoid conflicts in new maritime zones. Therefore, Trans-Arctic routes have potential due to short travel time and fuel, but they also have logistical constraints. This route is less suited to container shipping due to unpredictability and a less developed Arctic environment, as container shipping follows a strict schedule and has fixed cargo exchange ports. Bulk shipping, such as oil, LNG and minerals, can use Arctic routes as they are flexible. Similarly, destination shipping used for community resupply, fishing, natural resource extraction, scientific research, and maritime tourism is expected to increase, and land transportation in the Arctic is expected to decline due to melting permafrost, thus relying heavily on maritime transport links. Arctic shipping operations face challenges like freezing weather, ice conditions and operational malfunctions, and reduced visibility, all require specialist equipment, an experienced Arctic crew and vessels. The lack of infrastructure, such as poor communication, navigational charts, rescue services, and remoteness from all help sources (when an incident occurs), also increases challenges. Lack of trained and experienced crew increase human element risk. As most maritime accidents happen due to human error, autonomous systems are expected to become important for Arctic navigation (DNV, n.d.).

The risks in Arctic routes' operational uncertainty, instead of expanding the summer window, as advanced technologies for ice forecasting and insurance adaptations are required. The opening of the Arctic passage has increased commercial, military, and scientific interest of major powers like Russia, the United States and China (Puranen & Kopra, 2023). As maritime trade and traffic increase, there is a need for multilateral maritime governance policies to ensure security and equitable access. The Arctic Council and UNCLOS-based policy frameworks should encourage strong enforcement mechanisms and sustainability standards (Buixadé Farré et al., 2014).

The economic viability of Trans-Arctic shipping has been debated widely. The studies of Wan (2025) and Lasserre (2014) show a split opinion about the profitability of Trans-Arctic shipping. Lasserre analysed 26 studies, and 13 concluded that Arctic routes could be more profitable, while 7 viewed the conditions in the Arctic still too harsh. For example, Bekkers et al. (2016) expected a shift to Arctic routes from the Suez, while Christodoulou & Demirel (2018) predicted only a marginal increase in Arctic shipping. Transit tariffs of Russia on the Northern Sea Routes (NSR) have been expensive (Northern Sea Route Administration, 2013).

The Arctic infrastructure is not so developed, having limited ports, weak emergency response abilities during harsh weather. Despite climate change impacts, maritime trade in the Arctic region is still confined to a seasonal trade route due to thick sea ice cover for more than half a year. Special ice-class vessels with specialised designs are needed to use this route, which would result in high insurance and more operational costs due to navigational maritime trade risks.

Lasserre (2014) noted that companies can negotiate better rates, as done by Tschudi successfully. The NSR requires applying for a transit permit 15-120 days prior and fulfilling technical and safety rules and regulations (Arctic Logistics Information Office, 2015). Whereas the Northwest Passage (NWP) has no transit fee and Canada won't do it in future, but insurance premiums are higher than NSR due to harsh ice conditions. Currently, NSR remains the most attractive commercial route of the three major route choices due to favourable ice conditions, and Russia has control over the waters of NSR. Lasserre (2014) also highlighted that transit time is an important factor of profitability, along with the fuel cost, with Yokohama port being more profitable than Shanghai due to time savings.

Due to its strategic importance, the UK and NATO's military presence is also expected. Sectors like resource-driven destination shipping, seasonal trans-Arctic routes and cruise tourism are expected to grow in future, and it is evident from successful voyages through NWP by the *Crystal Serenity* cruise in 2016 (Macalister, 2016, ; Snider, 2016). Route-dependent opportunities are high in NSR compared to the other two Arctic passages TSR (Transpolar Sea Route) and NWP. NSR is most feasible due to Russia's support and infrastructure. NWP lacks Icebreaking support, although Canada provides SAR coverage and weather forecasts. The Cruise companies are more interested to the clean and remote waters of Canada and Greenland, as shown by the careful planning of the *Crystal Serenity* cruise journey (Snider, 2016). Commercial-scale Arctic shipping is possible with major developments. These developments include the Arctic infrastructure expansion with fuel stations and ports, polar-class vessels and icebreaking services, strong SAR agreements, growth in Arctic imports and a strong political and regulatory framework (World Economic Forum, 2014).

Geopolitical and Economic Risks

Global powers like Russia, China and the U.S. are interested in the Arctic routes as these routes offer more opportunities. Port infrastructure and development, satellite-based navigation, the autonomous ships option and investment in

icebreakers can mitigate maritime operational constraints. The Arctic region can be reliable and resilient with Trans-Arctic cooperation and collaboration on sustainable Arctic maritime governance and technological development in sustainable shipping. Offshore resources can also be utilised due to ice melting in the Arctic region. Climate change opens new maritime trade route opportunities, along with unpredictable risks of maritime accidents and environmental damage. The U.S. and Canada dispute over the NWP challenge maritime governance and control of Russia over NSR, and Russia's condition to seek permission and authorisation for foreign ships adds maritime governance tensions. Maritime shipping and maritime tourism can also contribute to environmental degradation and trigger militarisation in the region. Maritime safety regulations, expansion of icebreaking and search and rescue operation capabilities in the Arctic region, and international cooperation are essential to promote shared benefits and to avoid conflicts in new maritime zones (Heininen, 2024).

The analysis highlights the causal relationship which can impact the future of the Suez Canal and Arctic Sea trade routes, as shown in table 1. The Suez Canal holds an important position due to its infrastructural strengths and longstanding maritime trade route, but its vulnerabilities connected to this route are also evident. Arctic routes are developing as strategic alternative maritime trade routes, driven by climate change impacts and geopolitical interests, however, they continue to be considered with challenges and risks that demand practical and sensible global commitment.

Table 1: SWOT Analysis of The Suez Canal and The Arctic Sea Routes

SWOT (strengths, weaknesses, opportunities, threats) Analysis		
Dimensions	Arctic Sea Routes (NSR/NWP)	Suez Canal
Strengths	<ul style="list-style-type: none"> -Shorter distance between Asia and Europe -Potential fuel and time savings -Increasing seasonal accessibility due to ice melt 	<ul style="list-style-type: none"> - Established global trade artery - Well-developed port infrastructure - Strategic chokepoint linking Europe and Asia
Weaknesses	<ul style="list-style-type: none"> -Harsh environmental conditions -Lack of year-round navigability -Inadequate infrastructure and SAR (Search & Rescue) capabilities 	<ul style="list-style-type: none"> -Vulnerability to climate-induced disruptions (e.g., droughts, reduced canal depth) - Congestion and over-reliance - Limited route alternatives
Opportunities	<ul style="list-style-type: none"> -Emergence as a new maritime highway -Strategic importance for Russia and Arctic littoral states -Opening new markets and 	<ul style="list-style-type: none"> - Modernization and expansion projects - Potential for smart shipping and green corridor development

	economic zones	
Threats	<ul style="list-style-type: none"> - Environmental fragility and ecosystem disruption - Territorial disputes and governance gaps - Risk of over-militarisation 	<ul style="list-style-type: none"> - Geopolitical risks and security threats (e.g., regional conflicts, piracy) - Environmental degradation and salinisation

Source: Generated by the researcher

The results show that rising sea levels and extreme weather, frequent storms and floods pose a significant challenge that can cause operational disruptions, thus affecting global trade flow. Sea Ice melting in the Arctic offers a longer summer period and reduces transit time between Europe and Asia, and America offers global economic and trade opportunities. These opportunities also pose some challenges to the environment and the maritime ecosystem due to the possibility of oil spills and pollution. Another challenge is the possibility of geopolitical conflicts as powerful states try to control the new shipping routes. Shorter shipping routes of the Arctic can reduce fuel consumption and travel time, increasing trade efficiency.

CONCLUSION

Climate change is redefining the global maritime trade route map due to shifting environmental patterns. Historically, the Suez Canal was one of the key trade routes connecting Europe and Asia, but it remains vulnerable to climate change and political conflicts. The 2021 Ever Given blockage vividly illustrated the fragility of global trade and resulted in substantial economic losses. Similarly, the melting of Arctic Sea ice is opening new opportunities for maritime trade routes, particularly the Northern Sea Route (NSR), a shorter passage that can reduce travel time and fuel consumption. However, the Arctic maritime route also presents complex environmental, legal, and geopolitical challenges. Heavy reliance on the traditional Suez Canal route challenges smooth trade flow, and the emergence of new routes like those through the Arctic necessitates a review of maritime policies, infrastructure investments, developments, and regional partnerships. The broader impacts of climate change on maritime transformation require effective, adaptive, and resilient trade policies that align with climate goals while safeguarding the economic interests of nations. The strategic landscape of global sea routes is evolving, as climate change intersects with geopolitical and economic competition. The international community has a responsibility to act decisively, effectively, and thoughtfully to develop and strengthen maritime infrastructure and diversify trade routes, ensuring Arctic routes are no longer an inaccessible periphery but a vital part of global maritime trade.

Recommendations:

- Investment in Climate-resilient infrastructure to address climate change impacts in the Suez Canal. This infrastructure includes the implementation of advanced flood defence mechanisms, strengthening the coastal protection system and improved canal operational management. Egypt is investing in

improving the Suez Canal infrastructure to counter these climate change impacts but more investment is needed to ensure operational stability.

- International maritime policy for sustainable Arctic shipping is required to establish to minimise environmental impacts and to prevent oil spills, carbon emissions and waste management. The Arctic Council is working on the Arctic shipping policy, and the international community can expand this effort to ensure environmental sustainability.
- Diplomatic cooperation and shared governance mechanisms can address geopolitical tensions, including trade route security and territorial disputes in the Arctic Ocean and the Suez Canal.
- Investments in advanced satellite monitoring systems to monitor real-time for weather patterns, temperature, and sea ice can track maritime route conditions and share viable solutions in the Suez Canal and the Arctic shipping routes.
- To reduce heavy reliance on the Suez Canal, develop alternative infrastructure in rail and land transport routes across Central Asia and alternative maritime centres in the Red Sea region through regional partnership and international trade agreements to divert traffic during the Suez Canal disruptions
- Adopt green shipping technology by encouraging the shipping industry to use energy-efficient vessels and low-emission fuels in the Arctic region and providing subsidies, incentives and regulations which encourage green technology adoption.
- Countries near the Arctic and the Suez Canal region should establish a climate adaptation framework and collaborate for disaster risk management, such as flood protection, sustainable economic development and environmental monitoring in these regions.

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