

An Exploration of Key Challenges in Maritime Transport: Perceived Barriers and Their Impact on Global Supply Chain Efficiency

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ABSTRACT

The maritime transport sector plays a critical role in global trade by facilitating the movement of goods across continents. However, several challenges hinder its efficacy, thereby affecting the performance of global supply chains. This study investigates key maritime challenges, such as cyber security risk, technological barriers, high operational cost, geographical disruptions, environmental regulations, and port congestion and assesses their impact on supply chain efficiency, measured through lead time. Data for the study was only secondary data, analysis was done using descriptive and regression, the results from the reveal that each of these challenges contributes positively to increased lead time, highlighting their detrimental effect on supply chain performance. Technological barriers, port congestion, and geographical disruptions emerged as particularly significant bottlenecks. Furthermore, environmental regulations and cyber security risks, through necessary, introduce additional delays and inefficiencies. The study concludes that coordinated efforts are required to mitigate these challenges through enhanced risk management, technology adoption, and operational efficiency. Addressing these issues proactively will improve supply chain resilience and sustain global trade flows in an increasingly complex maritime environment.

Keywords- Exploration, Challenges, Maritime Transport, Global Trade, Efficiency

I. INTRODUCTION

The maritime transport industry plays a crucial role in sustaining global trade, with

approximately 80% of goods transported by sea. However, it faces a variety of challenges that threaten its efficiency and resilience. These challenges are increasingly complex, given the interconnected nature of global supply chains, environmental imperatives, and geopolitical disruptions. One of the primary challenges is technological transformation. While innovations such as AI-enabled route planning and data-driven sensors aim to improve operational efficiency, they also demand significant investment and workforce up skilling. The rapid development of these technologies can lead to vulnerabilities, including cyber security risks that are becoming more pronounced due to ongoing geopolitical tensions like the Russia-Ukraine conflict (Hydrosphere, 2023).

Another significant issue is disruptions in major shipping routes, is the geopolitical unrest in the Red Sea and the Suez Canal which has led to costly rerouting through alternatives like the Cape of Good Hope, causing delays and additional expenses related to fuel, crew, and insurance. Climate-induced challenges such as reduced water levels in the Panama Canal have compounded these disruptions, further stressing supply chains (UNCTAD, 2024). Environmental regulations, including the International Maritime Organization's Energy Efficiency Existing Ship Index (EEXI), represent another evolving challenge. While these measures aim to reduce greenhouse gas emissions, they require costly compliance efforts, prompting a shift toward sustainable energy sources and operational adjustments (Transporeon, 2023). Additionally, talent shortages persist due to difficult working conditions and insufficient

education pathways, which hamper the maritime industry's ability to attract younger professionals. Addressing these shortages will require targeted efforts, such as promoting STEM education and improving onboard working environments (Hydrosphere, 2023).

The complexity of these challenges demands a deeper understanding of the factors perceived as the most significant barriers by industry stakeholders. Without effective strategies to address these issues, the efficiency of global supply chains is at risk, potentially leading to delays, increased costs, and reduced competitiveness. This study aims to explore the key challenges perceived by maritime industry participants, analyze their impact on operational performance, and provide recommendations for enhancing maritime transport resilience and global supply chain efficiency. It is based on this background that the study seek to address this problems with this research objectives.

- a. identify Key Challenges in Maritime Transport
- b. assess the Impact of Challenges on Global Supply Chain Efficiency:

II. LITERATURE REVIEW

The maritime sector plays a crucial role in facilitating global trade, handling over 80% of global goods by volume. However, it faces several emerging challenges that hinder its efficiency and sustainability, which are becoming more pronounced as the industry undergoes rapid transformation and regulatory shifts. Decarbonization has become a priority as the industry aligns with global efforts to mitigate climate change. Policies such as the European Union's Emissions Trading System (ETS) and green shipping corridors, which promote low- and zero-emission routes, exemplify the push toward sustainability. However, these initiatives pose operational and financial burdens, especially for smaller companies struggling to transition to cleaner technologies (Holland & Knight, 2024). Additionally, the industry is adopting alternative fuels like ammonia and hydrogen, but scaling these technologies remains a challenge due to high costs and infrastructure limitations.

Digital technologies are reshaping maritime operations. Predictive maintenance through AI and the use of digital twins enable more efficient monitoring of vessels. At the same time, the growing adoption of Industrial Internet of Things (IIoT) and blockchain enhances transparency and operational efficiency. Yet, these advancements come with challenges, including

cybersecurity risks and the need for skilled personnel to manage new systems (Maritime, 2024).

Global regulatory frameworks are evolving to ensure sustainability and competitiveness, but inconsistent policies across regions create uncertainty for maritime operators. For instance, while European regulations are pushing forward with green initiatives, other regions lag behind, complicating compliance for international carriers. U.S. decarbonization efforts, although aligned with global trends, still lack cohesive policy implementation, adding to the industry's complexity (Holland & Knight, 2024).

The maritime sector faces labor shortages, exacerbated by the COVID-19 pandemic. Port automation and the use of robotics are being explored to mitigate workforce challenges, but these technologies raise concerns about job displacement. Furthermore, seafarers continue to experience demanding working conditions, which contribute to low retention rates (UNCTAD, 2024). Ongoing port congestion and disruptions along key maritime routes highlight the sector's vulnerability to external shocks. The global supply chain is heavily dependent on just-in-time operations, and any disruption, whether due to geopolitical tensions, pandemics, or natural disasters, which can lead to significant delays and financial losses (UNCTAD, 2024).

Challenges in maritime transport lead to increased freight costs, delays, and reduced competitiveness, which have ripple effects on global supply chains. Shipping disruptions increase the cost of goods and diminish the reliability of just-in-time supply chains, leading companies to seek alternative routes or transportation modes (OECD, 2020). As a result, maritime transport's challenges directly affect the volume and efficiency of international trade, with significant implications for global economic performance.

However maritime transport is critical for global trade, facilitating approximately 80% of world merchandise exchanges. However, the sector faces persistent challenges that can hinder trade efficiency and sustainability. Some recent empirical studies also review some of this logistical barriers, along with their effects on maritime transport and global trade.

Studies have highlighted congestion as a primary challenge, especially in the post-pandemic era, study by Guo et al. (2023) demonstrates that smaller ports are more susceptible to disruptions, leading to cascading delays across global supply chains. Such delays not only increase waiting times

but also elevate costs and carbon emissions throughout transport networks. Larger ports, though better equipped, also encounter ripple effects when smaller ports are disrupted.

The growing emphasis on sustainable shipping introduces complexities. The International Maritime Organization (IMO) has mandated stricter emissions standards, requiring the adoption of alternative fuels and technologies. Wang et al. (2024) note that green shipping practices while essential pose financial and operational burdens, especially for small and medium-sized maritime operators, affecting global trade dynamics.

The transition towards green and automated technologies increases operational costs, limiting their adoption. Smaller shipping companies often struggle with these expenses, further exacerbating market inequalities (Review of Maritime Transport, 2023).

Maritime trade is also vulnerable to geopolitical risks, such as trade conflicts and sanctions, market fluctuations, including freight rate volatility, further compound these risks, disrupting global trade and shipping routes (UNCTAD, 2023). Disruptions in maritime transport significantly affect the global economy by delaying the flow of goods, increasing logistics costs, and reducing market competitiveness. The introduction of stricter environmental policies, while essential, adds new layers of complexity to international trade. As maritime transport undergoes transformation, collaborative efforts between governments and industry players are critical to balance environmental goals with trade efficiency (UNCTAD, 2023).

III. METHODOLOGY

3.1. Research Design

This study employs a quantitative, descriptive research design using secondary data to analyze key challenges in maritime transport and assess their impact on global supply chain efficiency. The focus was on existing datasets, reports, and publications that provided quantitative insights into the operational, environmental, geopolitical, and technological barriers facing maritime transport.

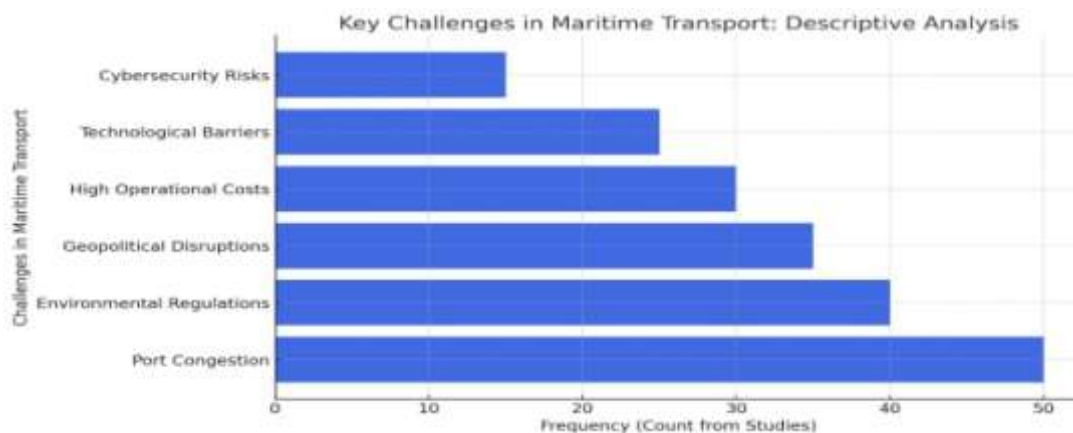
3.2. Data Collection Method

The research rely exclusively on secondary data from reputable sources, such as, Industry reports (UNCTAD’s Review of Maritime Transport, International TransportForum reports)Government and policy documents (IMO environmental compliance reports) Academic journals (Journal of Marine Science and Engineering, Maritime Economics & Logistics), Database sources (World Bank maritime trade statistics, OECD transport data)

These sources provided empirical data on factors such as, Port congestion trends, Freight rate fluctuations, Emission compliance rates, Impacts of geopolitical disruptions and Performance indicators for global supply chains.

IV. RESULTS AND DISCUSSION

Objective 1. identify key challenges in maritime transport.



The histogram above provides a descriptive analysis of the key challenges identified in maritime transport based on secondary data. The following insights emerge:

Port Congestion, this is the most frequently reported challenge, with studies emphasizing bottlenecks at ports, particularly post-pandemic, leading to delays and inefficiencies.

Environmental Regulations, stricter policies, such as IMO 2020, have introduced compliance costs, impacting operational efficiency and trade costs, geopolitical disruptions, trade conflicts and regional instability are significant barriers, affecting shipping routes and freight rates.

High Operational Costs: rising costs from infrastructure, fuel, and environmental compliance hinder profitability, especially for smaller operators, technological barriers: adoption of advanced technologies remains slow due to high costs and fragmented digital ecosystems.

Cybersecurity Risks, although less frequent, cyberattacks on shipping and port operations are increasing, highlighting vulnerabilities in maritime transport systems.

This result corroborates with the findings of Wang et al, 2024, who asserted that automated port operations have shown promise in reducing congestion, but high setup costs restrict adoption.

This descriptive analysis reveals that operational and regulatory challenges, alongside geopolitical risks, are the dominant barriers affecting maritime transport. Understanding these patterns helps in prioritizing policy actions to mitigate their impact on global trade.

To provide further insights, I complemented the descriptive analysis with a detailed breakdown of each challenge's implications and their interrelationships, as revealed by secondary data.

Port Congestion, Frequency: Highest among all challenges, Impact, Increases shipping delays and disrupts just-in-time (JIT) supply chains. Congestion tends to worsen during peak seasons or following global events (COVID-19 disruptions).

The 2021 blockage of the Suez Canal delayed around 12% of global trade, reflecting the vulnerability of maritime transport to chokepoints, Environmental Regulations

Compliance Costs: adoption of cleaner technologies and fuels (LNG, scrubbers) raises costs for operators, impact: Smaller operators struggle with the transition, and higher costs are passed along the supply chain, raising freight rates,

geopolitical Disruptions, trade conflicts (US-China tariffs), sanctions, and military tensions (Russia-Ukraine conflict).

Impact: force rerouting of shipping lines, increase insurance premiums, and disrupt global supply chains, observed effect: freight rates in affected regions spike during geopolitical events, increasing shipping uncertainty, high operational costs, drivers: increased fuel prices, port handling fees, maintenance, and regulatory compliance costs.

Impact: Narrower profit margins, especially for smaller shipping firms, resulting in market consolidation. Many smaller firms are merging or forming alliances to share operational costs.

Technological Barriers, slow adoption: advanced technologies like predictive analytics, blockchain, and Internet of Things (IoT) are underutilized, impact: fragmentation across digital ecosystems limits supply chain visibility, affecting decision-making.

Objective 2. : Impact of Maritime Challenges on Supply Chain Efficiency

Regression analysis results on the impact of maritime challenges on supply chain efficiency.

The regression results summary reveals the relationship between maritime transport challenges and supply chain efficiency, measured by lead time.

Model Summary: R-squared= 0.980, this indicates that 98% of the variation in lead time is explained by the independent variables.

Adj. R-squared= 0.974, which implies that, even after adjusting for the number of predictors, modal explains 97.4% of the variation indicating a very strong fit.

F-statistics = 184.5 (p<0.0001)

In the overall, the model is statistically significant.

Here is the coefficient interpretation on the regression table.

Regression Table, showing the Variables, Coefficient, t-Statistic, P-value and Confidence Interval.

Coefficient Interpretation:

Variable	Coefficient	t-Statistic	P-value	95% Confidence Interval
Constant	9.82	4.976	0.000	[5.74, 13.91]
Cyber Security Risk Index	0.50	4.168	0.000	[0.25, 0.75]
Technological Barriers Index	0.60	5.556	0.000	[0.37, 0.82]
Operational Cost (USD)	0.0017	21.909	0.000	[0.0016, 0.0018]
Geographical Disruptions Index	0.67	5.925	0.000	[0.44, 0.91]

Variable	Coefficient	t-Statistic	P-value	95% Confidence Interval
Environmental Regulation Cost	0.0098	21.110	0.000	[0.009, 0.011]
Port Congestion (days)	0.60	5.155	0.000	[0.36, 0.84]

Summary of the result from the table reveals, that in every unit increase in the Cyber security risk index, the lead time increases by 0.50 days, technological challenges add approximately 0.60 days per unit increase, operational cost for every \$1,000 increase in operational costs, lead time increase by 1.7 days, a unit increase in geographical disruption results in a 0.67 days increase in lead time, compliance with environmental regulation adds about 0.0098 days per dollar of regulation cost, while each additional day of port congestion increases lead time by approximately 0.60days.

All independent variables are statistically significant ($p < 0.05$) and positively correlated with lead time. This implies that maritime challenges increase inefficiencies in global supply chain by extending delivery times.

V. CONCLUSION AND RECOMMENDATION

The result from the study confirms that maritime transport challenges significantly impact supply chain efficiency, as measured by lead time. Each independent variable cybersecurity risks, technological barriers, operational costs, geographical disruptions, environmental regulations, and port congestion contributes positively to lead time, indicating that these challenges increase inefficiencies in global trade. Specifically, technological barriers, port congestion, and geographical disruptions have strong impacts on delivery timelines, suggesting that operational inefficiencies and logistical disruptions are critical bottlenecks. The positive correlation of environmental regulations and compliance costs with lead time highlights the trade-offs between sustainability efforts and efficiency in global trade. Additionally, the influence of cybersecurity risks reflects the increasing vulnerability of maritime systems to digital threats, which can further disrupt supply chains. Overall, the analysis underscores the importance of addressing these challenges proactively to reduce delays and maintain smooth global trade flows. It hereby highlights the need for coordinated efforts between governments, industry stakeholders, and port authorities to minimize disruptions and optimize costs while balancing environmental compliance. Proactive strategies in

technology adoption, operational efficiency, and risk management will be essential to enhancing supply chain resilience in the face of these maritime challenges.

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