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MSc in Energy: Strategy, Law and Economics

The Geopolitics of Global Maritime Energy Transportation: Chokepoints, Markets, Risks and Security

Master Thesis

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George Smailis

Abstract

Global maritime energy transportation is a critical pillar of the world economy and is deeply intertwined with geopolitics, as vital chokepoints—such as the Strait of Hormuz, the Strait of Malacca, and the Suez Canal—control the flow of oil and liquefied natural gas (LNG). These chokepoints are strategic maritime passages essential to the global energy system. This thesis explores the geopolitical and economic significance of maritime chokepoints in global energy transportation, focusing on their vulnerabilities, risks, and resilience. Maritime chokepoints serve as critical nodes for transporting oil and natural gas, which form the backbone of the global energy supply chain. However, these chokepoints face significant risks from conflicts, piracy, terrorism, and environmental hazards, making their security a pressing concern for energy markets and international stability. To address these challenges, this study introduces the Chokepoint Resilience Index (CRI), a novel analytical framework that evaluates resilience across six dimensions: geopolitical, economic, alternative routes, geomorphological, historical, and environmental factors. By analyzing quantitative data from 2020 to 2024, the CRI reveals the resilience levels of major chokepoints. It identifies the Strait of Hormuz as the most resilient due to its strong military presence and robust infrastructure, while Bab-el-Mandeb ranks as the least resilient, reflecting heightened instability and recent Houthi attacks. Furthermore, the thesis examines disruptions in chokepoints, particularly in the Red Sea, concluding that these events have increased shipping costs, affected global energy prices, and raised insurance premiums. The research also evaluates the potential of emerging alternative routes, such as the Northern Sea Route (NSR), as a viable solution to minimize dependence on traditional chokepoints. However, the geopolitical complexities in the Arctic—driven by competing Russian and NATO interests—underscore the challenges of adopting these new pathways. By offering a multidimensional perspective on chokepoint vulnerabilities, this thesis provides valuable insights for policymakers, energy stakeholders, and the maritime industry. It underscores the urgent need for international collaboration, enhanced security measures, and innovative strategies to ensure the stability of global energy flows amid evolving geopolitical tensions. Ultimately, this research advances discussions on energy security, maritime logistics, and global economic resilience in an era of heightened uncertainty.

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List of Abbreviations

AFRA – Average Freight Rate Assessment

b/d – Barrels per day

BDI – Baltic Dry Index

CMIP – Critical Maritime Infrastructure Protection

CRI – Chokepoint Resilience Index

EEZ – Exclusive Economic Zone

EIA – U.S. Energy Information Administration

EU – European Union

GPR – Geopolitical Risk Index

IMB – International Maritime Bureau

IMO – International Maritime Organization

IOC – International Oil Company

IOCs – International Oil Companies

ITOPF – International Tanker Owners Pollution Federation

JWC – Joint War Committee (Lloyd’s of London)

LNG – Liquefied Natural Gas

LTBP – London Tanker Brokers' Panel

MENA – Middle East and North Africa

MR – Medium Range (tanker category)

MSI – Maritime Security Index

NATO – North Atlantic Treaty Organization

NG – Natural Gas

NOC – National Oil Company

NOCs – National Oil Companies

NSR – Northern Sea Route

OPEC – Organization of the Petroleum Exporting Countries

Q3 – Third Quarter

SLOC – Sea Lines of Communication

UNCTAD – United Nations Conference on Trade and Development

US – United States

VLCC – Very Large Crude Carrier

WTI – West Texas Intermediate

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Chapter 1: Introduction

1.1. Preamble

Energy plays a vital role in shaping the global economy, and maritime transportation is its lifeline, connecting production hubs with energy-hungry markets. Approximately 80% of global trade by volume, and 70% by value, moves across the seas, with oil and natural gas forming the backbone of this supply chain[1]. However, this indispensable network is inherently fragile, traversing chokepoints like the Strait of Hormuz, the Suez Canal, and the Strait of Malacca—critical yet vulnerable junctures.

These maritime chokepoints are geopolitical hotspots, susceptible to natural disasters, piracy, terrorism, and military conflicts. Any disruption, however brief, can reverberate across global markets, raising energy prices and threatening energy security. Moreover, the intensification of geopolitical tensions and the strategic militarization of these waterways add layers of complexity, highlighting the need for robust risk assessments and resilience mechanisms.

The main goal of the present thesis is to highlight the critical and complex geopolitical and economic importance of the maritime chokepoints for the global maritime energy transportation. The past, but also the ongoing chokepoint disruptions and potential claims or disputes, like the President Trump's recent threat for US control over the Panama Canal[2], need to be examined with detailed and multi-dimensional approach in order to make the general uncertainty of the global energy markets more obvious. The thesis introduces the Chokepoint Resilience Index, an analytical framework assessing the resilience of key maritime nodes based on historical, geopolitical, economic, environmental, and geomorphological factors. The study also evaluates the geopolitical and economic impact of Red Sea disruptions caused by Houthi attacks, focusing on energy transport. Lastly, it explores alternative maritime routes, like the Northern Sea Route, as solutions to energy disruptions. Key questions include: What is the Chokepoint Resilience Index? How do Red Sea disruptions affect energy markets? What are the implications of emerging maritime routes? By addressing these, the study not only contributes to the academic discourse but also informs policymakers and industry stakeholders striving for a resilient and secure energy future.

1.2. Structure of Thesis

This thesis examines the geopolitical and economic dimensions of global maritime energy transportation, focusing on chokepoints' profiles, features, and vulnerabilities. The thesis is structured into five chapters. Chapter 1 introduces the research, providing a preamble to the topic and outlining the thesis structure. Chapter 2 presents a comprehensive literature review, covering geopolitics, global maritime energy transportation, maritime security, and the significance of chokepoints, along with the risks and economic implications of their disruption. Chapter 3 outlines the research methodology, detailing the research questions and methods used to develop the Chokepoint Resilience Index and analyze maritime disruptions. Chapter 4 discusses the results, focusing on the Chokepoint Resilience Index, the geopolitical and economic impacts of the Red Sea disruption, and the potential of the Northern Sea Route as an alternative for energy transport. Finally, Finally, Chapter 5 summarizes the findings, acknowledges limitations, and provides recommendations for future research.

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[1] Rodrigue (2017).

[2] Williams (2025).

Chapter 2: Literature Review

2.1. Introduction

The global maritime transport of energy resources, such as oil and natural gas, forms the backbone of the world's energy supply chain, connecting producers and consumers across vast distances[3]. However, this vital artery of international trade is fraught with geopolitical risks that can disrupt supply, influence market prices, and even trigger broader conflicts. The complex interplay of national interests, territorial disputes, and strategic chokepoints makes maritime energy transport highly susceptible to geopolitical volatility.

This chapter explores the structure of global maritime energy transportation network, the features and risks of maritime chokepoints for energy transportation and the disruption impacts on energy prices, shipping freights markets and global economy.

2.2. Geopolitics

Geopolitics has a profound impact on societies and the economy. This field studies the geographical distribution of state power and political interests or otherwise the geographical zone of influence of a state and the competition with other actors[4]. Understanding the geopolitical framework for state and economic actors requires a sufficient grasp of the concept of "Geopolitics." Although diplomacy and political strategy have existed for thousands of years, Geopolitics is a relatively recent theoretical and practical tool from the last 200 years.

The classical geopolitics focused on the analysis of the means and tools for maximizing national power. Many thinkers embraced the concept of "politics through geographical control". In 1890, in his famous book *The Influence of Sea Power upon History, 1660-1783*, Mahan argued that controlling the seas and achieving great naval power was the key to the success of the nation's political goals[5]. Subsequently, in 1902 in the book *Britain and the British Seas*[6] and in 1904 in the article entitled *The Geographical Pivot of History*[7], Mackinder focused, in contrast to Mahan, on the control of the giant land mass surrounded by large oceanic expanses, which he called the "Heartland". According to Mackinder, if one controlled that, one controlled the world. The Heartland was a "pivot area" that encompassed Eastern Europe through Russia and into Asia[8].

Also important was the contribution of Kjellén, who coined the term *"geopolitics*" and justified the territorial expansion of the state/*reich* to achieve the national interest and economic well-being of the people/*volk*[9]. Finally, Haushofer's war experience as a German general helped him to formulate the idea of "*wehrgeopolitik"*(war geopolitics), which also became a subject of study by the Nazis[10].

The fact that Nazi Germany instrumentalized parts, sayings and theories of geopolitics through the war effort between 1939 and 1945 did not invalidate the theoretical and political importance of this field; on the contrary, the contemplation and production of ploys continued in the post-war years under the new framework of the Cold War. During this period, the theories of N. Spykman as the

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[3] Rodrigue (2017).

[4] Caldara & Iacoviello (2022); Germond (2015).

[5] Mahan (1890).

[6] Mackinder (1902).

[7] Mackinder (1904).

[8] Malmgren (2015).

[9] Holdar (1992).

[10] Ibid.

"father of containment" flourished. Spykman (1944)[11], unlike Mackinder, did not consider the control of the "Heartland" of primary importance, but the field of projection of national power according to him was the outer perimeter acting as a strategic mound, which he called the "Rimland" as it is described in Figure 1. This area in essence includes Europe and Asia, which in the Cold War years between the U.S., Europe and Japan would act as bastions of containment against the projection of expansive Soviet power. This geopolitical rationale influenced American governments, and the case of the American involvement in Vietnam was illustrative, where, according to President D. Eisenhower, there was a danger of a "domino effect"[12].

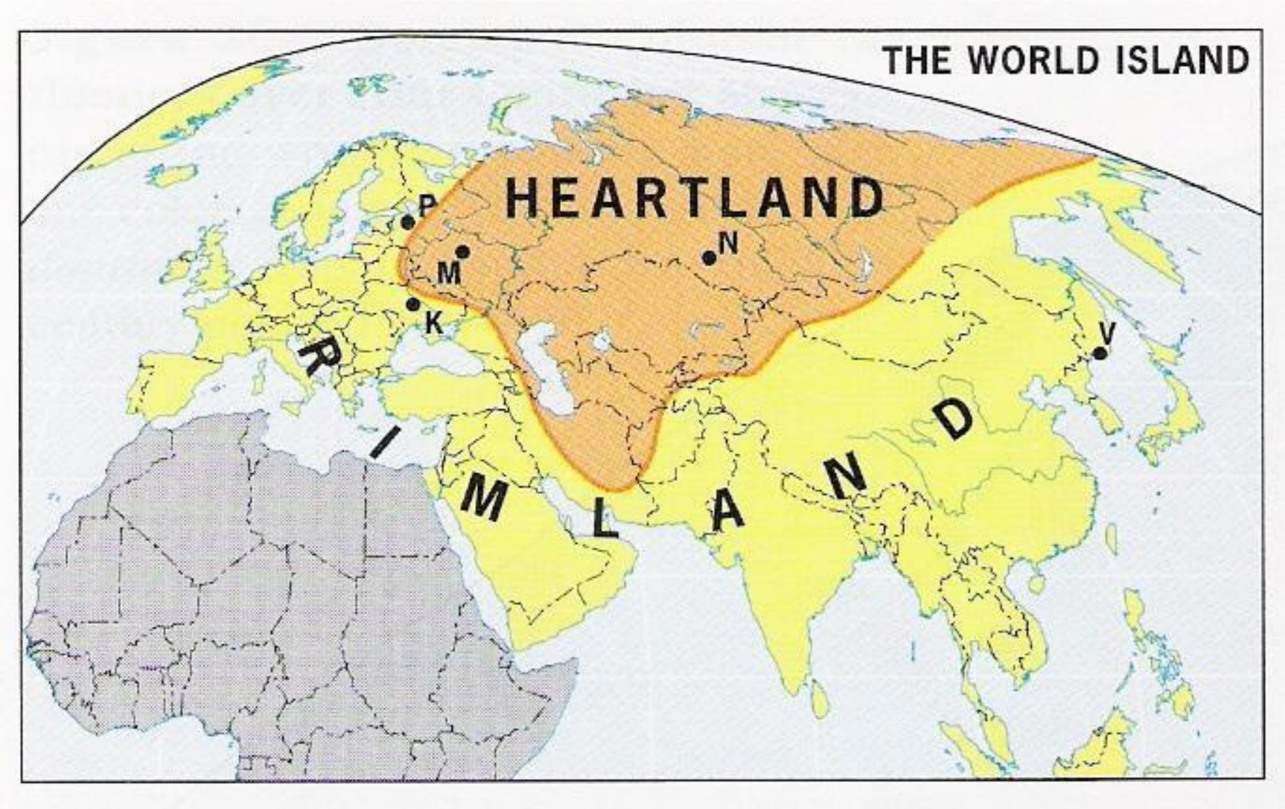

Figure 1. *The Heartland and Rimland Areas[13].*

The end of the Cold War with the dissolution of the Soviet Union, according to some thinkers such as F. Fukuyama (1992)[14], would mean the gradual retreat of geopolitics as a field of analysis of interstate competition based on military power, due to American monarchy, and the flourishing of international trade and the development of globalization would gain ground. But Edward Luttwak (1990)[15] argued with the development of "Geo-economics" that it would assist in reorganizing the nature of international competition with an emphasis not on military superiority, but on the field of economics as an "admixture of the logic of conflict and the methods of commerce".

2.3. Global maritime energy transportation

Global maritime energy transportation is a critical component of the international energy supply chain, facilitating the movement of oil, gas, and other fuels across the world's oceans. In 2022,

[11] Spykman (1944).

[12] Ibid.

[13] Wakkumbura (2023).

[14] Fukuyama (1992).

[15] Luttwak (1990).

maritime trade encapsulated roughly 80% of the global trade volume and exceeded 70% in terms of the global merchandise value. In the case of oil and natural gas (NG), land pipelines are helpful to connect production centers to markets in an extensive supply chain[16]. Nevertheless, distances and geographical barriers such as rugged topography or massive water bodies (e.g., oceans and others) make pipelaying unfeasible and expensive. Maritime operations fill the gap for a massive transportation system across oceans[17].

2.3.1. Crude oil & natural gas markets

The oil and gas markets are considered the most important and complex commodities, not only given their key roles for consumption and production functions, but also with regard to their liquidities and trading volumes[18]. Since the beginning of the oil industry, petroleum producers and consumers have feared that eventually the oil would run out. In 1950, the US Geological Survey estimated that the world's conventional recoverable resource base was about 1 trillion barrels[19]. Fifty years later, that estimate had tripled to 3 trillion barrels. In recent years, the concept of Peak Oil has been much debated. The Peak Oil Theory is based on the fact that the amount of oil is finite, but IEA predicts that the energy demand will rise by an average of 1.5% each year through 2030 and this demand will continue to be met by oil, gas and coal[20].

The oil and gas markets have two major players: The International Oil Companies (IOCs) and the National Oil Companies (NOCs). IOCs are private owned companies, they can compete globally and they have large amounts of capital, technological capacity and knowledge that it gives them international credibility[21]. NOCs as a government-controlled entity usually formed to manage the hydrocarbon resources of the country and they can operate in their home country or across the borders[22]. The IOCs are competing with the NOCs for the share of oil and gas reserves, but in some cases they come to cooperation schemes (joint ventures) as they shown in Table 1[23]. Many of the NOCs are controlled by countries that are members of the OPEC, which is the cartel of non-Western oil-producing countries with important influence on the oil production and price determination and it controls the 80% of proven world crude oil reserves[24].

***Table 1**. Differences between IOCs and NOCs[25].*

Operational capabilities	**IOCs**	**NOCs**
Access to capital	Publicly floated companies with access to liquid stock markets, banks and bond buyers	State-backed with increased access to equity and debt in global capital markets

[16] Ari, Koc, Meza & Sada (2022).

[17] Ibid.

[18] Ameur & Jawadi (2022).

[19] Hughes & Rudolph (2011); Inkpen & Moffett (2011).

[20] Ibid.

[21] Ameur & Jawadi (2022); EIA (2022); Energy Charter Secretariat (2007); Inkpen & Moffett (2011).

[22] Ibid.

[23] EIA (2022); Library of Congress (no date).

[24] Morse (1999); OPEC Official Website.

[25] Inkpen & Moffett (2011).

Operational capabilities	IOCs	NOCs
Standard technology	Leaning toward low R&D expenditures that drive down costs in complex development environments	Rapid growth of R&D technology and innovation
Breadth of capabilities and partnerships	International focus and partnerships with governments, NOCs and other IOCs	Primarily domestic focus of operations. Expanding business globally and partnerships with IOCs
Effective local engagement	Developing models for local engagement by necessity and more diverse international workforce	Operating mostly in their domestic market and globally to access resources. Attracting international workforce

The oil and gas industry is frequently divided into three segments: upstream, midstream and downstream[26]. The upstream sector includes the exploration, development and production of oil & gas. The midstream handles the transportation and storage via pipeline or ships (tankers) and the downstream sector is the refining into different products[27].

The crude oil markets are global with many producers and consumers from several geographic locations. The main crude oil benchmarks are the Brent, the WTI, Dubai and Urals[28]. Crude oil price depends on many factors, like oil and petroleum product's quality, location of reserves, security and availability of supply[29]. Also, the financial derivatives based on energy has been developed since 1980s, whose value comes from the underlying asset and the risk is transferred from a party who wants to take a less risk to a party who is able to take the same risk in for a certain price. These transactions constitute the oil futures or options markets[30].

Regarding the natural gas, the most widely used gas price formation mechanisms are the following: (1) oil indexation, where the gas price is linked to the current oil price, especially used for the LNG pricing, (2) gas-to-gas competition[31], determined by the dynamics of supply and demand in a physical or virtual hub, (3) regulated gas pricing, as a non-market approach for the domestic gas[32], (4) netback pricing, when the gas is used as a raw material in an industrial production and (5) a hybrid pricing[33].

[26] Ibid.

[27] Ibid.

[28] Energy Charter Secretariat (2007); Inkpen & Moffett (2011); Jukic, Nosic & Sedlar (2017).

[29] Energy Charter Secretariat (2007); Hafner & Luciani (2022).

[30] Energy Charter Secretariat (2007); Inkpen & Moffett (2011); Jukic, Nosic & Sedlar (2017).

[31] Energy Charter Secretariat (2007).

[32] Hafner & Luciani (2022).

[33] Energy Charter Secretariat (2007); Gas Exporting Countries Forum (no date); Hafner & Luciani (2022).

2.3.2. Routes

Based on the above, the midstream energy transportation is done via pipelines and ships. Although, oceans account for 71% of the earth's surface, maritime transportation of energy mostly takes place only along specific routes[34]. These routes are a complex network of points of passage and their density faces multiple fluctuations, like in Covid-19 pandemic in 2020, as Figure 2 shows[35].

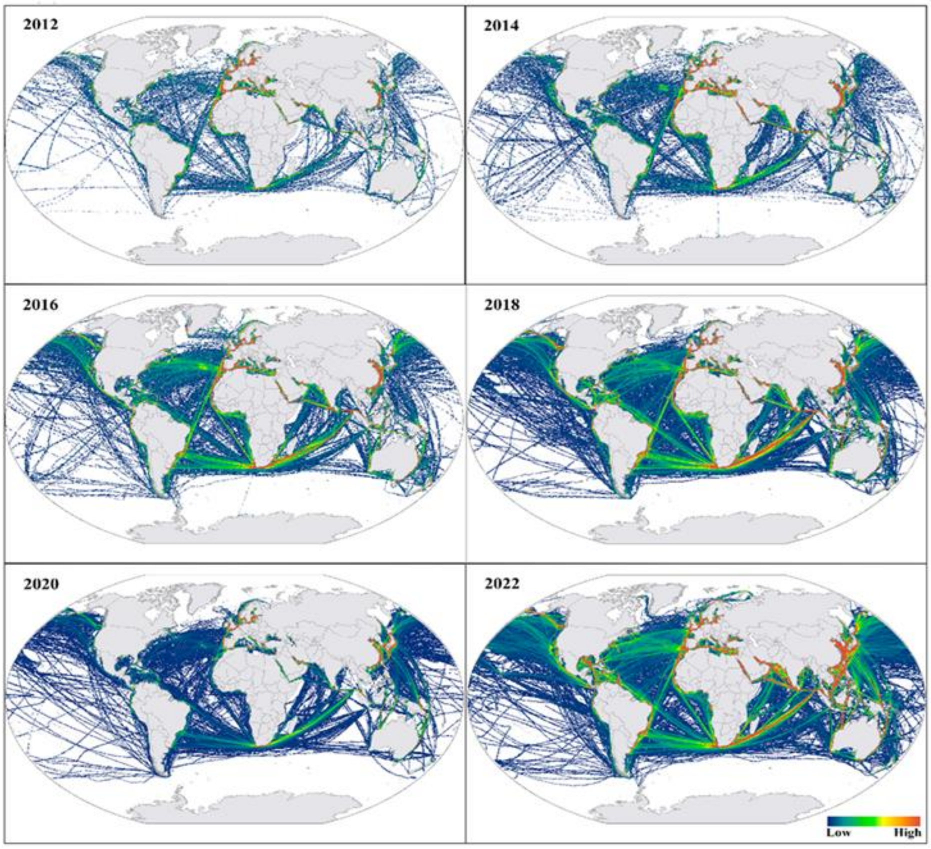

Figure 2. *Global density of marine traffic, 2012–2022[36].*

There are potentially an infinite number of maritime shipping routes that can be used for maritime shipping, but the configuration of the global maritime shipping system is relatively simple. The central axis is a circum-equatorial corridor linking North America, Europe, and Pacific Asia through the Suez Canal, the Strait of Malacca, and the Panama Canal. These routes handle the majority of the traffic, but numerous other routes exist (namely for coastal shipping), depending on the origin and destination of the maritime shipment[37]. Transatlantic and transpacific traffic concerns a wide variety of ports, so there are numerous routes, most of them having a path along the great circle. Trans-Indian ocean traffic is predominantly intermediary between Pacific Asia and Europe, implying a series of clearly defined routes between the Strait of Malacca and Bab el-Mandeb[38].

Core routes are those that are most used because they service major markets, while secondary rotes are mostly connectors between secondary and major markets[39]. Maritime routes are organized according to the commercial services they support. Firstly, the port-to-port represents the

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[34] Rodrigue (2017).

[35] Ibid.

[36] Du, Peng & Wang (2024).

[37] Rodrigue (2017).

[38] Port Economics, Management and Policy (no date).

[39] Port Economics, Management and Policy (no date); Rodrigue (2017).

conventional service structure which concerns regular calls between two ports. Secondly, the pendulum services are typical of container shipping with regular itineraries covering a set of ports calls that are sequentially serviced and the most significant pendulum routes are between East Asia, North America, and Western Europe, the three main poles of the global economy. Finally, the round-the-world services also relate to the container shipping and involve calling at a sequence of ports, often in both directions, such that the sequence involves a trip around the world[40].

2.3.3. Vessel types and nationality

Ships carrying crude oil and petroleum products are limited by size restrictions imposed by maritime oil chokepoints, that will be examined below. The global crude oil and refined product tanker fleet uses a classification system to standardize contract terms, to establish shipping costs, and to classify vessels for chartering contracts. This system, known as the Average Freight Rate Assessment (AFRA) system, was established by Royal Dutch Shell six decades ago, and the London Tanker Brokers' Panel (LTBP), an independent group of shipping brokers, oversees the system, as presented in Figure 3[41].

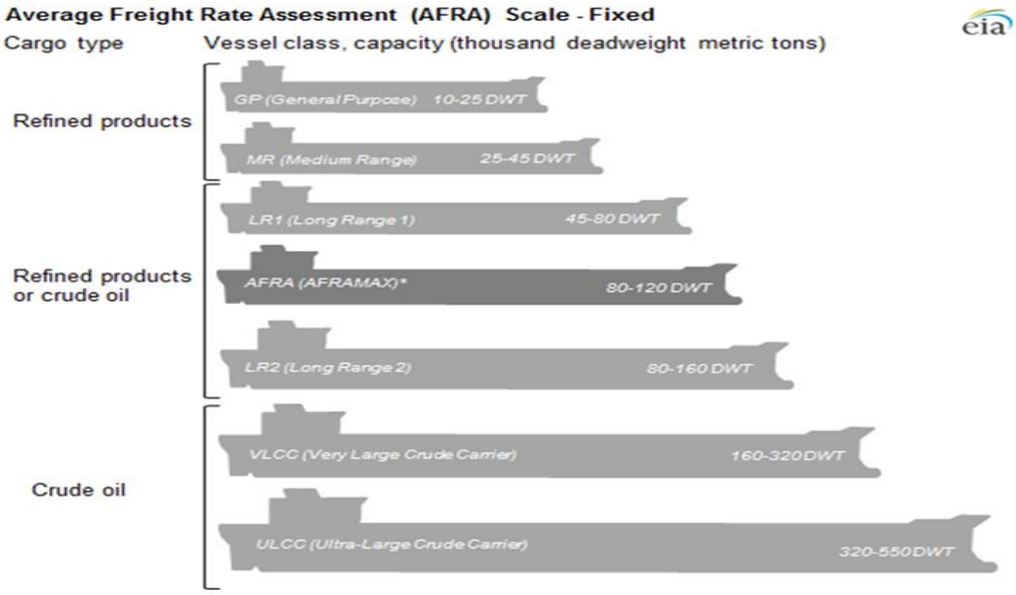

Figure 3. *Average Freight Rate Assessment (AFRA) Scale[42].*

AFRA uses a scale that classifies tanker vessels according to deadweight tons—a measure of a ship's capacity to carry cargo. The approximate capacity of a ship in barrels is determined using an estimated 90% of a ship's deadweight tonnage, which is multiplied by a barrel-per-metric-ton conversion factor specific to each type of petroleum product and crude oil, as liquid fuel densities vary by type and grade[43].

The smaller vessels on the AFRA scale—the General Purpose (GP) and Medium Range (MR) tankers—are commonly used to transport cargos of refined petroleum products over relatively shorter distances, such as from Europe to the U.S. East Coast[44]. Their smaller size allows them to access most ports around the globe. A GP tanker can carry between 70,000 barrels and 190,000 barrels of motor gasoline (3.2-8 million gallons), and an MR tanker can carry between 190,000

[40] Rodrigue (2017).

[41] EIA (2014).

[42] Ibid.

[43] Ibid.

[44] Ibid.

barrels and 345,000 barrels of motor gasoline (8-14.5 million gallons). Long Range (LR) class ships are the most common ships in the global tanker fleet, as they are used to carry both refined products and crude oil[45]. These ships can access most large ports that ship crude oil and petroleum products. An LR1 tanker can carry between 345,000 barrels and 615,000 barrels of gasoline (14.5-25.8 million gallons) or between 310,000 barrels and 550,000 barrels of light sweet crude oil[46].

A large portion of the global tanker fleet is classified as AFRAMAX. AFRAMAX vessels are ships between 80,000 deadweight tons and 120,000 deadweight tons. Over the history of AFRA, vessels grew in size, and newer classifications were added. The Very Large Crude Carrier (VLCC) and Ultra-Large Crude Carrier (ULCC) were added as the global oil trade expanded and larger vessels provided better economics for crude oil shipments. VLCCs are responsible for most crude oil shipments around the globe, including in the North Sea, home of the crude oil price benchmark Brent. A VLCC can carry between 1.9 million and 2.2 million barrels of a West Texas Intermediate (WTI) type crude oil[47].

Vessel nationality is also an important parameter in the energy transport via ship. This concept describes a legal relationship between the vessel and the state of the flag and it is corollary of the principle of the freedom of the high seas[48]. It reflects the belief that the ship is subject to the sovereignty of some state. This state can ensure that the ship fulfills its international responsibilities. So the maritime flags not only represent the link between the vessel and the state, but also the link between the state and the international community[49].

Besides oil tankers, other forms of vessels exist in order to transport LNG. Liquefied natural gas (LNG) is natural gas that has been cooled to a liquid state (liquefied), to about -260° Fahrenheit, for shipping and storage. The volume of natural gas in a liquid state is about 600 times smaller than its volume in a gaseous state (in natural gas pipelines)[50]. The liquefaction process, developed in the 19th century, makes it possible to transport natural gas to places natural gas pipelines do not reach and to use natural gas as a transportation fuel[51]. LNG carriers can be categorized in different ways. They are categorized based on pressurization as fully pressurized, semi-pressurized, refrigerated, and fully refrigerated; based on the hazard level of the material being transported as Type 1G, Type 2G, Type 2PG, and Type 3G; and based on their type of cargo tanks as those with Independent tanks (Type A, Type B, Type C) and Integral tanks (TGZ Mark III and GT 96)[52].

2.3.4. Energy loads and flows

According International Energy Association’s Oil Market Report (August, 2024), the global oil demand increased by 870 kb/d in 2024, with a contraction in China limiting gains[53]. Demand is set to rise by less than 1 mb/d in both 2024 and 2025. This is largely unchanged from July’s Report and far slower than 2023 2.1 mb/d growth as comparatively lackluster macroeconomic drivers come to the fore. Global supply rose 230 kb/d to 103.4 mb/d in July as a substantial OPEC+ increase more than offset losses from non-OPEC+. Annual gains accelerate from 730 kb/d in 2024 to 1.9 mb/d in

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45 Ibid.

46 Ibid.

47 EIA (2014); Inkpen & Moffett (2011).

48 Mertus (1988).

49 Ibid.

50 Clarksons (no date).

51 EIA (2023).

52 Clarksons (no date).

53 IEA (2024).

2025. Non-OPEC+ production increases by 1.5 mb/d in 2024 and next, while OPEC+ may fall by 760 kb/d in 2024 but rise by 400 kb/d in 2025 if voluntary cuts stay in place[54].

A brief overview of the key trends in the global oil market would be helpful in understanding its complex nature and significance. First, the low price volatility and resilience, despite the rise in uncertainty, geopolitical tensions and shocks hit the oil market. Though sanctions and geopolitical shocks did not result in large oil supply losses, they have transformed oil and products trade flows, reduced transparency, created more segmented markets, lengthened trade routes and supply chains, increased costs and logistical complex and resulted in more constrained optimization for the various players[55].

Subsequently, the impact of these shocks have also shaped and transformed the behavior of key players in the oil market and their relations. US oil policy has become more interventionist, while US oil supply continues to transform the non-OPEC oil supply and trade flows. The US shale oil and gas revolution has important implications, not only in terms of balances and prices, but also on the structure of the oil market, where US is the world's largest oil producer with Saudi Arabia and Russia in the second and third position respectively, as EIA's Figure 4 shows.

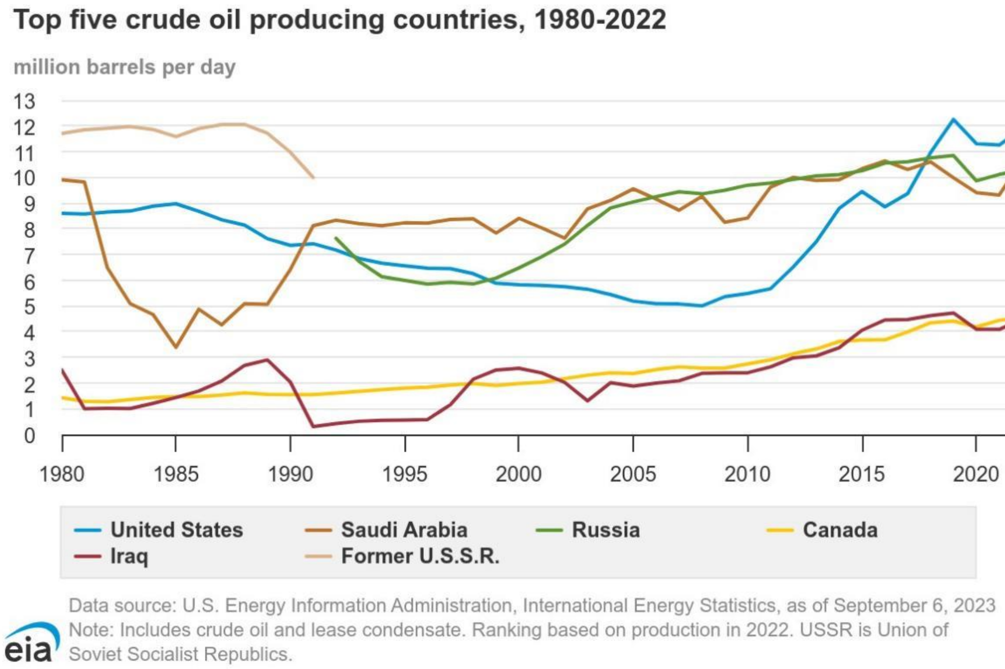

Figure 4. *Top five crude oil producers, 1980-2022[56].*

OPEC has shown its willingness to act in a proactive manner to address market imbalances[57]. Russia is no longer seen as a reliable supplier and has become heavily depended on smaller collection of buyers with important implications on pricing, competition, trade and geopolitical tension[58]. China as the world's largest crude oil importer, has been the main beneficiary of these shifts arbitrating between different sanctioned crudes and its import/export products quota policy has grown in strategic importance[59].

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[54] Ibid.

[55] Economou & Fattouh (2024); Hughes & Rudolph (2011).

[56] EIA (2022).

[57] Economou & Fattouh (2024); Hughes & Rudolph (2011); IEA (2024).

[58] Ibid.

[59] Ibid.

Furthermore, the changes in the refining scene has been profound over the last two decades, which kick-started some of the above trends including the reconfiguration in trade flows and rise of China as a swing refiner. Moreover, the crude oil pricing system has already seen key structural transformations, especially with the inclusion of WTI Midland into the Brent basket. As WTI increasingly sets the price of Brent, larger volumes of oil traded globally pricing off Brent are now linked to trading activities and the various physical and financial layers around WTI (Platts, 2023). Finally, these transformations are happening against a background of wide uncertainty over oil demand growth prospects, with the divergence not only limited to projections over the medium-and long term demand trajectory, but also the short term one[60].

Regarding the natural gas markets, IEA Gas Market Report Q3 2024[61] moved to more pronounced growth in the first half of 2024, with initial estimates indicating that global gas demand increased at a rate well above its historical average during this period[62]. Demand growth is primarily supported by higher gas use in industry and is increasingly concentrated in Asia, where both China and India returned to double-digit growth rates in the first half of 2024[63]. Despite this strong growth, the outlook for gas demand remains fragile. Global LNG production underperformed in the second quarter of 2024, while geopolitical tensions are fueling price volatility, but with steady volume of exports from Qatar, US, Russia and Australia, to China, Japan, India and South Korea as Figure 5 shows[64].

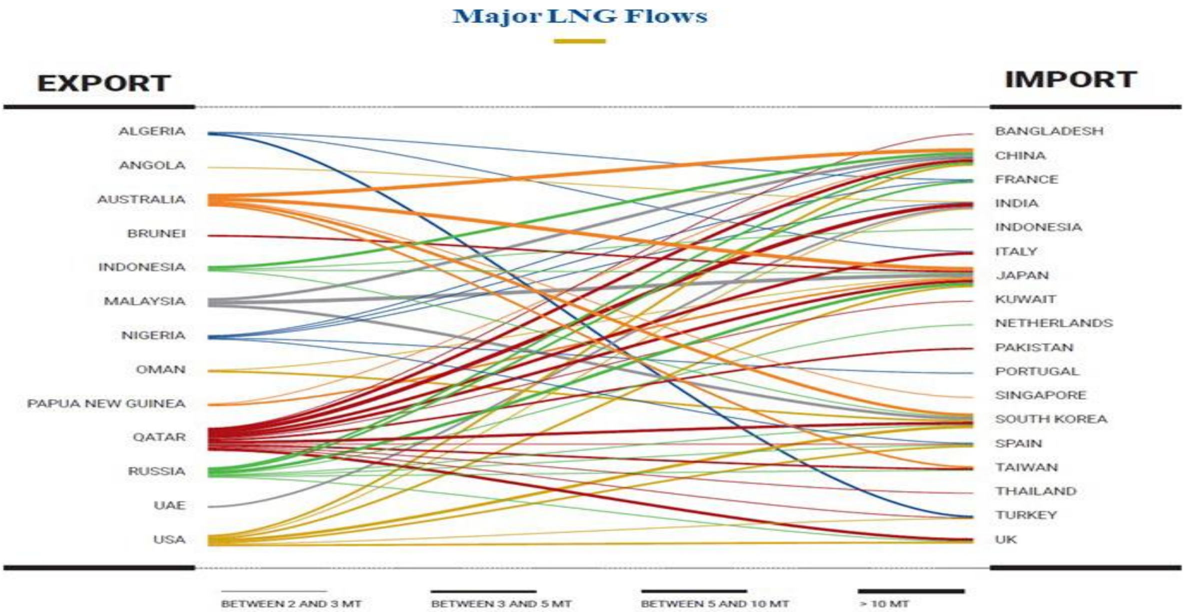

Figure 5. *Major LNG Flows*[65].

Natural gas prices increased across all key markets in the second quarter of 2024, reflecting tighter market fundamentals[66]. For the full year of 2024, according to IEA, natural gas demand is forecast to increase by 2.5% in 2024, primarily driven by fast-growing Asian markets[67].

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[60] Economou & Fattouh (2024); IEA (2024).

[61] IEA (2024).

[62] Ibid.

[63] Ibid.

[64] International Group of LNG Importers (2024).

[65] Ibid.

[66] IEA (2024).

[67] Ibid.

2.4. Maritime Security

Oceans serve as a crucial wellspring of global prosperity, constituting a sophisticated system for the sustainable advancement of the global economy[68].The increase in global energy demand, the utilization of unconventional energy resources, and shifts in energy markets could dramatically alter future energy flows, impacting the transportation of energy commodities. In particular, maritime security for energy transportation will be of significant importance in evaluating the risks of fuel procurement and analyzing energy security more comprehensively, taking into account changes in the energy landscape[69]. The risks associated with maritime security in energy transportation have not yet been fully incorporated as an element of energy security[70].

2.4.1. Definitions

The term "Maritime security" appeared after the end of the Cold War and it can be understood according to Bueger (2015) as *"the negative definition of absence of a range of threat"*[71]. Many institutions and think tanks have defined the term differently, as be described in Table 2.

Table 2*. The definitions of maritime security[72].*

Name of institution/researcher	**Definition of maritime security**
Center for International Maritime Security (2012)	*"Freedom of the risk of serious incursions against a nation's sovereignty launched from maritime domain and from the risk of successful attack against a nation's maritime interests".*
Hussain (2011)	*"Measures employed by owners, operators and administration of vessels, port facilities, offshore installations or other marine organizations and establishments to protect against seizure, sabotage, piracy, theft, terrorism activities and hostile interference with lawful operation".*
US National Strategy for Maritime Security (The U.S. Navy) (2007)	*"Mitigating threats as piracy, terrorism, weapon proliferation, drug trafficking and other illicit activities to protect, secure and enhance global stability of navigation".*
Rahman (2009)	*"The five perspectives: security of the sea itself, ocean governance, maritime border protection, military activities at sea, security regulation of the maritime transportation system".*
Bueger (2015)	*"The negative definition of absence of a range of threat".*

[68] Du, Peng & Wang (2024).

[69] Michail & Melas (2022).

[70] Kosai & Unesaki (2016).

[71] Ibid.

[72] Ibid.

Name of institution/researcher	Definition of maritime security
Council for Security Cooperation in the Asia Pacific (Maritime Terrorism Research Center)	*"The undertaking of terrorist attacks and activities within the maritime environment, using or against vessels or fixed platforms at sea or in port or against any one of their passengers or personnel, against coastal facilities or settlements, including tourist resorts, port areas and port towns and cities".*

In academia, the term "maritime security" was largely absent from discussions on the security of the maritime domain until the early 2000s[73]. Since 2002, references to maritime security in academic literature have increased linearly, driven by terrorist and pirate attacks on ships, as shown in Figure 6[74].

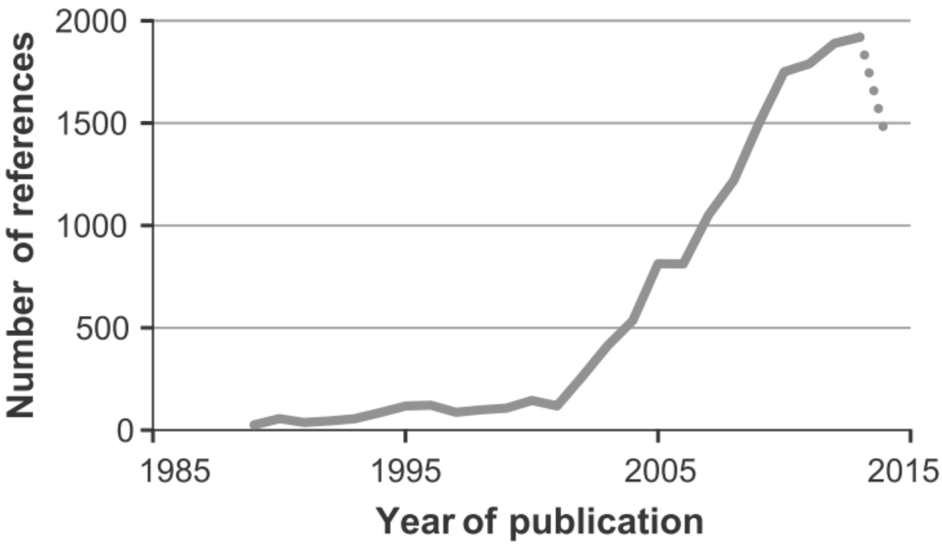

Figure 6. *Evolution between 1989 and 2014 of the number of academic publications mentioning 'maritime security' listed by Google Scholars[75].*

According to Kosai and Unesaki (2016), the maritime security has three dimensions, which have some indicators, as shown in Figure 7. The first dimension is chokepoints with the destruction risk and alternative routes as the indicators. The second is piracy with the piracy act area and piracy level as the indicators. Finally, the third is the ship loss dimension with the case of maritime accident as indicator. Many different geographical areas are characterized by political and social instability that harms the maritime status quo and some of them are under the control of major military and economic blocks, like NATO (the EEZ of NATO members cover 15% of the oceans) and G20 (69% of the world EEZ comes under the jurisdiction of G20 members)[76].

[73] Ibid.

[74] Ibid.

[75] Germond (2015).

[76] Vivero & Rodriguez Mateos (2017).

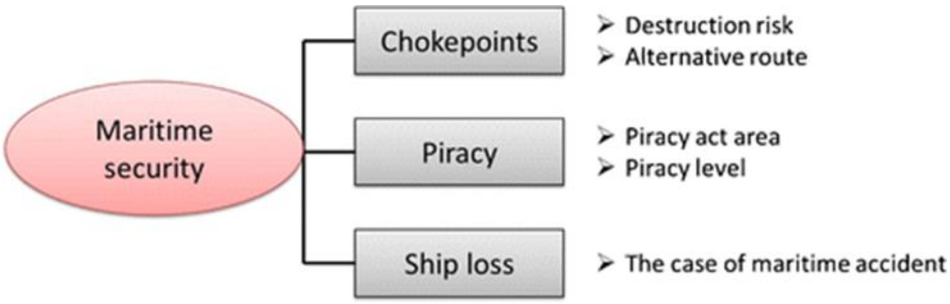

Figure 7. *The framework of maritime security for energy transportation security*[77].

2.4.2. Conflicts

Many factors can affect the maritime security. Based on the 2008 UN Secretary General's Report on Oceans and the Law of the Sea, maritime security could be subdivided into (1) piracy and armed robbery, (2) terrorist acts, (3) the illicit trafficking in arms and weapons of mass destruction, (4) illegal, unreported and unregulated fishing, (5) the illicit trafficking in narcotics, (6) smuggling and trafficking of persons by sea and (7) intentional and unlawful damage to marine environment[78].

Furthermore, other important dimension of maritime conflicts is the intra-state disputes, that are sometimes excluded from debates, because they are viewed as a part of the broader international security dynamics[79]. The intra-state disputes can escalate a conflict and disrupt the maritime activities or they can also undermine the law protection and other maritime cooperation schemes. the difficulty of delimitation of maritime zones and jurisdictions proliferate the maritime grey-zones tensions or attacks, that harm shipping trade[80].

Related to this is the threat of maximization of militarization is some key sea points, like the West Indian Ocean due to the Indian fears of the enhancement of strategic influence of China in the region and raises concerns to major naval powers, like US and United Kingdom for the security of the free trade[81]. Some crucial maritime areas are under the control of major military and economic blocks, like NATO (the EEZ of NATO members is 15% of the oceans) and G20 (69% of the world EEZ comes under the jurisdiction of G20 members)[82].

Kosai and Unesaki (2016) have also created a Maritime Security Index (MSI). This MSI defines that the most vulnerable sea routes to chokepoints disruptions, piratical actions and ship losses are Far East Asia-Baltic, Far East Asia-Europe, Baltic-Middle East and North Europe-Middle East, while the least vulnerable sea route is East Cost North America-East Coast South America as Figure 8 presents.

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77 Kosai & Unesaki (2016).

78 Ibid.

79 Bueger & Stockbruegger (2022).

80 Vivero & Rodriguez Mateos (2017).

81 Bueger & Stockbruegger (2022).

82 Vivero & Rodriguez Mateos (2017).

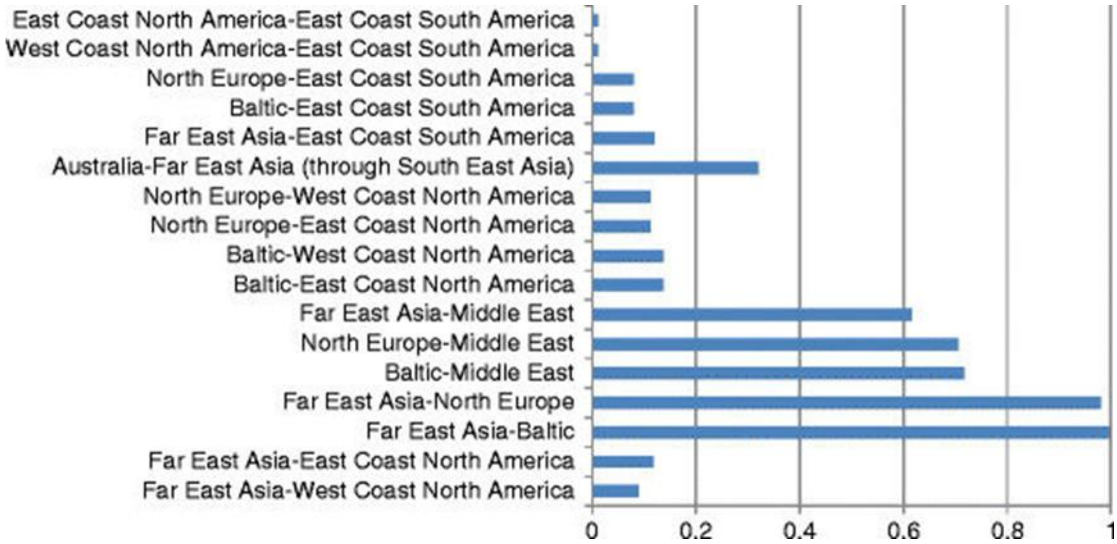

Figure 8*. Figure 8. The Maritime Security Index*[83].

2.4.3. Maritime chokepoints

Based on the Kosai & Unesaki's framework of maritime security for energy security, it is useful for the current research to understand the basic dimensions of the maritime security. The dimension of chokepoints is taken very seriously when analyzing risks in maritime energy transport and maritime security in general, as the Figure 9 demonstrates. The global energy transportation system is vulnerable to maritime disruptions in key chokepoints,[84] as well as the energy supplies of the importing countries[85]. The impact of a disruption on energy supply, prices and markets depends on its extent and duration[86].

[83] Kosai & Unesaki (2016).

[84] Gu, Lu, Wallace & Wang (2020).

[85] Ersen & Celikpala (2019); Gupta (2008).

[86] EIA (2024); Emmerson & Stevens (2012); Komiss & Huntzinger (2011); Michail & Melas (2022).

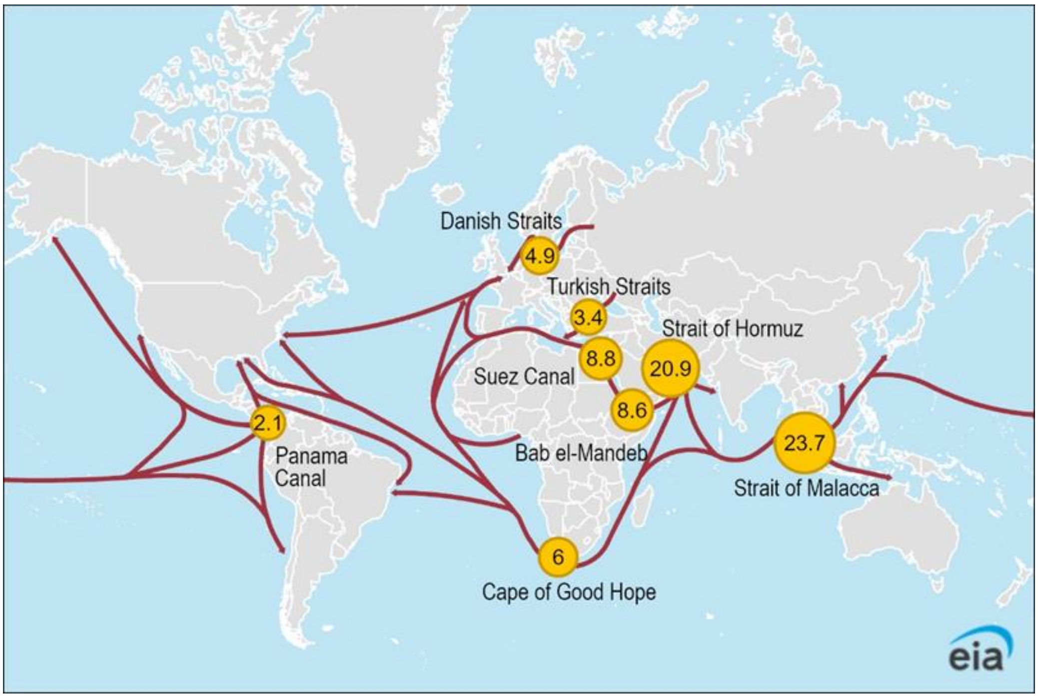

Figure 9. *Daily transit volumes of petroleum and other liquids through world maritime oil chokepoints (million barrels per day) (2023)* [87].

The term "Chokepoint" is derived from military terminology, that describes a narrow geographic passageway that cannot easily bypassed and it is crucial for military troops or warships, like the Thermopylae[88]. But, except from military/geopolitical perspective, chokepoint is included, also, in maritime transportation and international shipping trade[89].

Chokepoints are narrow, strategically critical maritime passages that connect major global trade and energy routes, facilitating the transportation of oil, natural gas, and goods[90]. These vital nodes in the global supply chain are highly susceptible to disruptions caused by geopolitical tensions, piracy, terrorism, and natural hazards[91]. Their security is essential for maintaining energy stability and ensuring uninterrupted global trade flows, making them a focal point for both economic and geopolitical analyses[92].

Particularly in the context of oil and gas transportation, chokepoints are linked to more complex issues. Large-scale industrial systems, encompassing extraction, processing, and distribution, necessitate secure and unobstructed chokepoints. Disruptions to these chokepoints can have significant implications for refinery capacities. Furthermore, inadequate tanker capacity may be exacerbated if key and interconnected chokepoints are closed, necessitating the rerouting of oil tankers along longer and more costly routes[93].

Serving as strategic highpoints in the maritime domain, marine chokepoints confront challenges encompassing both traditional and non-traditional security aspects[94]. From the Age of Exploration

[87] EIA (2024).

[88] Ari, Koc, Meza & Sada (2022); Emmerson & Stevens (2012).

[89] Rodrigue (2004).

[90] Du, Peng & Wang (2024); Emmerson & Stevens (2012); Rodrigue (2004).

[91] Ibid.

[92] Ibid.

[93] Ibid.

[94] Ari, Koc, Meza & Sada (2022); Pratson (2023).

(15th-17th century) to the Cold War era (1945-1991), these vital channels for the expansion of Western nations predominantly encountered challenges rooted in traditional security concerns. Post-Cold War, substantial shifts in the global political and economic landscape have led to a reorientation of strategic priorities for nations, thereby transforming security threats in straits from traditional to non-traditional[95].

2.4.4. Piracy

The threat posed by piracy and armed robbery against ships has been on the International Maritime Organization's agenda since the early 1980s[96]. In the late 1990s and the early 2000s the focus was on the South China Sea and the Straits of Malacca and Singapore[97]. More recently, since 2005, IMO has concentrated on addressing piracy off the coast of Somalia, in the Gulf of Aden and the wider Indian Ocean, and is currently implementing a strategy to enhance maritime security in West and Central Africa, in alignment with the region's maritime security agreements[98].

Pirates are primarily engaged in the plundering of resources and property at sea[99]. The International Maritime Bureau (IMB), established in 1981, defines piracy as "an act of boarding a ship to commit theft or any other crime, with the intent or ability to use force to facilitate that act"[100]. Gao, He, Wang & Xie (2023) illustrate in Figure 10 that while piratical incidents have declined since 2015, they continue to pose a significant threat to shipping[101].

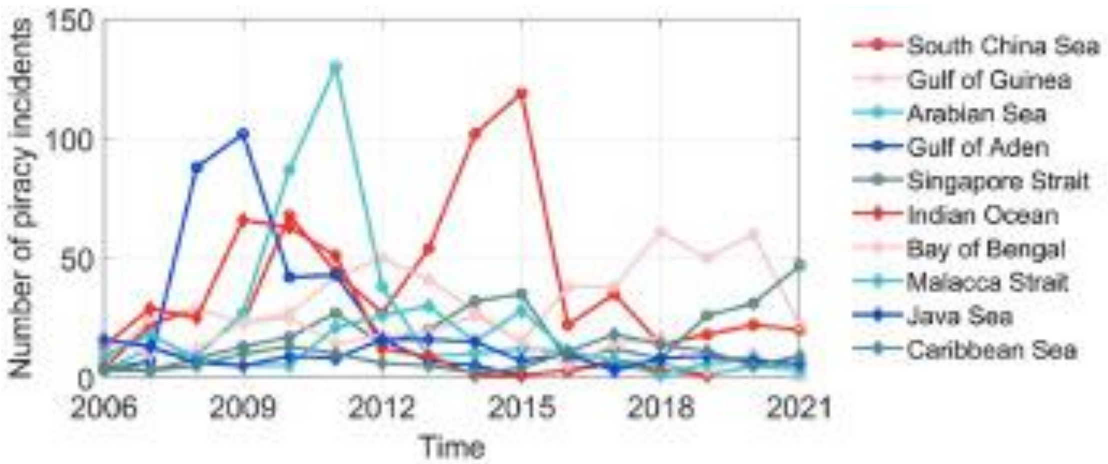

***Figure 10**. Number of pirate attacks in global key marine from 2006 to 2021[102].*

Pratson & Shepard (2020) have demonstrated that piracy in the Strait of Hormuz remains a significant and active threat to energy exports from the Persian Gulf, with China's energy needs particularly affected by restrictions caused by piratical actions[103]. However, they found that crude oil exports are resilient to such soft restrictions, as the oil operates within an oligopolistic global market, is only producible in select geographies, and is critical for meeting global energy

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[95] Du, Peng & Wang (2024).

[96] IMO (no date).

[97] Ibid.

[98] IMO (no date); Kosai & Unesaki (2016).

[99] Gao, He, Wang & Xie (2023)

[100] International Maritime Bureau (1992).

[101] Gao, He, Wang & Xie (2023).

[102] Ibid.

[103] Pratson & Shepard (2020).

demand[104]. The global demand for crude oil is so substantial that importers are willing to deploy military forces to the Persian Gulf to safeguard the flow of crude exports[105]. For example, India signed a defense cooperation agreement with Qatar in 2008 to protect maritime shipping, and China has recently increased its naval presence in the Strait of Hormuz to secure its crude oil exports from the region.[106].

2.4.5. Vessel accidents and pollution

Oil tanker accidents have long been recognized as one of the primary causes of marine pollution, due to the significant volume of tanker trade involving the seaborne transportation of oil and its derivatives between supply and demand points[107]. Many of these accidents result in oil spills, which disrupt the ecological balance; such events are often categorized as marine pollution-causing incidents or disasters throughout the history of seaborne transportation[108].

According to the International Tanker Owners Pollution Federation (ITOPF), 50% of large oil spills between 1970 and 2018 occurred in open water, with collisions and groundings accounting for 58% of the causes[109]. Notably, the same causes contribute to an even greater proportion of accidents when vessels are navigating inland or restricted water areas, such as the Strait of Hormuz, where they are responsible for approximately 99% of spills, as illustrated in Figure 11[110].

Figure 11. *Location of top 20 major spills [111].*

In 2023, the total volume of oil lost to the environment from tanker spills was approximately 2,000 tonnes[112].The average number of spills per year in the 1970s was around 79, but this figure decreased by over 90%, dropping to 6.3 per year in the 2010s. The number of spills has remained at a similar level in the current decade, as shown in Figure 12[113].

[104] Ibid.

[105] Ibid.

[106] Ibid.

[107] Aşan et al. (2020); International Tankers Owners Pollution Federation (2023).

[108] Ibid.

[109] International Tankers Owners Pollution Federation (2024).

[110] Ibid.

[111] Ibid.

[112] Ibid.

[113] Ibid.

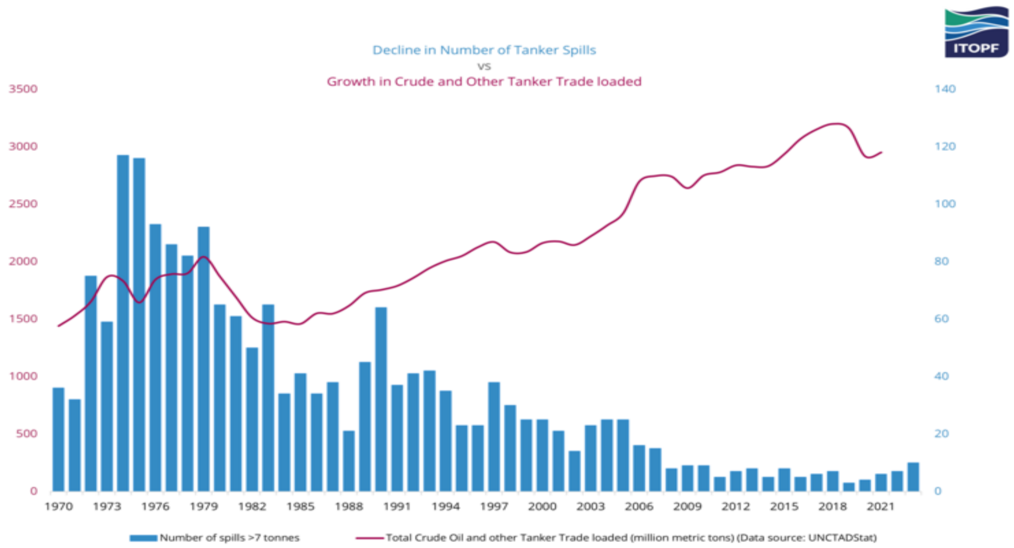

Figure 12. *Decline in number of tanker spills vs growth in crude and other tanker trade loaded, 1970-2023*[114].

A clear and ongoing example of the importance of oil tankers accidents and maritime pollution is the Shia Yemeni political movement of Houthi's attacks on vessels connected to Israel and transiting the Red Sea in response to the ongoing Israeli military operation in Gaza Strip (October 2023-today)[115]. The Houthi attacks, particularly on oil tankers, have resulted in oil and chemical spills, raising significant concerns about the future of the Red Sea ecosystem Additionally, there is increasing apprehension regarding potential threats to carbon storage facilities currently being developed beneath the seabed[116].

2.5. Chokepoints: profile and features

Maritime chokepoints play a pivotal role as key nodes in maritime navigation, serving as indispensable passageways for vessels owing to their navigational convenience[117]. However, their narrow channels and strategic locations make them vulnerable points and bottlenecks in maritime transportation routes, subject to external attacks and blockades[118].

The U.S. Energy Information Administration (EIA) estimates that approximately 76% of the global petroleum and other liquid supplies (77.5 million b/d) are transported via seaborne trade[119]. Oil tankers represented nearly 29% of global shipping by deadweight tonnage in 2022, according to data from the United Nations Conference on Trade and Development (UNCTAD)[120].

Figure 13 illustrates the global LNG trade routes as interconnected points, closely linked to the most critical chokepoints. It highlights that China, Japan, Korea, the Rest of Asia, Africa, and Europe are the primary importers of LNG, emphasizing the importance of secure seaborne trade to meet their energy needs[121].

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[114] Ibid.

[115] CNBC (2024).

[116] Braw (2023).

[117] Emmerson & Stevens (2012); Ersen & Celikpala (2019); Gupta (2008); Komiss & Huntzinger (2011); Pratson (2023).

[118] Ari, Koc, Meza & Sada (2022); Fletcher et al. (2016); Gupta, (2008); Michail & Melas (2022); Rodrigue (2004).

[119] EIA (2024).

[120] Ibid.

[121] Li, Zeng, Zhang & Wang (2022).

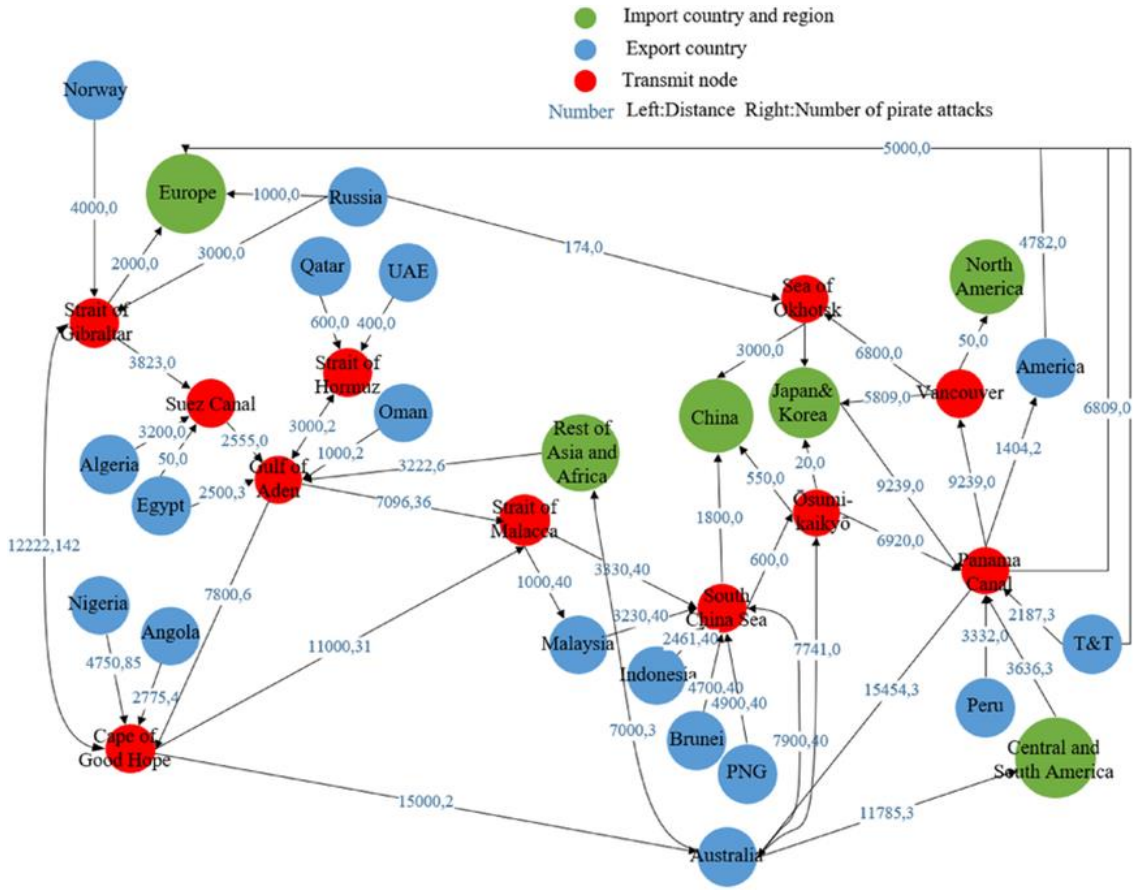

Figure 13. *Generalized map of global LNG trade shipping routes (The unit of distance is a kilometer)*[122].

Therefore, ensuring that Sea Lines of Communication (SLOCs) or chokepoints remain open and secure is beneficial not only to shipping and energy companies but also to the broader trade sector. This is particularly important to the national interests of the Great Naval Powers, as noted by N. Spykman in 1942, and as articulated by President Jimmy Carter in his 1980 declaration regarding the Persian Gulf's free navigation, which he referred to as a "vital interest"[123]. Additionally, securing these maritime routes is crucial for low-income energy-importing countries[124].

2.5.1 Strait of Hormuz

In 2023, oil flows through Hormuz averaged 20.9 million barrels per day (b/d), or the equivalent of about 20% of global petroleum liquids consumption[125]. Total oil flows through the Strait of Hormuz in 2023 were slightly lower than in 2022, as decreased flows of crude oil and condensate offset increased flows of oil products[126]. According to the EIA, around 80% of the crude oil that passed through this chokepoint was destined for Asian markets, based on data from the Lloyd's List

[122] Ibid.

[123] Emmerson & Stevens (2012); Gupta (2008); Komiss & Huntzinger (2011).

[124] Emmerson & Stevens (2012).

[125] EIA (2024); Komiss & Huntzinger (2011); Rodrigue (2004).

[126] Ibid.

Intelligence tanker tracking service[127]. China, Japan, Singapore, India, and South Korea are the largest destinations for oil moving through the Strait of Hormuz, as shown in Figure 13[128].

Regarding liquefied natural gas (LNG), all LNG exports from Qatar and the United Arab Emirates (totaling 90 bcm), which represent 20% of global LNG trade, transited the Strait of Hormuz in 2023. Approximately 80% of these volumes were destined for Asian markets[129].

At its narrowest point, the Strait is 21 miles wide, but the width of the shipping lane in either direction is only two miles wide, separated by two-mile buffer zone[130]. The Strait is deep and wide enough to accommodate the world's largest crude oil tankers, with about two-thirds of oil shipments carried by tankers in excess of 150,000 dwt coming through this chokepoint[131]. Oman, Iran, and the United Arab Emirates are the only countries bordering the Strait, and they are involved in ongoing geopolitical tensions[132].

2.5.2. Strait of Malacca

The Strait of Malacca, linking the Indian Ocean and the Pacific Ocean, is situated between Indonesia, Malaysia, and Singapore[133]. It represents the shortest maritime route between Middle Eastern suppliers and the rapidly growing Asian markets, which account for 43% of global energy demand, notably from China, Japan, South Korea, and the broader Pacific Rim[134]. As the primary chokepoint in Asia, the Strait experienced an estimated oil flow of 23.7 million b/d in 2023, making it the largest chokepoint globally in terms of oil transit volume[135]. Crude oil typically comprises about 70% of total oil flows annually, with petroleum products making up the remainder[136]. The Strait is only 1.7 miles wide, creating a natural bottleneck with the potential for collisions, grounding, or oil spills[137]. Piracy remains a significant threat in this region.[138].

If the Strait be blocked, nearly the half of the world's fleet would need to reroute around the Indonesian archipelago, either through the Lombok Strait between the Indonesian islands of Bali and Lombok, or through the Sunda Strait between Java and Sumatra[139].

The Strait of Malacca is also a vital route for LNG shipments from the Persian Gulf to East Asian markets, such as Japan and South Korea, where LNG demand is rapidly increasing[140]. Asia's role in the global natural gas market has become increasingly significant, with the region's share of global demand rising from 12% to 21% since the early 2000s, while overall consumption has more than

[127] EIA (2024).

[128] Alola, & Olanipekun (2020); EIA (2024); Komiss & Huntzinger (2011); Rodrigue (2004).

[129] IEA (2023).

[130] Komiss & Huntzinger (2011); Pratson & Shepard (2020).

[131] Ibid.

[132] Komiss & Huntzinger (2011).

[133] Vivoda (2019).

[134] Ibid.

[135] Ibid.

[136] Ibid.

[137] Komiss & Huntzinger (2011).

[138] Ari, Koc, Meza & Sada (2022); EIA (2024).

[139] EIA (2024).

[140] Ari, Koc, Meza & Sada (2022); EIA (2024).

doubled[141]. The natural gas demand in the Asia-Pacific region is projected to grow by 78%, reaching 1,590 bcm[142] Concurrently, Asian nations are striving to enhance energy diversification in order to mitigate the impact of disruptions in the Strait of Hormuz and the Strait of Malacca, particularly China[143]. China faces what is known as the "Malacca Dilemma" due to the lack of alternative routes to this critical chokepoint, compounded by the presence of the US Navy in the region[144].

2.5.3. Suez Canal

This is a strategic route for Persian Gulf oil and natural gas shipments to Europe and North America. This route accounted for about 9% of the world's seaborne oil trade in 2023[145]. The Suez Canal is located in Egypt and connects the Red Sea and the Gulf of Suez with the Mediterranean Sea[146]. However, the Suez Canal cannot accommodate ULCC or fully laden VLCC oil tankers[147]. The Suezmax was the largest ship capable of transiting the canal until 2010, when the Suez Canal Authority deepened the canal to 66 feet, allowing more than 60% of all tankers to pass through[148].

In March 2021, the mega-container ship Ever Given, en route from Malaysia to the Netherlands, became stuck in the southern end of the canal due to strong winds[149]. This incident disrupted global supply chains for six days[150].

In 2016, the largest importers of northbound oil flows through the Suez Canal were European countries (78%) and the United States (14%), while China, India, and Singapore accounted for 50% of the total[151]. Additionally, LNG flows through the Suez Canal represented 9% of global LNG trade. Southbound LNG transits primarily originate from Nigeria, France, and Trinidad and Tobago, with Egypt, Jordan, and Japan receiving 65% of the total southbound LNG imports via the canal[152].

2.5.4. Bab-el-Mandeb

In mid-November 2023, the Shia political movement Houthis from Yemen began attacking vessels in the Bab el-Mandeb Strait and the Red Sea in response to the Israeli military operation in the Gaza Strip[153].Initially, these attacks primarily targeted container ships transporting non-energy goods[154]. However, as the attacks escalated, more oil and LNG vessels have opted to avoid the Bab el-Mandeb and Suez Canal routes, choosing instead to take the longer route around Africa[155]. This

[141] Vivoda (2019).

[142] Gas Exporting Countries Forum (2024).

[143] Gas Exporting Countries Forum (2024); Paszak (2021).

[144] Gas Exporting Countries Forum (2024); Paszak (2021); Vivoda (2019).

[145] EIA (2024).

[146] Ibid.

[147] Ibid.

[148] EIA (2024); Komiss & Huntzinger (2011).

[149] Pratson (2023).

[150] Ibid.

[151] Ari, Koc, Meza & Sada (2022); EIA (2024).

[152] Ibid.

[153] Braw (2023).

[154] Ibid.

[155] Sharples (2024).

extended trade route significantly increases shipping costs for oil tankers and causes delays in voyage times[156]. Ships that choose to traverse the Bab el-Mandeb and Suez Canal are also facing higher insurance premiums due to the increased risks[157].

The Bab el-Mandeb Strait is a critical chokepoint between the Horn of Africa and the Middle East, serving as a strategic link between the Mediterranean Sea and the Indian Ocean[158].Located between Yemen, Djibouti, and Eritrea, it connects the Red Sea with the Gulf of Aden and the Arabian Sea[159].Most exports from the Persian Gulf that transit the Suez Canal also pass through Bab el-Mandeb[160]. In 2016, an estimated 4.8 million b/d of crude oil and refined petroleum products flowed through this waterway toward Europe, the United States, and Asia[161].The strait is 18 miles wide, with tanker traffic limited to two-mile-wide channels for both inbound and outbound shipments[162].

2.5.5. Turkish Straits

An estimated 3.4 million b/d of crude oil and petroleum products flowed through the Turkish Straits in 2023[163]. Slightly more than half of this volume consisted of crude oil, with the remainder made up of oil products. Black Sea ports are one of the primary export routes for both crude oil and oil products from Russia and other Eurasian countries, including Azerbaijan and Kazakhstan[164]. Oil passing through these straits is essential to supplying Western and Southern Europe[165].

he Turkish Straits consist of the Bosporus and Dardanelles waterways, which separate Asia from Europe[166]. The Bosporus, a 17-mile waterway, connects the Black Sea with the Sea of Marmara, while the Dardanelles is a 40-mile waterway linking the Sea of Marmara with the Aegean and Mediterranean Seas[167]. These waterways are located in Turkey and play a crucial role in supplying Western and Southern Europe with oil from Russia and the Caspian Sea region[168]. The Black Sea ports, including those in Russia, Azerbaijan, and Kazakhstan, are among the primary routes for these oil exports[169].

At its narrowest point, the Turkish Straits are only half a mile wide, making them some of the most challenging waterways to navigate due to their sinuous geography[170]. Approximately 48,000 vessels transit the straits annually, making this area one of the busiest maritime chokepoints in the

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[156] Ibid.

[157] Ibid.

[158] EIA (2024).

[159] Ibid.

[160] Ari, Koc, Meza & Sada (2022); EIA (2024).

[161] Ibid.

[162] Ibid.

[163] EIA (2024).

[164] Ibid.

[165] Ibid.

[166] Ibid.

[167] Ibid.

[168] Ibid.

[169] EIA (2024); Oil Companies International Marine Forum (2021).

[170] Ibid.

world[171].Commercial shipping has the right of free passage through the Turkish Straits in peacetime; however, Turkey retains the authority to impose regulations for safety and environmental purposes[172].The Montreux Convention of 1936 established the general principle of freedom of navigation through the straits, but Turkish authorities have certain powers to control transit vessels[173]. Pilotage and towage services are specifically outlined as operational requirements[174]. Bottlenecks and heavy traffic in these straits also pose significant challenges for oil tankers[175].

2.5.6. Panama Canal

The recently completed expansion of the Panama Canal is unlikely to significantly alter crude oil and petroleum product flows, with the exception of increased U.S. propane exports[176].The canal serves as a vital maritime route, connecting the Pacific Ocean with the Caribbean Sea and the Atlantic Ocean[177]. It spans 50 miles in length and narrows to just 110 feet at its narrowest point, the Culebra Cut at the Continental Divide[178].

Although only 3% of total global maritime petroleum and petroleum product flows transited the Panama Canal in 2023, it remains a crucial passage for petroleum products and liquefied natural gas (LNG) shipments traveling from the U.S. Gulf Coast to western South America and Asia[179].Between October 2022 and September 2023, crude oil, petroleum products, and LNG accounted for 48% of all commodities transported through the canal from the Atlantic Ocean to the Pacific Ocean[180].

The strategic and economic significance of the Panama Canal has been underscored in recent geopolitical discourse, particularly in light of concerns raised by the new U.S. administration under President Donald J. Trump regarding its commercial and military importance[181]. These concerns stem from increasing competition with China, which has expanded its influence in global trade and infrastructure projects[182].

2.6. Disruption risks and economic implications

2.6.1. Geopolitical risks and chokepoint disruptions

As it is mentioned above, energy is of strategic importance to all countries and secure transportation requires connectivity reliability[183]. However, many crude oil exporters, particularly those in the

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[171] Oil Companies International Marine Forum (2021); Rodrigue (2004).

[172] EIA (2024); Rodrigue (2004).

[173] Oil Companies International Marine Forum (2021).

[174] Ibid.

[175] EIA (2024); Rodrigue (2004).

[176] EIA (2024); Komiss & Huntzinger (2011).

[177] Ibid.

[178] Ibid.

[179] EIA (2024); Komiss & Huntzinger (2011); Sharples (2024).

[180] Ibid.

[181] Williams (2025).

[182] Ibid.

[183] Jia, Lu, Wang & Jang (2023).

Middle East, Africa, and Latin America, experience political instability or face a high level of risk[184].

Specifically, the concept of 'oil vulnerability' refers to the insecurity of an energy importer's supply due to geopolitical and economic shocks, such as chokepoint closures[185]. Gupta (2008) developed a supply risk indicator for geopolitical events, the Geopolitical Oil Risk (GOR), which is defined as *"the exposure of an economy to physical supply distortions due to strategically motivated control of supply by oil-exporting countries or breakdowns in political and economic systems or in major chokepoints"*[186]. Table 3 presents key disruptions affecting global trade and energy transportation.

***Table 3**. The profile and features of some crucial chokepoints for the maritime energy transport[187].*

Chokepoints	**Connecting**	**Bordering Countries**	**Type**	**Width**	**Affected by**	**Incidents**
Strait of Hormuz	The Persian Gulf, Gulf of Oman, and the Indian Ocean	Iran, United Arab Emirates (UAE), and Oman	Natural Strait	48 km	War Piracy Threat of terrorism	Tanker War (1984 – 1987) Iran's several threats for blockading
Bab-el Mandeb	The Red Sea and the Arabian Sea	Eritrea, Somalia, Djibouti, and Yemen	Natural - Strait	32 km	Piracy Hijacking Terrorist attacks	USS *Cole* Attack (2000) Houthis attacks on ships (2023-)
Suez Canal	The Mediterranean and the Red Sea	Egypt	Artificial Waterway	0.2 km	War Diplomatic Disputes Operational Incidents	Ever Given blockade (2021) Invasion of Sinai Peninsula Six Days War
Malacca Strait	The Indian Ocean, the South China	Indonesia, Singapore,	Natural Strait	2.5 km	Diplomatic disputes	Orapin 4 piracy

[184]Alola, & Olanipekun (2020); Gu, Lu, Wallace & Wang (2020); Komiss & Huntzinger (2011).

[185] Gupta (2008).

[186] Alola, & Olanipekun (2020); Bailey & Wellesley (2017).

[187] Ari, Koc, Meza & Sada (2022); Infortal (2024); Komiss & Huntzinger (2011); Sharples (2024).

	Sea, and the Pacific Ocean	and Malaysia			Threat of terrorism/piracy	attack (2014)
Turkish Straits	The Black Sea and the Mediterranean Sea	Turkey	Natural Strait	1 km	War/ Diplomatic disputes	Decrease in shipping due to Russia-Ukraine War (2022-)

It is evident that the most vulnerable chokepoints are located in Middle Eastern and North African countries, where armed conflicts, political instability, corruption, regulatory and bureaucratic restrictions, attempted coups, and social unrest—such as the Arab Spring—as well as civil wars, cyber insecurity[188], terrorist attacks, and piratical actions are common assurances[189].

Notably, according to the Global Conflict Tracker database, several of these risks are interconnected and transnational in nature in key chokepoints such as the Strait of Hormuz, Bab el-Mandeb, and the Suez Canal[190]. Additionally, the South China Sea is expected to become a de facto chokepoint in the future due to China's increasingly assertive maritime policy in the region[191].

As shown in Figure 14, geopolitical threats and incidents of political violence have risen in the current year, with many countries near chokepoints now engaged in conflict, the most critical of which is Palestine[192].

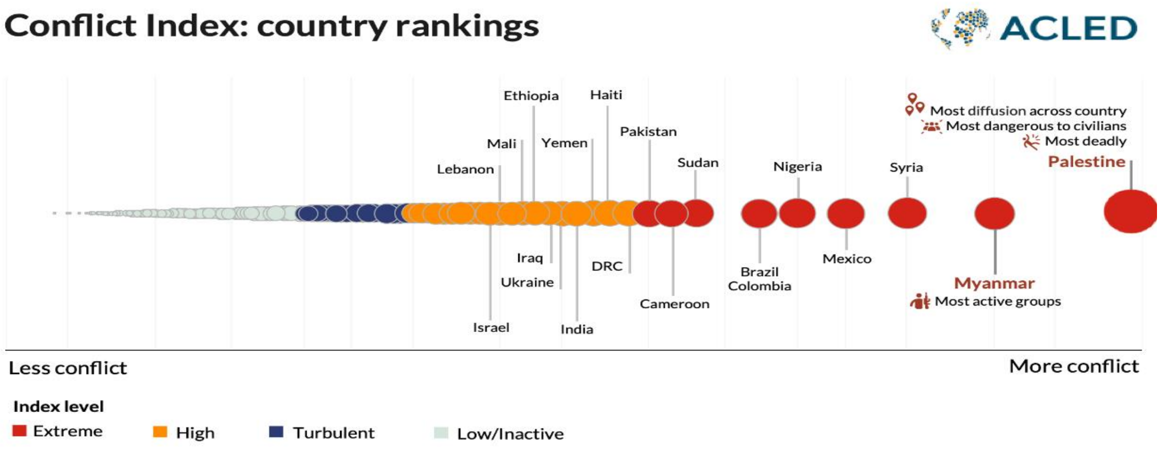

***Figure 14**. Conflict Index: country rankings, ACLED, (2024)[193].*

2.6.2. Geopolitical risk, oil price and freight market

Although the role of geopolitical factors in shaping macroeconomic outcomes has not been the subject of systematic empirical analysis[194], numerous studies have demonstrated the significant

[188] Bailey & Wellesley (2017).

[189] Caldara & Iacoviello (2022).

[190] Alola, & Olanipekun (2020); CFR (2024).

[191] Bailey & Wellesley (2024).

[192] ACLED (2024).

[193] Ibid.

[194] Caldara & Iacoviello (2022).

impact of geopolitical risk on the correlation between crude oil prices and freight rates[195]. While crude oil futures serve as unbiased forecasts of realized spot prices, under certain circumstances, both oil futures and spot prices respond simultaneously to new market information[196].

A potential disruption at key chokepoints, whether driven by domestic or international political factors, would, depending on its duration and magnitude[197], result in supply scarcity and subsequent price increases, as demonstrated in the simulation presented in Table 4[198]. Figure 15 illustrates the co-movement of Geopolitical Risk with WTI and Brent crude oil prices[199].

Additionally, the Baltic Dry Index is highly sensitive to fluctuations in crude oil prices, given that oil constitutes the largest fuel cost in the shipping industry, as shown in Figure 16[200]. The scarcity and uneven distribution of oil may also trigger conflicts over resource control, further exacerbating geopolitical risk and influencing oil prices—an adverse development for the shipping industry[201]. Furthermore, price volatility leads to higher costs for energy-importing countries, necessitating various energy hedging strategies to manage price risks, such as forward physical contracts based on fixed prices between exporters and importers[202].

Table 4. *Simulation of gross disruption (million b/d), by chokepoint and percent of daily barrels not transported based on the data of EIA [203].*

Chokepoints	**20% disruption**	**50% disruption**	**100% disruption**
Strait of Hormuz	3.4	8.5	17
Strait of Malacca	3	7.5	15
Suez Canal	0.9	2.25	4.5
Bab-el-Mandeb	0.66	1.65	3.3
Turkish Straits	0.48	1.2	2.4
Panama Canal	0.1	0.25	0.5

195 Albitar, Huang, Li & Zhong (2020); Alola. & Olanipekun (2020); Ari, Koc, Meza & Sada (2022); Ghoble (2009); Gu, Lu, Wallace & Wang (2020); Khan, Su, Tao & Umar (2021); Michail & Melas (2022); Rodrigue (2004).

196 Alizadeh & Nomikos (2004); Emmerson & Stevens (2012); Komiss & Huntzinger (2011).

197 Komiss & Huntzinger (2011).

198 Ibid.

199 Ghoble (2009).

200 Komiss & Huntzinger (2011).

201 Khan, Su, Tao & Umar (2021).

202 Chang, McAleer & Tansuchat (2011); Gu, Lu, Wallace & Wang (2020).

203 Komiss & Huntzinger (2011).

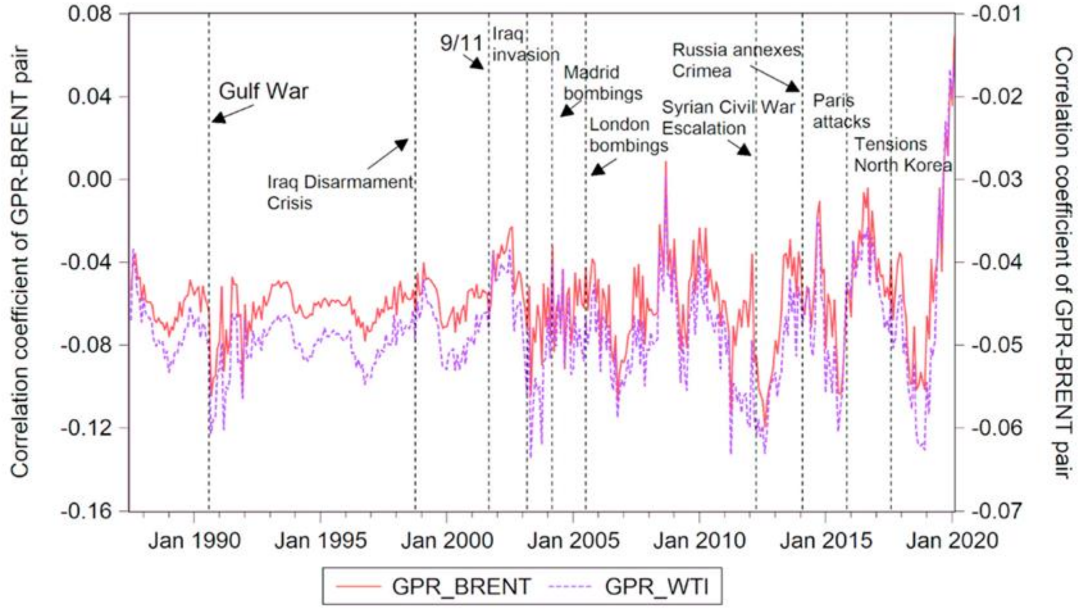

Figure 15. *Dynamic correlations between the GPR index and crude oil prices* [204].

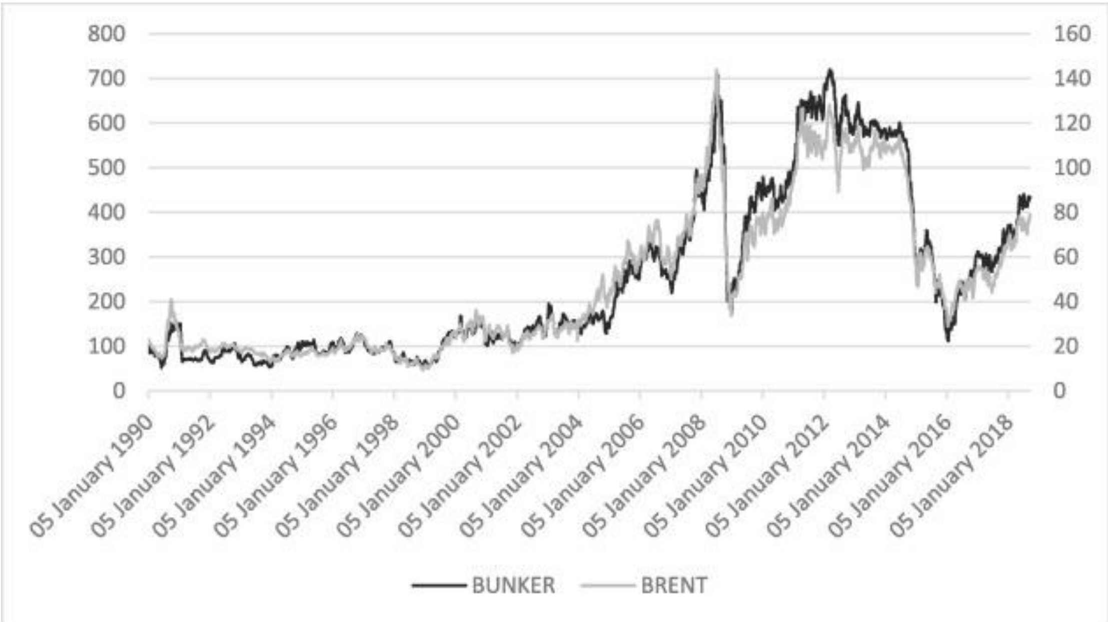

Figure 16. *Discrete distribution of the Brent barrel prices and bunker fuel prices between January 1990 and September 2018*[205].

For shipping freight rates, political instability and geopolitical threats or events are key influencing factors, as ocean trade remains highly exposed to political actions, as demonstrated in Figure 17[206]. It is evident that modern tankers have made the global transportation of oil and gas feasible, primarily due to their cost efficiency[207]. However, as these tankers navigate critical straits along their routes, ensuring their security is essential to prevent potential price shocks[208].

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[204] Albitar, Huang, Li & Zhong (2020).

[205] Cheaitou, Faury & Givry (2020).

[206] Vivero & Rodriguez Mateos (2017).

[207] Albitar, Huang, Li & Zhong (2020); Ghoble (2009).

[208] Ibid.

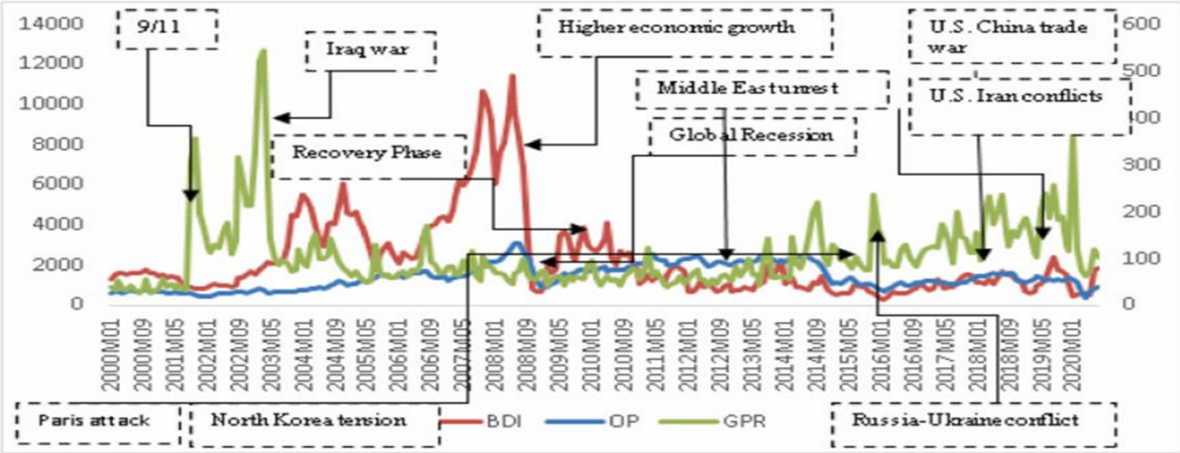

Figure 17. Trends of oil price, BDI and geopolitical risk [209].

2.6.3. Transportation cost, insurance and the financial impact

The rerouting of shipping schedules and the associated transportation costs are primary considerations in any proposed adjustments to maritime routes[210]. Several models have been introduced to determine the most efficient transportation routes, typically aiming to minimize costs[211]. The rescheduling of voyages following maritime disruptions, based on the three models developed by Al-e-Hashem and Soltani (2023), has been found to be more cost-effective and profitable, as illustrated in Figure 18, although it may result in longer voyage durations[212].

In addition to fuel consumption costs[213], factors such as engine power, vessel classification, voyage distance, and sailing speed influence route selection in these models, which account for the prevailing economic, climatic, and geopolitical conditions[214]. These parameters are closely linked to the concept of connectivity reliability, as proposed by Jia, Lu, Wang, and Jang (2023), which seeks to identify lower-risk options for maritime energy transportation through cost-benefit analysis[215]. However, in certain cases, shipping companies may prioritize lower transportation costs despite the associated higher risks[216].

[209] Khan, Su, Tao & Umar (2021).

[210] Jia, Lu, Wang & Jang (2023).

[211] Al-e-Hashem & Soltani (2023); Cheaitou, Faury & Givry (2020); Christiansen et al. (2012); Jia, Lu, Wang & Jang (2023); Lasserre (2014); Hartley & McKay (1974).

[212] Sharples (2024).

[213] Komiss & Huntzinger (2011); Lasserre (2014).

[214] Al-e-Hashem & Soltani (2023); Christiansen et al. (2012); Eppler et al. (1996); Hartley & McKay (1974).

[215] Jia, Lu, Wang & Jang (2023).

[216] Gu, Lu, Wallace & Wang (2020)

Figure 18. *Cargo time* [217].

Apart from transportation and fuel costs, energy industries and shipping companies also face significantly high insurance expenses. Due to the increasing geopolitical risks in certain regions and maritime routes, insurance companies have introduced new insurance products tailored to their customers' needs[218].

War risk insurance, in particular, provides financial protection to policyholders against losses resulting from events such as invasions, insurrections, riots, strikes, revolutions, military coups, and acts of terrorism[219]. Given their frequent operations in high-risk areas, energy and shipping companies are among the primary candidates for such coverage[220].

Military-related threats, including attacks on ships and seaports, blockades, and mine threats, are considered force majeure circumstances. As a result, these situations can lead to delays in contractual obligations, necessitate contract revisions, or even result in contract cancellations[221].

The aforementioned factors have led to an increase in shipping costs for companies seeking to secure their fleets and cargo, particularly in the aftermath of the Russia-Ukraine war and disruptions in the Red Sea, as illustrated in Figure 19[222].

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[217] Ibid.

[218] Komiss & Huntzinger (2011).

[219] Kivalov (2024); Maitra (2024); Komiss & Huntzinger (2011).

[220] Fasii (2023).

[221] Ibid.

[222] Chang, Duan & Zhao (2023).

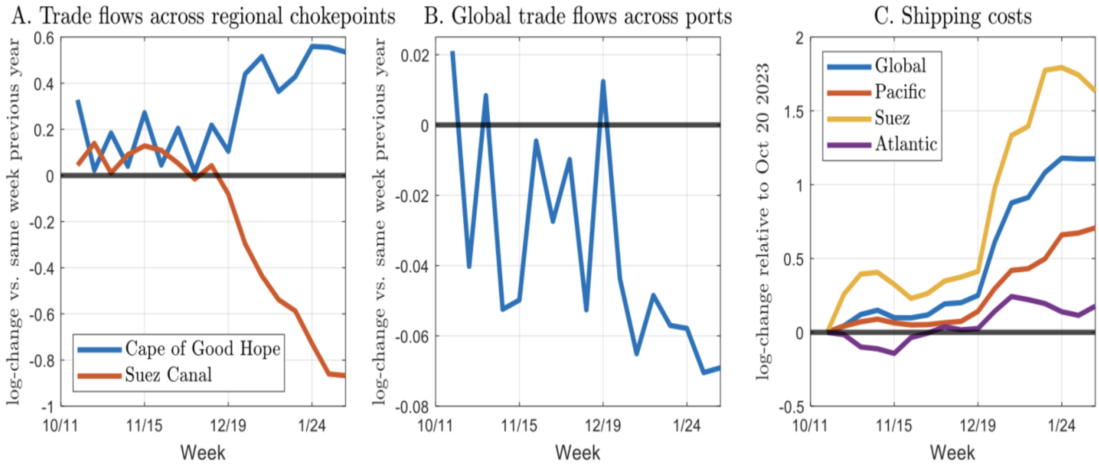

Figure 19*. Impact of Russia-Ukraine War and Red Sea disruption on global shipping* [223].

The Joint War Committee (JWC) of Lloyd's of London plays a crucial role in assessing and managing war-related risks in maritime insurance. The JWC comprises underwriting representatives from both Lloyd's and the International Underwriting Association (IUA) company markets, representing the interests of those involved in marine hull war insurance within the London market[224]. Periodically, the JWC updates and publishes the Listed Areas, identifying regions with elevated risk levels, such as the Red Sea, the Strait of Hormuz, and the Black Sea-Ukraine, where increased insurance premiums have contributed to rising freight costs[225].

For instance, current war risk premiums range between 0.7% and 1% in the Red Sea and between 2.5% and 3% in the Black Sea[226]. In 2023, total global marine insurance premiums reached USD 35.8 billion, reflecting an 8.3% increase compared to 2021[227]. However, many leading insurance companies have emphasized the need to reassess marine insurance policies in light of evolving geopolitical risks[228].

Regarding broader economic implications, oil price fluctuations following a geopolitical supply disruption can affect economies through three main channels. The first is the supply-side channel (input costs channel), where changes in oil prices directly impact production costs, which in turn influence consumer prices, GDP growth, inflation, and unemployment rates [229]. The second is the demand-side channel (real income shifts channel), in which higher (or lower) oil prices reduce (or increase) consumers' real income, thereby affecting overall consumption levels[230]. Lastly, oil prices can impact domestic economic conditions through policy responses (monetary and fiscal policies channel)[231]. According to the International Monetary Fund (IMF), fluctuations in oil prices can contribute to inflationary pressures or even trigger recession[232].

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[223] Dunn & Leibovici (2024).

[224] Lloyd's Market Association (2023).

[225] Economist Intelligence (2024); Lloyd's Market Association (2023).

[226] Economist Intelligence (2024); Maitra (2024).

[227] Economist Intelligence (2024).

[228] Ibid.

[229] Komiss & Huntzinger (2011); Sek (2017).

[230] Ibid.

[231] Ibid.

[232] Arezki, Milesi-Ferretti & Obstfeld (2016); Chatziantoniou & Filis (2014); Christophe & El Hedi (2012); Sek (2017).

However, other studies suggest that the impact of oil price fluctuations on the economy may vary depending on the economic structure, oil intensity, and dependency, as well as the aforementioned concept of oil vulnerability[233]. For instance, highly oil-consuming MENA countries may experience more significant impacts due to rising oil prices, as seen in the energy crises of 1973 and 1979[234]. Conversely, in some cases, certain countries' GDP and oil revenues may be positively impacted by MENA oil supply shocks driven by political events[235].

2.7. Discussion

The aforementioned overview highlights the nature of global maritime energy transportation, which is closely linked to geopolitical developments and power dynamics in specific regions. Maritime energy transportation is a crucial element of global energy security, yet it remains inherently vulnerable to geopolitical risks associated with certain chokepoints. Chokepoints such as the Strait of Hormuz, the Strait of Malacca, the Suez Canal, and the Bab-el-Mandeb are of significant geopolitical importance in global maritime energy transport, serving as essential gateways for the movement of oil and natural gas between producers and consumers. These strategic locations are vital to global energy security, but they are also prone to risks such as conflicts, piracy, and territorial disputes. Control over these chokepoints often influences regional power dynamics, and disruptions can lead to economic instability and energy price shocks, underscoring their pivotal role in the interconnected global energy system.

This discussion explores key aspects of these risks through the development of a Chokepoint Resilience Index, designed to assess the resilience levels of critical chokepoints in energy transportation. Additionally, the potential for diversifying energy supplies via new alternative maritime routes, such as the Northern Sea Route, is examined, alongside the geopolitical and economic implications of current disturbances at chokepoints like the Red Sea.

First, understanding the complexity of risks at chokepoints requires a theoretical foundation, encompassing concepts such as geopolitical theory and qualitative data analysis, while also addressing ongoing developments, changes, and outcomes. Consequently, the creation of a Chokepoint Resilience Index is necessary to enrich research on the risks and impacts of chokepoint disruptions by incorporating new data. The proposed Index includes dimensions such as geopolitical, historical, economic, geological, environmental, and alternative solutions contexts.

Secondly, the vulnerability of the Red Sea, particularly under the threat of Houthi attacks, presents a complex challenge for the shipping, marine insurance, and energy sectors. This discussion aims to analyze an ongoing chokepoint disruption that has heightened scientific interest in maritime security research. The impact of these threats on the global energy market is examined, with a focus on the geopolitical and economic outcomes linked to the Chokepoint Resilience Index. This can help industries navigate this complexity while maintaining profitability and security.

Finally, exploring new alternative maritime routes for energy transportation could prove beneficial for the scientific community. The Northern Sea Route (NSR) represents a transformative shift in global maritime energy transport. The evolving military dynamics in the Arctic, driven by the interests of Russia and NATO, are analyzed to assess their potential to either stabilize or destabilize this emerging route, providing a forward-looking evaluation of the NSR's role in future energy transport scenarios.

[233] Gupta (2008).

[234] Sek (2017).

[235] Komiss & Huntzinger (2011).

Chapter 3: Methodology

3.1. Research Questions

The previous chapter provided a literature review on the geopolitical risks and broader economic consequences associated with disruptions at key chokepoints in global marine oil and LNG transportation. The stability of global energy flows by sea and the vulnerability of critical chokepoints are of significant concern not only to major naval powers but also to states that heavily depend on uninterrupted energy imports, as well as shipping companies and the oil and gas industries.

In light of the above, the research questions addressed by this paper are as follows:

Q1: How can a Chokepoint Resilience Index be conceptualized and defined?

Q2: How can the Chokepoint Resilience Index be applied to rank the resilience of critical chokepoints?

Q3: What are the geopolitical risks to the resilience of energy transport through the Red Sea and the emerging Northern Sea Route?

3.2. Research Methods

To answer Question 1 and 2, this research will begin with an examination of the existing literature on maritime supply chain resilience, critical maritime infrastructure protection, and the application of maritime security technologies. Based on these findings, a Chokepoint Resilience Index will be developed.

For Question 3, a specific analysis will be conducted of the geopolitical implications of the ongoing disruption in the Red Sea, caused by Houthi attacks on vessels. The results of the proposed Chokepoint Resilience Index will be used to assess the subsequent impact on energy prices, shipping freight rates, and War Risk insurance costs.

Finally, the potential economic costs and geopolitical significance of the emerging Northern Sea Route for energy transport will be examined, with particular focus on the new geopolitical competition in the Arctic region.

Chapter 4: Results

4.1. Introduction

Major global supply chain disruptions are closely linked to maritime chokepoints, as demonstrated in the previous chapter, and can have a profound impact on both the global economy and international relations. In the context of global energy markets, the rapid increase in energy demand is altering energy flows, which in turn affects the transportation of these commodities. Chokepoints are critical nodes within the global transportation network, and their significance warrants thorough examination. As previously discussed, disruptions to chokepoints can influence global energy prices and may require the rerouting of shipments, adding thousands of miles to alternative transit routes. These disruptions can result from various factors, including warfare and conflict, piracy and terrorism, economic competition, or harsh environmental and natural conditions. To further advance scientific interest in maritime chokepoints and their role in global energy transport, a Chokepoint Resilience Index is proposed. This index will incorporate key dimensions and supporting quantitative data, providing a comprehensive understanding of the vulnerability levels associated with each chokepoint.

4.2. Chokepoint Resilience Index

4.2.1. Maritime Supply Chain Resilience

It is important to note that there is a significant gap in academic research regarding the resilience assessment of global energy flows through major chokepoint risks. Limited research exists on the security of oil and LNG supply, or on the potential disruption risks associated with chokepoints. Therefore, before presenting and analyzing a new Chokepoint Resilience Index, it is necessary to provide a brief overview of the concept of Maritime Supply Chain Resilience.

The extensive network of maritime routes is vulnerable to disruption risks, making it essential to have a well-designed resilience system for response and recovery following unforeseen events, particularly in the current environment of geopolitical and financial uncertainty. The concept of maritime transport resilience, as proposed by Jiao, Li, Wang, and Zhou (2024), consists of three key components: maritime disruption classification, resilience capability measurement, and resilience evaluation, as illustrated in Figure 20[236]. This framework is based on the maritime supply chain's ability to recover from disruptions or unexpected shocks while preventing the occurrence of failure modes[237].

[236] Jiao, Li, Wang & Zhou (2024).

[237] Ibid.

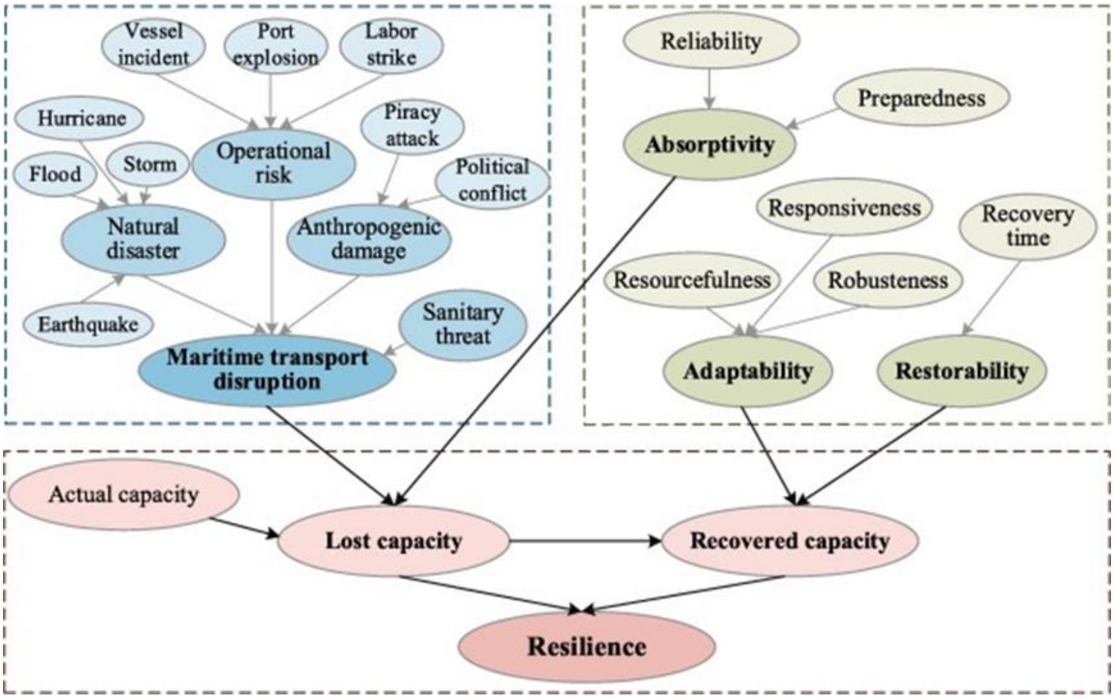

***Figure 20**. Bayesian network developed for resilience evaluation* [238].

Numerous studies have examined the importance of maritime supply chain resilience[239]. In the context of energy transportation, maritime supply resilience is critical for meeting the energy import needs of major industrial countries, such as China[240].

4.2.2. Critical Maritime Infrastructure Protection

The concept of Maritime Supply Chain Resilience is closely linked to the notion of Critical Maritime Infrastructure Protection (CMIP), which emerged as a priority in ocean governance, particularly in Europe, during the 1990s and early 2000s[241]. Heightened geopolitical tensions, regional conflicts, the surge in piracy off the coast of Somalia in 2008, the Nord Stream pipeline attacks in the Baltic Sea in September 2022, and the Houthi attacks on vessels in the Red Sea from November 2023 have been key catalysts in driving this agenda forward[242]. While calls for strengthening critical maritime infrastructure protection have intensified, the practical implications of such measures remain less clear[243]. Addressing this challenge requires a reassessment of approaches to safety, resilience, and risk management at sea[244].

CMIP encompasses multiple dimensions of maritime security, including marine safety, energy security, cybersecurity, and deterrence, with significant implications for marine conservation efforts as well[245]. A primary concern is that attacks on maritime infrastructure may have a force-multiplying effect, where relatively small-scale and unsophisticated assaults can generate

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[238] Ibid.

[239] Bai & Lam (2016); Gong, Liu & Wu (2023); Jiao, Li, Wang & Zhou (2024).

[240] Delman & Odgaard (2014); Jiao, Li, Wang & Zhou (2024).

[241] Bryant, Leclerc & Townslay (2013); Bueger & Liebetrau (2024).

[242] Bueger & Liebetrau (2024); Dogan & Cetikli (2023).

[243] Ibid.

[244] Ibid.

[245] Bryant, Leclerc & Townslay (2013); Bueger & Liebetrau (2024); Dogan & Cetikli (2023).

disproportionately large disruptions across various societal sectors[246]. The concept of CMIP is underpinned by four key pillars: the assessment of threats; the identification and classification of vulnerable maritime infrastructures, along with the development of new methodologies incorporating quantitative analysis; the implementation of protective measures, such as infrastructure hardening, surveillance, and deterrence through maritime security operations; and, finally, institutional coordination between private sector actors and governmental agencies[247].

Given that maritime infrastructure often extends across regions and connects multiple states, effective CMIP requires cross-jurisdictional cooperation, necessitating legal harmonization and diplomatic engagement across territorial waters, Exclusive Economic Zones, and the high seas[248].

4.2.3. Chokepoint Resilience Index theoretical framework

The aforementioned concepts of Maritime Supply Chain Resilience and Critical Maritime Infrastructure Protection (CMIP) provide an appropriate theoretical framework for developing a novel analytical tool. The proposal to construct a Chokepoint Resilience Index emerges from the integration of key concepts drawn from existing literature.

Firstly, the concept of Sea Lines of Communication (SLOC) Security, as formulated by Kimura, Morikawa & Singh (2015)[249], offers significant theoretical and methodological benefits, particularly in its emphasis on the growing dependence on oil and liquefied natural gas (LNG) imports and the associated risks in maritime energy transportation[250]. Furthermore, Liu & Yang (2022)[251] in their examination of the Maritime Silk Road, underscored the importance of shipping network structure resilience in mitigating disruptions[252]. Building on this, Jiang (2022)[253] provided an initial framework for assessing the interdependence of chokepoints based on their vulnerability levels[254]. Lastly, Fan, Gong & Lyu (2023)[255] analyzed the critical factors influencing chokepoint resilience under conditions of heightened risk[256].

All the aforementioned scientific research converges on the recognition that chokepoints serve as critical hotspots vulnerable to a wide range of risks, whether of human origin (e.g., warfare) or natural causes (e.g., natural disasters). Therefore, a comprehensive inventory of quantitative data on chokepoint resilience is essential. This data must then undergo qualitative analysis and interpretation to generate valuable scientific insights that can contribute to the enhancement of global maritime energy transport.

While the aforementioned studies make valuable contributions to the broader effort of defining chokepoint risks, it is essential to expand their scope by incorporating additional dimensions and quantitative data. This will facilitate a more comprehensive measurement of the resilience of critical maritime nodes within the global energy transport network.

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[246] Bueger (2024); Bueger & Liebetrau (2024); Dogan & Cetikli (2023).

[247] Ibid.

[248] Ibid.

[249] Kimura, Morikawa & Singh (2015).

[250] Ibid.

[251] Liu & Yang (2022).

[252] Ibid.

[253] Jiang (2022).

[254] Ibid.

[255] Fan, Gong & Lyu (2023).

[256] Ibid.

Building on this foundation, a new theoretical construct and analytical tool is proposed: Chokepoint Resilience, which refers to a chokepoint's ability to maintain effective functionality despite disruptions or threats at critical junctures in the global energy transportation supply chain.

The presentation of this index will be accompanied by a detailed description of the proposed Dimensions and Indicators, as illustrated in Table 5. This study focuses on four chokepoints selected for their high-risk levels and strategic significance: The Strait of Hormuz, the Strait of Malacca, the Suez Canal, and the Bab-el-Mandeb Strait. These chokepoints represent pivotal points in global maritime oil and LNG transport and remain subjects of sustained interest within the scientific and business communities due to their direct connection to geopolitical, economic, and technological developments. The selected quantitative data for the proposed indicators cover the period 2020–2024.

Table 5 *.The Theoretical Framework of the Chokepoint Resilience Index.*

Dimensions	**Components**	**Indicators (metrics)**
D1:Geopolitical resilience	Military presence, piracy actions and terrorist attacks Political instability and international cooperation	• Number of Affiliated Countries • Number of Management Authorities • Number of US bases • Number of piracy/terrorist actions • Number of international cooperation schemes
D2: Economic and Trade resilience	Daily vessels and traffic Daily oil & gas volumes Energy price and inflation implications Insurance costs	• Daily number of oil tankers • Daily number of LNG carriers • Daily petroleum and other products million barrels • Daily LNG billion cubic feet • % increase in world oil price by 50% disruption (USD/barrel) • Aggregated inflation growth in US Europe & Japan in 50% disruption (%) • War Risk Premium (%)
D3: Alternative Routes resilience	Alternative route energy capacity Reroute distance and fuel cost	• Alternative route oil capacity (million barrels/day)

Dimensions	Components	Indicators (metrics)
	Military presence	• Alternative route LNG capacity (billion cubic feet/day) • Shipping distance (nm) • Distance time (day) • Number of military installations (rerouted areas) • Total fuel cost per round (USD)
D4: Geomorphological resilience	Size and depth Geological status	• Water depth (meters) • Width (km) • Cyclone frequency • Seismic activity • Tidal range (meters) • Coastal erosion rate (m/year)
D5: Historical resilience	Disruption and piracy record Oil spills	• Past disruption frequency • Piracy incidents • Oil spill incidents • Natural disasters
D6: Environmental resilience	Natural disasters Pollution	• Number of major natural disasters • Number of oil spills

4.2.4. Z-Score Calculation for Chokepoint Resilience

Based on the theoretical framework outlined above, an assessment of resilience for the four identified chokepoints was conducted using a quantitative approach. This evaluation involved calculating the z-scores for each chokepoint across multiple dimensions, allowing for a standardized comparison of their relative resilience. The z-score formula is $z = (x - \mu) / \sigma$, where z represents the standardized value, x is the observed data point, μ is the mean of the dataset, and σ is the standard deviation. This transformation allows for a comparison of the four chokepoints by expressing their resilience in terms of standard deviations from the mean, enabling a more intuitive assessment of their relative strengths and vulnerabilities.

To ensure a rigorous and balanced assessment, each dimension was assigned a specific weight, reflecting its significance in the broader geopolitical, economic, and environmental context. These weightings were determined through a detailed review of existing literature, drawing from key disciplines such as geopolitics and international relations, global trade and economic dynamics, energy markets and supply chains, evaluations of alternative transportation routes, historical precedents, geographic and natural conditions, and environmental impact studies.

Tables 6 to 12 present the numerical data for each dimension of the Chokepoint Resilience Index, detailing the specific metrics used to assess resilience. Each table corresponds to a different dimension, capturing key factors such as geopolitical risks, economic dependencies, environmental vulnerabilities, and the availability of alternative routes. By systematically analyzing these metrics, the index provides a well-rounded numerical representation of resilience, ensuring a clear and structured evaluation of each chokepoint's stability and adaptability.

Table 6. *Dimension 1: Geopolitical Resilience.*

Chokepoint name	**Number of Affiliated Countries**	**Number of Management Authorities**	**Number of US bases**	**Number of piracy/terrorist actions**	**Number of International Cooperation Schemes**
Hormuz	3	0	5	2	1
Malacca	3	6	3	21	4
Suez	1	2	1	3	0
Bab-el-Mandeb	2	0	3	133	1
X_bar	*2.250*	*2.000*	*3.000*	*39.750*	*1.500*
SD	*0.829*	*2.449*	*1.414*	*54.366*	*1.500*

Table 6. *Dimension 2: Economic and Trade Resilience.*

Chokepoint name	**Daily number of oil tankers**	**Daily passage of petroleum & other products (million barrels)**	**Daily LNG billion cubic feet**	**% increase in world oil price by 50% disruption (USD/barrel)**	**Aggregated inflation growth in US Europe & Japan in 50% disruption (%)**
Hormuz	70	21	10.4	90	0.16
Malacca	20	23	9	40	0.14
Suez	62	8.6	4	20	0.04
Bab-el-Mandeb	78	8.6	4	15	0.03
X_bar	*57.500*	*15.300*	*6.850*	*41.250*	*0.093*
SD	*22.377*	*6.737*	*2.893*	*29.660*	*0.058*

Table 7. Dimension 3: Alternative Routes Resilience.

Chokepoint name	Number of Alternative Routes (straits/pipelines)	Alternative route oil capacity (million barrels/day)
Hormuz	3	7.8
Malacca	2	0.4
Suez	3	2.5
Bab-el-Mandeb	3	2.5
X_bar	*2.750*	*3.300*
SD	*0.433*	*2.736*

***Table 8.** Dimension 4: Geomorphological Resilience..*

Chokepoint name	Water depth (meters)	Width (km)	Tidal range (meters)
Hormuz	10.5	48.3	1
Malacca	25	37	0.4
Suez	22.5	0.19	1
Bab-el-Mandeb	30	26	1
X_bar	*22.000*	*27.873*	*0.850*
SD	*7.16*	*17.821*	*0.260*

Table 9. Dimension 5: Historical Resilience.

Chokepoint name	Past frequency disruption	Piracy incidents	Natural disasters
Hormuz	4	107	1
Malacca	0	446	1
Suez	3	3	4

Chokepoint name	Past frequency disruption	Piracy incidents	Natural disasters
Bab-el-Mandeb	1	156	3
X_bar	*2.000*	*178.000*	*2.250*
SD	*1.581*	*164.297*	*1.299*

Table 10. *Dimension 6: Environmental Resilience.*

Chokepoint name	Number of oil spills
Hormuz	0
Malacca	1
Suez	0
Bab-el-Mandeb	2
X_bar	*0.750*
SD	*0.829*

The assigned weights were as follows: D1: 25%, D2: 20%, D3: 15%, D4: 15%, D5: 10% and D6: 15% as Table 12 shows. These weights ensured that the assessment accounted for both quantitative and qualitative factors affecting the resilience of each chokepoint.

Table 11. *Weight for each dimension.*

Dimension	Weight (%)	Sources
D1	25	BlackRock (2024), Caldara & Iacoviello (2022), Eurasia Group (2024), Jones, Krumbmuller & McCaffrey (2024), S&P Global (2024), World Economic Forum (2019).
D2	20	Backrot & Faure (2024), Chen, Li, Zhang, Zhang, Su & Wan. (2023), Denamiel, Reinsch, Schleich & Todman. (2024), Du, Peng & Wang (2024), EIA (2024), Kamali, Koepke, Sozzi & Verschuur (2024).
D3	15	Haider, Pettit, Rodrigues & Theocharis (2018), Nguyen, Park & Yeo. (2021).

D4	15	Chen, Li, Zhang, Zhang, Su & Wan. (2023), Li, Shen, Wang & Xu (2019).
D5	10	Ari, Koc, Meza & Sada (2022), Komiss & Huntzinger (2011).
D6	15	International Tankers Owners Pollution Federation (2024).

Table 13 presents the z-scores for each dimension, along with the total z-scores for each chokepoint. Based on the final z-scores, the most resilient chokepoint is the Strait of Hormuz, with a z-score of 0.39, while the least resilient is Bab-el-Mandeb, with a z-score of -0.24. The Strait of Hormuz consistently demonstrates positive contributions across dimensions, particularly excelling in D3 (Alternative Routes Resilience) and D6 (Environmental Resilience), resulting in the highest overall resilience score. The Strait of Malacca exhibits a mixed performance, with a notably negative impact from D3, which outweighs minor positive contributions in other dimensions. The Suez Canal presents a relatively balanced profile, experiencing slight negative impacts in multiple dimensions but benefiting from a strong score in D6. In contrast, Bab-el-Mandeb shows the greatest variability, with significant negative contributions in D6, which offset its positive scores in D4 (Geomorphological Resilience) and D2 (Economic and Trade Resilience), leading to the lowest overall resilience score.

Table 12. *Total Z-Scores (with Weighted Averages) for each maritime chokepoint.*

Maritime chokepoint name	**Z-Score D1**	**Z-Score D2**	**Z-Score D3**	**Z-Score D4**	**Z-Score D5**	**Z-Score D6**	**Total Z-Scores (with Weighted Averages)**
Hormuz	0.37	-0.03	1.11	0.04	0.04	0.90	**0.39**
Malacca	0.91	-0.11	-1.40	-0.27	0.20	-0.30	**-0.07**
Suez	-0.65	-0.03	0.14	-0.30	-0.30	0.90	**-0.08**
Bab-el-Mandeb	-0.63	0.18	0.14	0.53	0.06	-1.50	**-0.24**

Figure 21 provides a comparative analysis of the resilience levels of the selected chokepoints using a clustered bar chart. The chart visually highlights the comparative strengths and weaknesses of each chokepoint across key strategic factors, offering valuable insights into their vulnerabilities and capacities for resilience.

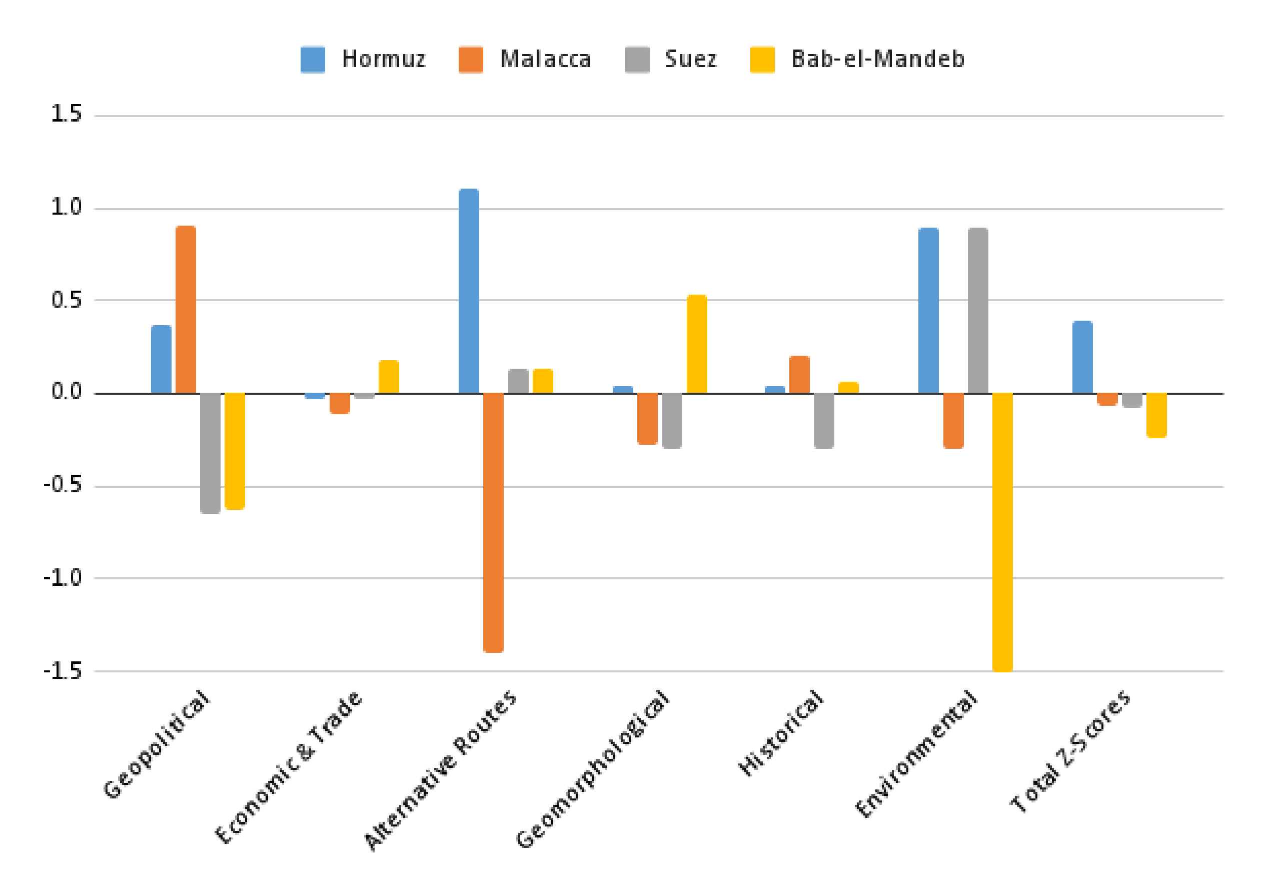

Figure 21. *The Chokepoint Resilience Index with dimensions and Total Z-Scores in a clustered bar chart.*

If an interpretation of these quantitative results is undertaken, several crucial geopolitical insights become evident.

Starting with the most resilient chokepoint, the Strait of Hormuz, its critical role in the global hydrocarbon supply chain is apparent, as the risk of oil and LNG transport disruption remains minimal. Despite the fragile geopolitical environment in the Middle East and the Persian Gulf—marked by the Israel-Hamas war, the Israel-Hezbollah conflict, the Israel-Iran tensions, and the Syrian crisis—the presence of multiple state actors, a strong U.S. military presence, and a well-established network of oil and gas pipelines contribute to Hormuz's resilience.

Regarding the Strait of Malacca, although frequent piracy incidents, adverse weather conditions, and complex geomorphology pose risks, political stability in the surrounding states, along with international military cooperation and maritime protection schemes, ensures that the likelihood of major disruptions remains manageable.

In contrast, the low resilience of the two Red Sea chokepoints—the Suez Canal and Bab-el-Mandeb—is justified due to their history of disruptions and current geopolitical instability. The Suez Canal has experienced multiple historical blockages, including the Suez Crisis of 1956, the Six-Day War of 1967, and the Yom Kippur War of 1973. The most recent and economically damaging blockage in March 2021, caused by the Ever Given incident, further highlights its vulnerability to geographical constraints and adverse weather conditions. Additionally, the ongoing Red Sea crisis complicates navigation through the Suez Canal, as transit from both northern and southern approaches is increasingly risky.

The Bab-el-Mandeb Strait stands at the epicenter of the current Red Sea crisis. The attacks by Yemeni Houthi rebels on commercial vessels and energy cargo ships have significantly disrupted international trade and escalated geopolitical tensions. While the Cape of Good Hope offers a reliable alternative sea lane, it does not entirely offset the strategic and economic consequences of the crisis. Given the ongoing conflict in Israel/Gaza and broader regional instability, a rapid de-escalation appears unlikely, reinforcing Bab-el-Mandeb's classification as the least resilient chokepoint in the Chokepoint Resilience Index.

4.3. Geopolitical and economic implications of the Red Sea disruption (2023 -)

The ongoing conflict in Yemen, particularly the Houthis' role in destabilizing the Red Sea region, underscores the fragile nature of global energy transport through maritime chokepoints[257]. The Bab-el-Mandeb Strait, a critical passage linking the Arabian Gulf with Europe and the Americas, has emerged as a focal point of geopolitical risk[258].

Using the Chokepoint Resilience Index (CRI) presented earlier, this section evaluates the resilience of Bab-el-Mandeb and connects the findings with the ongoing Red Sea crisis. This analysis highlights the challenges of maintaining energy security in conflict-prone regions, emphasizing the complex interplay between geopolitical instability and maritime trade in critical energy routes.

4.3.1. Geopolitical content and interests

Since the outbreak of the Israel-Palestine/Iran conflict following the October 7, 2023, attack, the Houthis have redirected their military operations toward the Red Sea, seeking to impose an embargo on Israel and disrupt Tel Aviv's offensive in Gaza[259]. In a pattern of continuous escalation, the Houthis initially targeted Israeli territory before expanding their operations to vessels linked to or bound for Israel, as well as to U.S. and U.K. warships and interests[260]. This progressive broadening of targets has significantly disrupted global trade transiting through the Red Sea[261].

In response, shipping companies have adjusted their routes to circumvent the Bab el-Mandeb–Suez Canal passage[262]. Rerouting via the Cape of Good Hope has extended voyages by approximately 3,500 nautical miles (6,482 km), increasing transit times by at least 14 days[263]. Trade flows between Europe and Asia, which predominantly rely on the Suez Canal, have been particularly affected[264]. Figures 22 and 23 illustrate the substantial decline in transit through Bab el-Mandeb and the corresponding increase in rerouting via the Cape of Good Hope[265].

[257] ACLED (2024); Dunn & Leibovici (2024).

[258] Ibid.

[259] Ibid.

[260] Ibid.

[261] ACLED (2024); Dunn & Leibovici (2024); IGU (2024).

[262] Dunn & Leibovici (2024).

[263] Ibid.

[264] Ibid.

[265] PortWatch (2024).

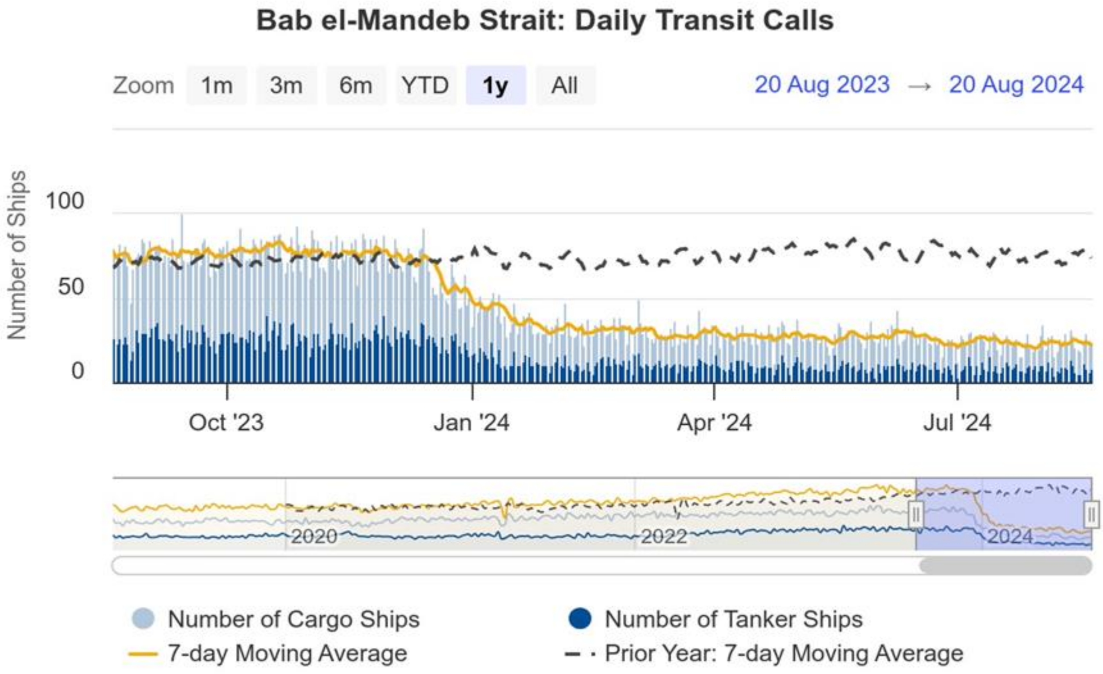

***Figure 22**. Bab-el-Mandeb Strait: Daily Transit Call.*[266].

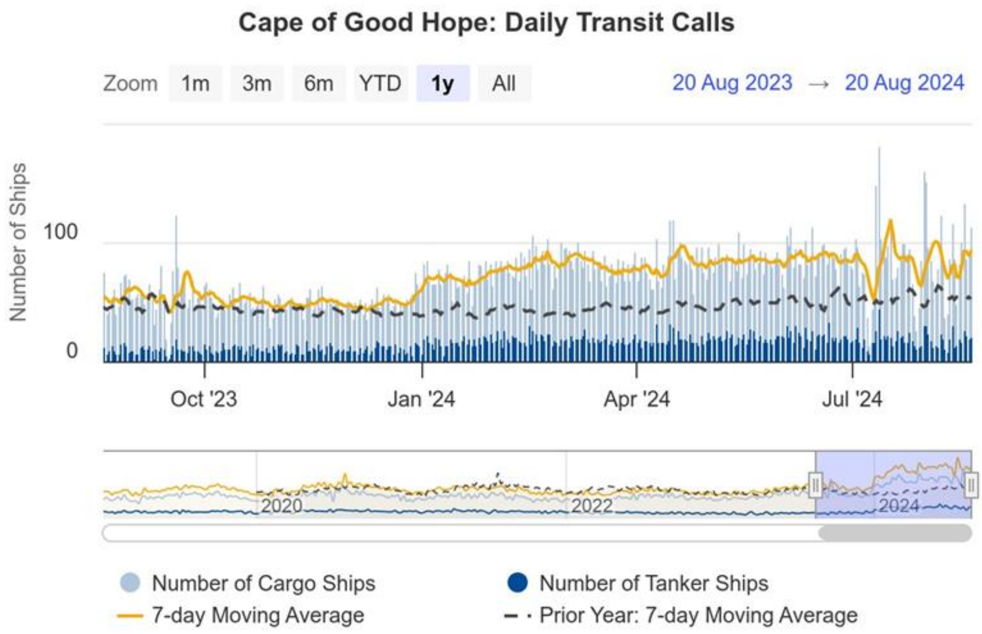

***Figure 23.** Cape of Good Hope: Daily Transit Calls*[267].

Houthi operations targeting international shipping in the Red Sea and surrounding waterways have heavily relied on drones, with over 40% of recorded incidents between October 2023 and June 2024, as documented by ACLED, involving drone usage[268]. However, drone attacks on international shipping have proven significantly less effective compared to missile strikes[269].

[266] Ibid.

[267] Ibid.

[268] ACLED (2024); Dunn & Leibovici (2024).

[269] Ibid.

Notably, 75% of Houthi drone attacks on international shipping have been intercepted by international coalition forces deployed in the Red Sea and the Gulf of Aden to counter the Houthi threat, whereas only about 16% of missile attacks have been intercepted[270]. Furthermore, among attacks that successfully hit their targets, drones were used in only one out of five cases[271].

Additionally, the Houthis appear to deploy different types of weaponry depending on the target's geographical location[272]. Drones are primarily used against targets in the southern Red Sea, which is closer to Houthi-controlled areas, while missiles are predominantly deployed in the Gulf of Aden, as illustrated in Figure 24[273]. A possible explanation for this pattern is that, given the slower speed of drones compared to missiles, the Houthis may prefer to use them in the relatively confined area of the southern Red Sea to minimize the risk of interception[274]. In contrast, in the Gulf of Aden, where international forces have more time to respond, missiles may be favored due to their greater speed and reduced vulnerability to interception[275].

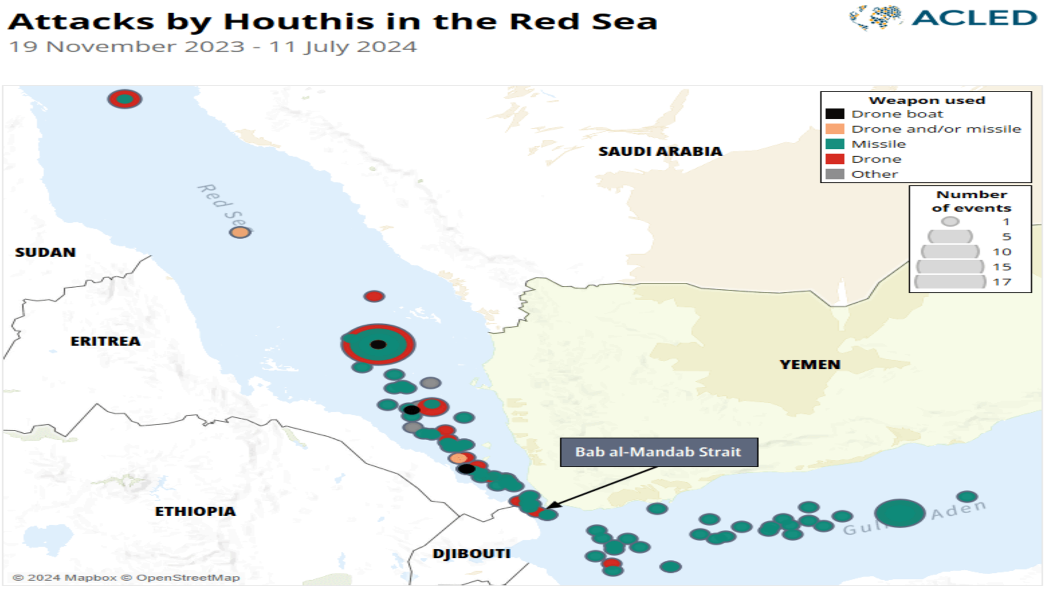

Figure 24. *Attacks by Houthis in the Red Sea (19 November 2023-11 July 2024)*[276].

On August 21, 2024, the Greek-flagged crude oil tanker *Sounion* was approached by two small craft approximately 77 nautical miles west of Hodeidah, Yemen, at 02:57 hours[277]. According to a report from the UK Maritime Trade Operations (UKMTO), the small craft hailed the tanker, prompting a brief exchange of small-arms fire[278]. he distance between the tanker and the small craft then increased to 2 nautical miles[279]. Two hours later, at 05:00 hours, the *Sounion*'s master reported that

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[270] Ibid.

[271] Ibid.

[272] ACLED (2024).

[273] Ibid.

[274] Ibid.

[275] Ibid.

[276] Ibid.

[277] Greenall (2024);

[278] Ibid.

[279] Ibid.

the vessel had been struck by two projectiles, followed by a third impact[280]. The latest update from UKMTO indicated that a fire had broken out on board, rendering the vessel not under command[281]. The master also reported the presence of a small craft exhibiting suspicious behavior in the vicinity[282]. According to the U.S. State Department, the attack posed a significant environmental threat[283].

On December 18, 2023, the United States announced Operation Prosperity Guardian, a multinational naval task force established to counter Houthi attacks on ships in the Red Sea[284]. The task force operates under the framework of the Combined Maritime Forces, an existing counterpiracy initiative headquartered in Bahrain. Member states participating in Operation Prosperity Guardian include Australia, Bahrain, Canada, Denmark, Greece, the Netherlands, New Zealand, Norway, Singapore, Sri Lanka, the United Kingdom, and the United States, with additional support from the Seychelles[285].

Under the umbrella of Operation Prosperity Guardian, multiple measures have been implemented to safeguard commercial shipping[286]. These include naval convoys escorting merchant vessels and the interception of drones and missiles targeting ships[287]. Additionally, a series of airstrikes against Houthi facilities in Yemen was conducted in January, February, and March 2024[288].

Since February 19, 2024, the European Union has established a naval mission in the Red Sea, Aspides, aimed at protecting commercial shipping from Houthi attacks[289]. However, the mission does not have a mandate to participate in strikes against the Houthis[290]. Naval operations have also been complemented by diplomatic efforts[291]. In a press statement on December 1, 2023, members of the United Nations Security Council strongly condemned recent Houthi attacks on commercial vessels in the Red Sea[292].

The present research on geopolitical developments related to disruptions in the Red Sea highlights several key findings. As illustrated in Figure 25, the number of visits by Iranian- and Chinese-flagged cargo vessels and tankers to the region increased by 55% and 13.5%, respectively, between October 2023 and February 2024, compared to the period from May to September 2023[293]. In contrast, visits by U.S.-flagged cargo vessels and tankers declined by 41%, while UK-flagged vessels experienced a 23% decrease[294].

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280 Ibid.

281 Ibid.

282 Greenall (2024); Lloyd’s List (2024).

283 US State Department (2024).

284 Cullinane, Haralambides & Notteboom (2024).

285 Ibid.

286 Cullinane, Haralambides & Notteboom (2024); International Transport Forum (2024).

287 Ibid.

288 Ibid.

289 Ibid.

290 Ibid.

291 Ibid.

292 Ibid.

293 Windward (2024).

294 Ibid.

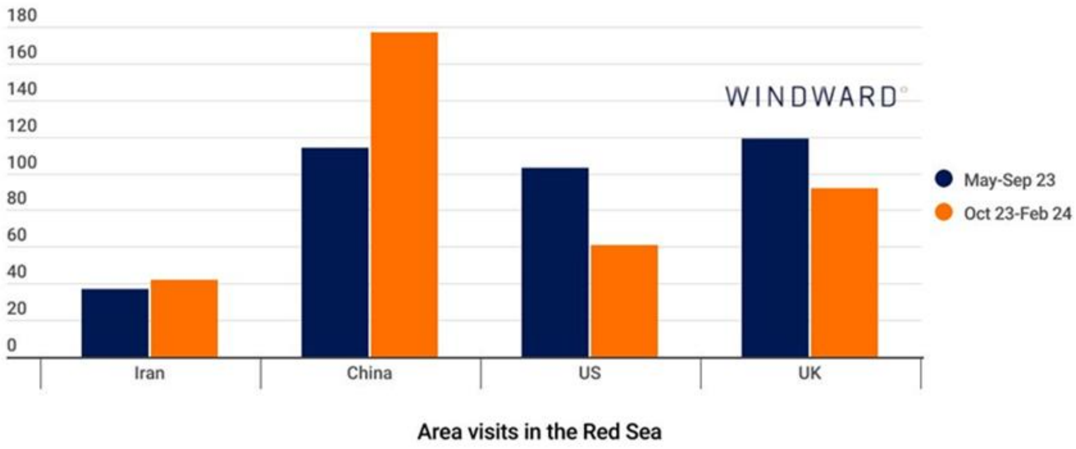

Figure 25. *Area visits in the Red Sea [295].*

Regarding Iran, its strategic interests in the Red Sea remain significant. By providing financial and operational support to the Houthis, Iran projects power in the maritime domain encompassed by what the Iranian Naval Forces refer to as the "Golden Triangle"—a network of three critical maritime chokepoints for energy transport: the Strait of Hormuz, the Bab el-Mandeb Strait, and the Strait of Malacca, as illustrated in Figure 26[296]. This maritime region is vital for international shipping and energy transport, and Iran has maintained an extensive naval presence due to its increasing geopolitical vulnerabilities[297].

Figure 26*. IRIN strategic vision and out-of-area port visits[298].*

Regarding China, trade volume to and from the country has increased following the onset of Houthi attacks, in contrast to the decline observed among member states of Operation Prosperity

[295] Ibid.

[296] US Navy Office of Naval Intelligence (2017).

[297] US Navy Office of Naval Intelligence (2017); Windward (2024).

[298] US Navy Office of Naval Intelligence (2017).

Guardian[299]. According to insights from Windward's Maritime AI™ platform, between mid-October 2023 and mid-March 2024, the weekly average of port calls in China by Chinese-owned vessels that had transited the Suez Canal (importing goods to China) rose by 73% compared to the weekly average over the preceding 6.5 months[300]. Additionally, regarding Chinese exports—measured by the number of Chinese-owned vessels passing through the Suez Canal after making a port call in China—the weekly average increased by 25% following a seasonal peak between mid-October and mid-November, ahead of the winter holiday period[301].

Notably, the Chinese Ministry of Commerce and the People's Liberation Army Navy (PLAN) have been actively supporting all Chinese-owned vessels operating in the Red Sea through the deployment of the PLAN Task Force to the Gulf of Aden, currently represented by the 45th Task Force[302]. As a result, Chinese trade has not been disrupted to the same extent as that of Western nations[303]. These trends further reinforce the geopolitical alignments that have become increasingly apparent. The ongoing Houthi disruptions, coupled with retaliatory strikes by the U.S. and the UK, are deepening the geopolitical divide between "the East"—comprising China, Iran, and Russia—and "the West", which includes the U.S., Europe, and select Asian and Middle Eastern countries[304].

4.3.2. Impact of Red Sea disruption on global energy markets and trade.

The Strait of Hormuz, the Bab el-Mandeb Strait, and the Suez Canal are critical transit routes for crude oil and natural gas shipments from the Middle East to Europe and North America. In the first half of 2023, total oil shipments via these routes accounted for approximately 12% of global seaborne-traded oil, while liquefied natural gas (LNG) shipments made up about 8% of the worldwide LNG trade[305].

Due to heightened security risks, major oil and natural gas companies have opted to avoid transit through the Bab el-Mandeb. Companies such as Equinor, BP, Shell, QatarEnergy, ADNOC, Hafnia, Stena Bulk, Euronav, Torm, K Line, Mitsui O.S.K. Lines, Frontline, and Reliance have suspended oil and gas shipments via this route, causing a significant impact on energy markets[306]. As illustrated in Figure 27, the flow of energy products—including LNG, LPG, crude oil, and petroleum products—through the Red Sea has experienced a notable decline since November 2023, following a pattern similar to the decrease observed during the 2020 pandemic-induced economic downturn[307].

[299] Windward (2024).

[300] Ibid.

[301] Ibid.

[302] Ibid.

[303] Ibid.

[304] Ibid.

[305] EIA (2023); International Transport Forum (2024).

[306] EIA (2024); LaRocco (2024).

[307] Ibid.

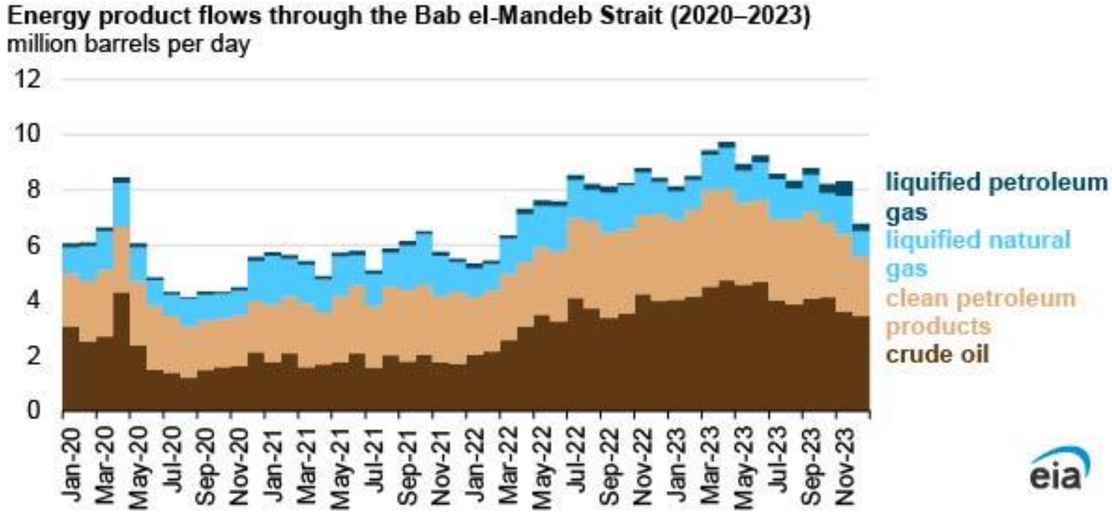

Figure 27. *Energy product flows through the Bab-el-Mandeb Strait (2020-2023)[308].*

To assess the impact on energy markets, it is essential to examine the shifts in energy flows and maritime routes following the Red Sea disruptions and the resulting increase in vessel traffic around the Cape of Good Hope. The volume of crude oil and oil products transiting the Cape in either direction rose to 8.7 million barrels per day (b/d) in the first five months of 2024, compared to an average of 5.9 million b/d in 2023[309]. The majority of this increase was driven by oil product shipments[310].

Several key trade patterns emerged around the Cape. Middle Eastern crude oil producers—notably Saudi Arabia and Iraq—redirected more crude oil westbound to Europe via the Cape rather than through the Suez Canal, which is accessed via the Red Sea and Bab el-Mandeb Strait[311]. This shift accounted for 15% of the total increase in trade volume between the 2023 average and the January–May 2024 period[312].

Asian and Middle Eastern refiners significantly increased oil product exports to Europe, diverting shipments westbound around the Cape[313]. This accounted for 29% of the increased trade in the region[314].

The United States both imported crude oil and oil products from the Middle East and Asia and increased its oil product exports to Asia via the Cape[315]. In total, U.S. trade around the Cape grew by approximately one-third, equating to an increase of just over 600,000 b/d in the first five months of 2024 compared to the 2023 average[316].

While the Red Sea disruptions had a lesser impact on Russia's oil shipments compared to other trade flows, Russia quadrupled its crude oil and oil product exports to Asia via the Cape—including

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[308] EIA (2024).

[309] Ibid.

[310] Ibid.

[311] EIA (2024); IMF (2024).

[312] Ibid.

[313] Ibid.

[314] Ibid.

[315] Ibid.

[316] Ibid.

volumes transported by the Caspian Pipeline Consortium—in the first five months of 2024 compared to total shipments in 2023[317].

Between 1 November 2023 and 28 February 2024, the number of ships transiting the Bab-el-Mandeb Strait decreased by 55%[318]. However, there are significant differences based on vessel type, as shown in Figure 28. The smallest declines in transit numbers were observed for bulk carriers (-12%) and crude oil tankers (-32%), followed by bulk carriers (-45%) and product tankers (-46%)[319]. In contrast, the largest reductions occurred in liquefied natural gas (LNG) carriers (-100%), liquefied petroleum gas (LPG) carriers (-88%), and container shipping (-75%)[320].

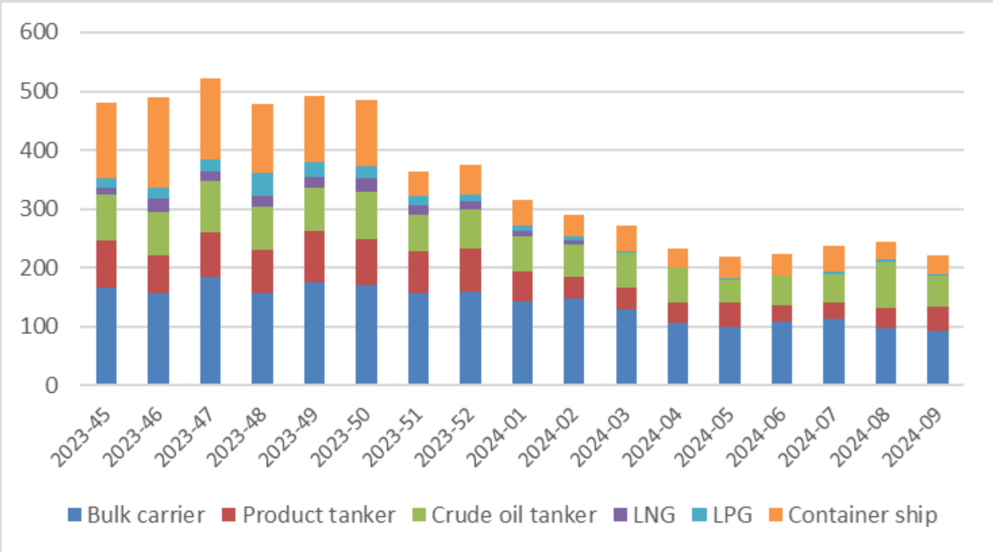

Figure 28. *Ship transit decrease via the Bab-el-Mandeb by vessel type [321].*

According to Kpler, the number of laden LNG carriers making port calls at the Suez Canal (traveling north to south or south to north) decreased from 519 in 2021 to 465 in 2022, and 434 in 2023[322]. Across these three years, the average was 39 per month, ranging from a high of 63 (January 2021) to a low of 25 (February 2022)[323]. In 2023, the monthly averages ranged from 29 to 41, with an overall average of 36 for the year[324]. Of the 434 LNG cargoes that passed through the Suez Canal in 2023, a total of 240 (55 percent) traveled from north to south, destined for the Middle East (Jordan or Kuwait) or Asia[325]. In the opposite direction, 195 cargoes (45 percent) traversed the canal from south to north, destined for Europe (EU-27 and the UK)[326].

Regarding export cargoes passing through the Suez Canal from north to south, 130 originated from the United States, and four came from other parts of the Americas[327]. The 45 cargoes that originated in Europe (EU-27, UK, and Turkey) were re-exports, 34 of which (75 percent) were reloaded at

[317] Ibid.

[318] International Transport Forum (2024).

[319] Ibid.

[320] Ibid.

[321] Ibid.

[322] Sharples (2024).

[323] Ibid.

[324] Ibid.

[325] Ibid.

[326] Ibid.

[327] Ibid.

Zeebrugge in Belgium, seven (15 percent) at Montoir in France, and two each from Spain and Turkey[328]. Additionally, 34 cargoes from North Africa (Algeria and Egypt) and 25 cargoes from Russia were joined by two cargoes delivered from Nigeria to India[329].

As for exports traversing the Suez Canal from south to north, Qatar accounted for 180 cargoes, Oman for 8 cargoes, and the UAE for 1 cargo[330]. Additionally, four cargoes originated from Mozambique, and one from Indonesia[331]. This totals 194 cargoes, of which 93 percent originated from Qatar[332].

Overall, the south-to-north export flow is predominantly comprised of Qatari cargoes destined for Europe, while the north-to-south flows are more diverse[333]. Cargoes from the United States take the largest share (54 percent), with the remainder primarily divided between Russian cargoes (direct from Yamal), European reloads, and North African cargoes (10-19 percent each)[334]. In 2023, total global gross LNG exports amounted to 412.3 million tonnes (mt)[335]. Of that volume, 32.4 mt was delivered via the Suez Canal, 10.3 mt via the Panama Canal, 2.3 mt via the Northern Sea Route, and 367.3 mt via other routes[336]. LNG shipping via the Suez Canal represents approximately 7%, meaning disruptions to these flows could have a significant, though not critical, impact on the global LNG market[337].

Regarding the other economic consequences of this disruption, shipping companies are facing several obstacles and additional costs. Firstly, damage to most commercial ships due to Houthi attacks has so far been limited, thanks to interventions from naval forces stationed in the region[338]. Many attacks have missed their targets, and when missiles have struck ships, the damage has often been minor, allowing the vessels to continue on their course[339]. These attacks also add stress to an already high-pressure working environment, which was further strained during the Covid-19 pandemic[340]. Although research on seafarers' mental health could be improved, worrying trends are emerging concerning their working conditions, particularly the increase in the abandonment of seafarers without pay[341].

Secondly, the Houthi attacks have led to longer transit times. In response, shipping companies may attempt to increase their speeds to minimize delays, but there is no evidence that they have done so[342]. Additionally, disruptions in the Red Sea have had a negative impact on the reliability of ship schedules, making re-routing plans difficult to execute[343]. A typical voyage from the Persian Gulf to

[328] Ibid.

[329] Ibid.

[330] Ibid.

[331] Ibid.

[332] Ibid.

[333] Ibid.

[334] Ibid.

[335] Ibid.

[336] Ibid.

[337] Ibid.

[338] EIA (2024); International Transport Forum (2024).

[339] Ibid.

[340] Ibid.

[341] Ibid.

[342] Ibid.

[343] Ibid.

the Amsterdam-Rotterdam-Antwerp (ARA) petroleum trading hub via the Suez Canal takes 19 days, whereas taking the Cape of Good Hope route would extend the journey to nearly 35 days[344]. Furthermore, the low predictability of vessel arrivals creates port congestion, presenting challenges for terminal operators[345].

Finally, fewer transits through the Suez Canal have resulted in a significant decline in toll revenues for Egypt. In the fiscal year 2022-2023, toll revenues reached a record USD 9.4 billion, representing 2% of the country's GDP[346]. Naturally, Egypt is eager to protect this vital source of revenue[347]. However, the Suez Canal Authority (SCA) reported a 40% decrease in toll revenues during the first two weeks of 2024 compared to the same period in 2023[348]. It is estimated that the SCA suffered a loss of USD 175 to 350 million in canal transit fees, solely from container vessels, between December 15, 2023, and January 9, 2024[349].

Apart from the above, the economic cost for shipping companies has increased. The assessment of various cost components is clearly outlined in Table 14. In particular, fuel and charter costs have risen, along with marine insurance costs[350].

Table 13. *Shipping cost increases due to Red Sea situation for median size container ships[351].*

Cost Item	**Via Suez Canal (USD)**	**Via Cape of Good Hope**
Fuel costs		1 million
Charter costs		1 million
Container hire		0.3 million
Canal fees		-0.6 million
Insurance cost	Up to 1 million	
Maritime security	0.03 million	
Total additional costs per ship	Up to 1 million	1.7 million
Additional costs per 40-foot container	Up to 160	272

The ongoing disruption of this important chokepoint has caused significant challenges, problems, and difficulties. However, the research indicates that it is not an enormous disaster for global energy trade, especially due to the availability of alternative maritime routes for the shipping of energy products.

344 Ibid.

345 Ibid.

346 Cullinane, Haralambides & Notteboom (2024).

347 Ibid.

348 Ibid.

349 Ibid.

350 International Transport Forum (2024).

351 Ibid.

4.3.3. The Red Sea disruption and the Chokepoint Resilience Index.

The position of the Bab-el-Mandeb Strait on the Chokepoint Resilience Index reveals significant vulnerabilities, particularly in dimensions such as Geopolitical Resilience (D1) and Environmental Resilience (D6). The current disruption of this maritime chokepoint exacerbates these vulnerabilities by creating a volatile security environment, characterized by missile attacks, drone strikes, and threats of naval blockades. These actions not only endanger commercial shipping and global energy transportation but also amplify the chokepoint's already low resilience, as reflected in its total Z-Score of -0.24.

A closer analysis of Bab-el-Mandeb's Z-Score breakdown provides a quantitative lens for assessing these vulnerabilities:

- D1 (Geopolitical Resilience): While the probability of extended regional conflict around the Red Sea remains low, the chokepoint is limited in both capacity and security, offering minimal mitigation against disruptions caused by conflict. This dimension reflects the chokepoint's constrained ability to handle crises effectively.
- D2 (Economic and Trade Resilience): A slightly positive Z-Score suggests that the strait can handle large energy volumes under normal conditions. However, the ongoing Houthi threats—such as their 2018 attacks on Saudi oil tankers—demonstrate how quickly resilience erodes under geopolitical strain.
- D3 (Alternative Routes Resilience): The low Z-Score in this dimension highlights the broader instability of the Red Sea region. Yemen's civil war, coupled with Houthi ambitions, has transformed Bab-el-Mandeb into a flashpoint where external actors like Saudi Arabia and Iran contend for influence.
- D4 (Geomorphological Resilience): Bab-el-Mandeb's geographical and physical attributes present challenges in ensuring smooth navigation and operational security under adverse conditions.
- D5 (Historical Resilience): While historical usage indicates strategic importance, it also reveals a legacy of conflicts and disruptions that exacerbate vulnerability during crises.
- D6 (Environmental Resilience): Bab-el-Mandeb's most negative score (-1.5) underscores its pivotal role in global energy flows. Approximately 8.6 million barrels of oil and 4 billion cubic feet of LNG pass through the strait daily, making any disruption disproportionately impactful to Europe and Asia's energy security.

4.4. The emerging alternative of Northern Sea Route

4.4.1. Economic importance for energy transport via NSR

The Northern Sea Route (NSR) stretches from Novaya Zemlya to the Bering Strait along the Russian Arctic coast and is part of the Northeast Passage (NEP)[352]. The route gained popularity between 2011 and 2013 due to an increase in transits between the Atlantic and Pacific Oceans, as well as destination voyages that either originated from or ended at Arctic ports[353]. The NSR can potentially offer distance and time savings depending on the origin-destination (OD) pair, as well as

[352] Haider, Pettit, Rodrigues & Theocharis (2021).

[353] Ibid.

prevailing market conditions and vessel positioning[354]. However, environmental factors largely determine the commercial viability of voyages through the Arctic[355].

Variability in sea ice conditions (extent, thickness, and concentration), fog, darkness, harsh climate, and low temperatures make the NSR a very challenging environment to navigate, where ice-class ships—those with enhanced hulls and special equipment depending on the ice class level—are required, as they are in the Baltic during the ice season[356]. The use of ice-class ships implies increased capital and operating costs, while the risk of ice damage and repairs can further increase costs and may render voyages unprofitable, even if the NSR offers shorter distances[357]. Moreover, transit fees paid for icebreaking assistance represent an additional cost factor, not least due to the uncertainty that the Northern Sea Route Administration (NSRA) exerts, highlighting the unpredictability of tariff policies[358].

The Northern Sea Route is one of several planned maritime routes, such as the Nicaragua Canal (in contrast to Panama Canal)[359], the Kra Canal (in contrast to Straits of Malacca)[360] and the Ben-Gurion Canal, all aimed at bypassing Egypt's monopoly on the crucial shipping route between Europe and Asia, as shown in Figure 29[361].

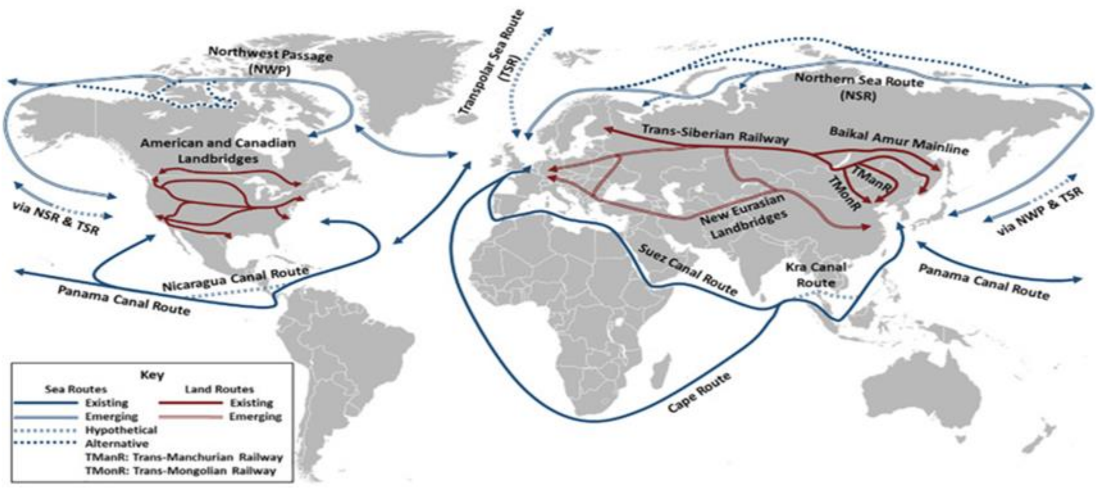

Figure 29*. Alternative sea and land routes between Eurasia and North America[362].*

Academic maritime research on transiting via the NSR began emerging as a theme after 2011, as shown in Figure 30[363]. This period also saw a steep increase in transit traffic (i.e., voyages between the Atlantic and the Pacific) through this new route, followed by a sharp decline in 2015[364]. Although the probability of choosing the NSR under current conditions remains low, future improvements in ice conditions and increased profit margins may encourage some shipping

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354 Ibid.

355 Ibid.

356 Ibid.

357 Ibid.

358 Ibid.

359 Chen et al. (2017).

360 Hung (2022).

361 Musmar (2024).

362 Haider, Pettit, Rodrigues & Theocharis (2018).

363 Dai, Hu, Jing & Wang (2021); Haider, Pettit, Rodrigues & Theocharis (2018).

364 Haider, Pettit, Rodrigues & Theocharis (2021).

companies to use the NSR seasonally, particularly in summer[365]. However, since profit is the primary driving force, port authorities along the Suez Canal may respond by offering price incentives to mitigate the impact of NSR's growing viability[366].

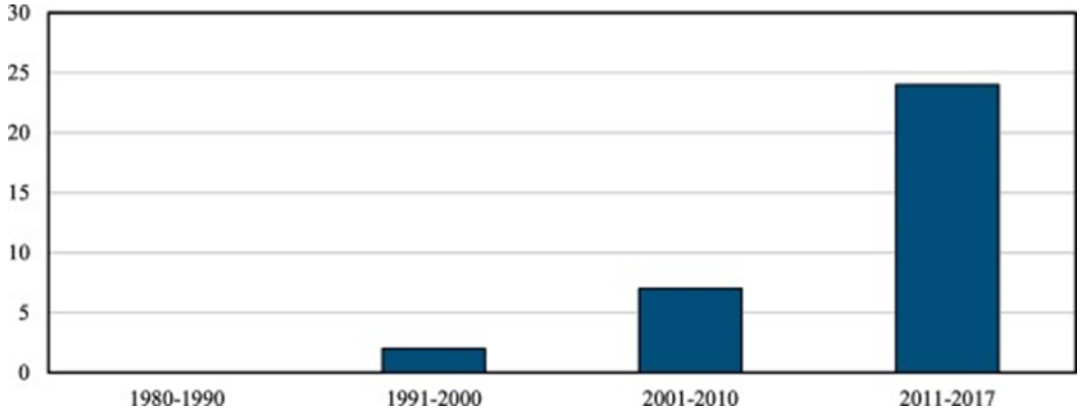

Figure 30. *Number of articles published between 1980 and 2017*[367].

For Russian oil and gas companies, the NSR offers the potential to unlock Arctic reserves that have remained stranded for many years. A sign of this emerging trend is Russia's flagship LNG project, Novatek's Yamal LNG, which has been using the NSR to deliver liquefied gas to Europe and Asia[368]. Novatek's plans to quadruple LNG production on the Yamal and Gydan peninsulas over the next 15 years suggest that approximately 70 million tonnes per annum (mtpa) of Russian LNG will be shipped via the NSR by the early 2030s, with even greater volumes expected beyond that[369].

In recent years, NSR shipping has experienced significant growth, primarily driven by hydrocarbon exports[370]. Hydrocarbons have accounted for the majority of overall shipments via the NSR, with crude oil supplied mainly from Gazprom Neft's Novoportovskoye and Prirazlomnoye projects, while LNG and condensate have been transported from Novatek's Yamal LNG project[371]. The launch of the Yamal LNG project in 2018 provided a major boost to NSR shipments, which reached 32 million tonnes in 2020, as shown in Figure 31[372].

[365] Dai, Hu, Jing & Wang (2021).

[366] Meng, Wang & Zhang (2018).

[367] Haider, Pettit, Rodrigues & Theocharis (2018).

[368] Haider, Pettit, Rodrigues & Theocharis (2018); Yermakov (2021).

[369] Yermakov (2021).

[370] Ibid.

[371] Ibid.

[372] Ibid.

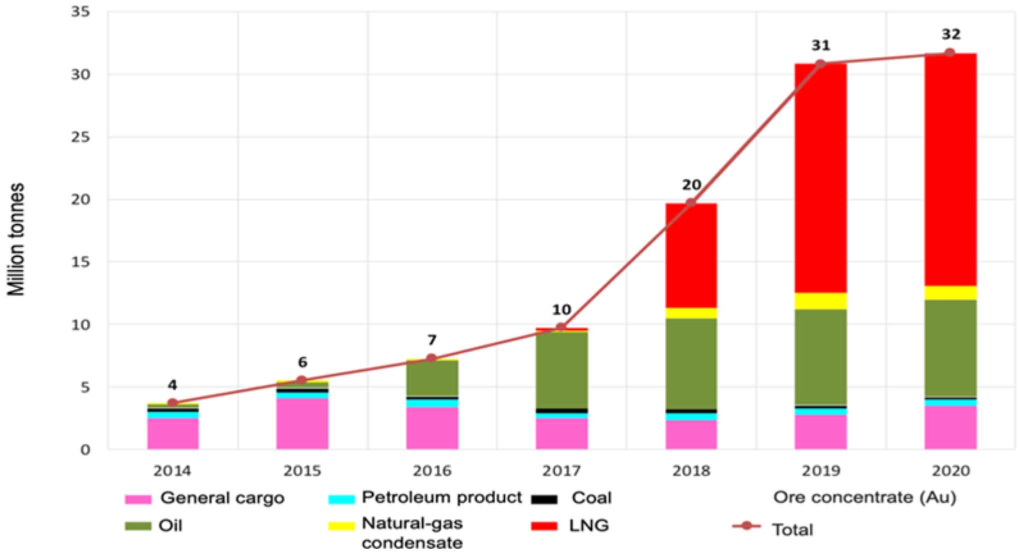

Figure 31. *Volume of shipments via NSR by type of cargo, 2014-2020* [373].

Furthermore, the emergence of the Northern Sea Route (NSR) as a viable shipping corridor would significantly enhance the transportation of liquefied natural gas (LNG) from Russian Arctic LNG plants to key Asian markets, including Japan, China, and South Korea. This development has the potential to reshape the global LNG supply-demand structure by offering a shorter and more cost-effective shipping alternative[374].

Additionally, Raza and Schøyen (2017) examined the economic feasibility of LNG carriers transporting LNG from Norway to Japan via the NSR. Their findings indicate that, compared to the Suez Canal, utilizing the NSR could yield economic savings of up to 4.7 million U.S. dollars for a full round trip, as illustrated in Tables 15 and 16[375]. Tables 8 and 9 demonstrate the economic advantages of the Northern Sea Route (NSR) over the Suez Canal for LNG transportation[376]. The NSR reduces both fuel consumption and vessel charter costs, leading to a 42% decrease in total round-trip costs and lower LNG transport costs per ton[377]. Despite additional insurance expenses and LNG wastage, the overall savings make the NSR a highly cost-effective alternative, provided that operational and environmental challenges are managed[378].

Table 14*. LNG shipping. Calculation of fuel cost via NSR and via Suez Canal* [379].

Data	**Suez Canal**	**Northern Sea Route** **Ice Water/No-Ice Water**
Distance between Hammerfest-Tobata (nm)	12,146	2,880/3,252
Speed (knot)	19.5	12/ 19.5

[373] Ibid.

[374] Dai, Hu, Jing & Wang (2021).

[375] Raza & Schoyens (2017).

[376] Ibid.

[377] Ibid.

[378] Ibid.

[379] Ibid.

Data	Suez Canal	Northern Sea Route Ice Water/No-Ice Water
LNG fuel consumption (tons per nm)	0,28 (for laden Trip) 0,27 (for ballast Trip)	0,16(for laden Trip) 0,28(for laden Trip)/0,15(for ballast trip) 0,27(for ballast Trip)
LNG fuel Consumption (tons) per round voyage	6,680	893/1,789 =2,682
LNG wastage in GCU in NSR (tons)	-	500
LNG fuel cost per round voyage ($505/MT FOE)	3,373,400	1,606,910
MDO pilot fuel (tons)	67	32
MDO pilot fuel cost per round voyage ($ 900/MT)	60,300	28,800
Total fuel cost ($) per round	3,433,700	1,635,710

Table 15. *LNG shipping. Cost comparison of a round voyage via the Suez Canal and via the NSR (Hammerfest-Tobata)*[380].

Cost Components	Suez Canal	NSR
Vessel charter cost per round voyage ($)	7,396,700	3,735,400
Total Fuel Cost ($)	171,693	807,975
Additional piracy insurance in Suez Canal per round voyage	158,204	-
Additional insurance premium for Increased Values (IV) in NSR ($)	-	20,250
Additional H&M insurance for NSR navigation ($)	-	281,250
Total Costs per round voyage ($)	11,160,297	6,480,585

[380] Ibid.

Cost Components	Suez Canal	NSR
Total Savings ($) **4,679, 712 (42%)**		
Cost per ton ($) (1MMBtu = 0.0192ton)	165 $/ton (3.2 $ / MMBtu)	96 $/ton (1.8 $ / MMBtu)
Savings per ton ($) **69 $ / ton (42%)**		

4.4.2. Geopolitics of the Arctic Region

The growing importance and utilization of the Northern Sea Route and, more broadly, the Arctic region is not merely a matter of commercial assessment and economic prospects but also a geopolitical concern involving power projection and the implementation of national strategies by Arctic states[381]. As the polar ice caps rapidly diminish, previously inaccessible ocean and land areas beyond any nation's control are becoming available[382]. Consequently, countries are increasingly seeking jurisdiction over these territories for resource extraction, trade routes, and strategic advantages, as illustrated in Figure 32[383].

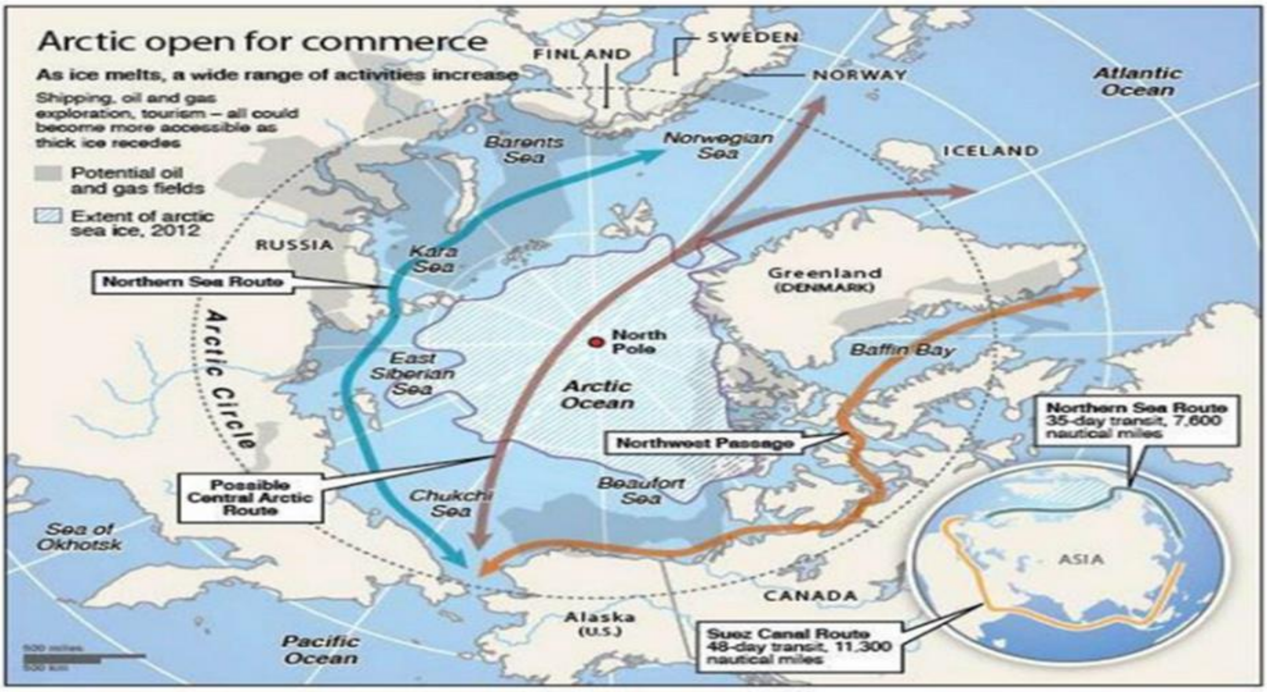

__Figure 32.__ Arctic open for commerce[384].

Beyond economic interests, nations such as the United States, Russia, and China are competing in the Arctic to assert military dominance and expand their strategic influence[385]. The region's critical

[381] Ebinger & Zambetakis (2009); Gross (2020); Yermakov (2021).

[382] Ibid.

[383] Ebinger & Zambetakis (2009).

[384] Walker (no date).

[385] Ebinger & Zambetakis (2009); Gross (2020); Yermakov (2021).

position between North America and Eurasia enhances its significance as a key military stronghold[386]. As the liberal international order faces growing challenges and great power tensions intensify, the Arctic Circle risks becoming a flashpoint for global conflict escalation[387].

The competition over territorial claims in the Arctic is largely driven by nations' pursuit of natural resources, particularly natural gas, which accounts for nearly a quarter of global energy consumption[388]. While most natural gas reserves worldwide have already been explored and exploited, the Arctic remains a vast, untapped source that nations are striving to control[389]. As a result, potential hydrocarbon reserves have become a key component of the national strategies of the world's major competitors—the United States and the Russia-China alliance[390].

A 2009 U.S. Geological Survey report estimated that the Arctic holds 1,699 trillion cubic feet of natural gas and other fuels—equivalent to Russia's entire oil reserves and three times those of the United States[391]. Reflecting the region's strategic importance, President Trump in 2019 expressed interest in purchasing Greenland, citing its Arctic location, though the proposal was strongly opposed by Denmark[392]. In 2025, Trump renewed his claims, stating that *"one way or the other, we're going to get Greenland,"* highlighting its critical role in Arctic geopolitics[393]. The U.S. fears that the Arctic could become a battleground for Russian and Chinese strategic competition, given their growing cooperation in energy, mining, and infrastructure[394].

For Russia, the Arctic is both an economic and geopolitical priority. As noted earlier, the Northern Sea Route (NSR) offers a Russia-controlled trade corridor to China and other Asian markets, outside U.S. naval control and secure from sanctions or blockades[395]. This eliminates the political risk of chokepoint disruptions that affect traditional global trade routes[396]. Additionally, Russia has steadily expanded its military presence in the Arctic over the past decade, opening new airfields, refurbishing old ones, and establishing a dedicated northern command, as illustrated in Figure 33[397].

[386] Ibid.

[387] Ibid.

[388] Gross (2020).

[389] Pezard (2018); Yermakov (2021).

[390] Gross (2020); Pezard (2018); Yermakov (2021).

[391] Ebinger & Zambetakis (2009).

[392] Congressional Research Service (2019).

[393] Williams (2025).

[394] Ibid.

[395] Yermakov (2021).

[396] Ibid.

[397] Gjørv & Sergunin (2020); Kjellén (2022); Pezard (2018); Yermakov (2021).

***Figure 33**. Russia's militarization of the Arctic*[398].

Finally, regarding China, its interest in polar issues is not new. China has a strong history of research and scientific expeditions in Antarctica since the 1980s and in the Arctic since the 1990s[399]. Over time, its interests in the Arctic have expanded, focusing increasingly on extractive industries, commercial ventures, and shipping routes[400]. In 2017, 11 of the 27 vessels that transited through the Northern Sea Route (NSR) originated from or were heading to a Chinese port[401]. China describes itself as a "Near Arctic State," a designation it uses to assert its interests in the region[402]. Since 2013, China has been an observer state to the Arctic Council, and while its investments in the region remain relatively modest, the Yamal LNG project in partnership with Russia stands as a notable exception[403].

In conclusion, the Northern Sea Route (NSR) presents a promising alternative for energy transport, particularly for liquefied natural gas (LNG), offering significant cost savings and shorter transit times compared to traditional routes like the Suez Canal. With the Arctic's vast untapped natural resources and its strategic geopolitical importance, the NSR is becoming a key focus for global powers such as Russia, China, and the United States. Despite challenges related to environmental conditions, navigational risks, and international competition, the NSR's potential to reshape global energy transport remains undeniable, positioning it as a crucial component of future energy supply chains.

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[398] Walker (no date).

[399] Gross (2020); Pezard (2018).

[400] Ibid.

[401] Ibid.

[402] Yamal LNG Website (no date).

[403] Gross (2020); Pezard (2018); Yamal LNG Website (no date).

Chapter 5: Conclusions

5.1. Summary and Conclusions

This thesis investigated the geopolitical and economic implications of global maritime energy transportation, with a particular focus on the resilience of key chokepoints. Maritime chokepoints, such as the Strait of Hormuz, the Malacca Strait, the Suez Canal, and Bab el-Mandeb, serve as critical passageways for the transportation of oil and liquefied natural gas (LNG). However, these chokepoints are highly vulnerable to disruptions caused by geopolitical conflicts, piracy, terrorism, and environmental hazards. Given their strategic importance, securing these routes is paramount for global energy stability and economic security.

To assess the vulnerability and adaptability of these chokepoints, this study developed a Chokepoint Resilience Index (CRI), an analytical framework that evaluates resilience across six dimensions: geopolitical, economic and trade, alternative routes, geomorphological, historical, and environmental resilience. Through a comprehensive analysis using quantitative data from 2020 to 2024, the CRI provided a systematic method for measuring the ability of each chokepoint to withstand disruptions.

The findings indicated that the Strait of Hormuz ranks as the most resilient chokepoint. The Strait demonstrates positive contributions across dimensions, particularly excelling in D3 (Alternative Routes Resilience) and D6 (Environmental Resilience), resulting in the highest overall resilience score. Despite the fragile geopolitical environment in the Middle East and the Persian Gulf, the presence of multiple state actors, strong U.S. military presence, and a well-established network of oil and gas pipelines contribute to Hormuz's resilience.

In contrast, Bab el-Mandeb emerges as the least resilient, reflecting regional instability, frequent security threats, and the recent Houthi attacks in the Red Sea. The chokepoint is limited in both capacity and security, offering minimal mitigation against disruptions caused by conflict (D1: Geopolitical Resilience) or by environmental disaster (D6: Environmental Resilience). The study also examined the impact of disruptions in the Red Sea, demonstrating how they have increased shipping costs, energy prices, and insurance premiums, ultimately affecting global trade flows.

Additionally, the thesis explored the Northern Sea Route (NSR) as an emerging alternative to mitigate dependency on traditional chokepoints. While the NSR offers shorter transit times and reduced shipping costs, its long-term viability is constrained by harsh environmental conditions, limited infrastructure, and geopolitical rivalries involving Russia and NATO.

5.2. Limitations and recommendations for further research

While this study provided a comprehensive assessment of chokepoint resilience, certain limitations must be acknowledged. The Chokepoint Resilience Index (CRI), despite its robust methodology, relied on data availability, which can be inconsistent across different regions. Some key dimensions—such as daily LNG carrier traffic, war risk premiums, alternative route LNG capacity, shipping distance, transit time, seismic activity, cyclone frequency, and coastal erosion rates—lacked sufficient numerical data, preventing their full inclusion in the final CRI calculations. Future research should focus on enhancing data collection to strengthen the accuracy and applicability of the CRI.

Another limitation is the dynamic nature of geopolitical and environmental risks, which evolve rapidly and may not be fully captured in a static index. While the CRI provided a historical snapshot of resilience, real-time assessments incorporating live maritime monitoring, geopolitical risk indices, and economic indicators would offer a more adaptive and predictive tool for policymakers and industry stakeholders.

Regarding the Northern Sea Route (NSR), the analysis was constrained by limited historical data on Arctic shipping and the evolving geopolitical landscape in the region. As Arctic ice conditions change and global interest in the NSR grows, future studies should explore the required infrastructure investments, legal frameworks, and environmental sustainability of this alternative route.

To overcome these limitations, future research should pursue the following directions. First, the development of real-time resilience monitoring through dynamic CRI models that integrate real-time data from maritime security networks, satellite surveillance, and economic indicators. Second, broadening the scope of chokepoint analysis to include additional strategic locations, such as the South China Sea and the Danish Straits, to enable a more comprehensive global assessment. Furthermore, the advancement of sophisticated economic simulations using high-resolution modeling techniques would enhance the analysis of macroeconomic impacts stemming from chokepoint disruptions, particularly in relation to energy prices, insurance costs, and supply chain efficiency. Finally, incorporating machine learning and predictive analytics would facilitate the assessment and forecasting of geopolitical risks affecting maritime energy transportation, thereby strengthening the robustness of future research in this field.

By addressing these areas, future research can further enhance the understanding of chokepoint resilience, providing actionable insights for securing global energy supply chains and ensuring maritime stability in an increasingly volatile world.

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