

MARITIME SUPPLY CHAIN DISRUPTIONS: AN AI-CONCEPTUAL FRAMEWORK FOR GEOPOLITICAL RISK FORECASTING

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Abstract: *In recent years, maritime trade supply chains' resilience was continually tested by an array of political, economic, security and technological global evolutions. The dynamic pace of subsequent routes and logistics changes, set by events such as the COVID-19 pandemic, multiple military conflicts, trade wars, brought under the spotlight key vulnerabilities of so-called neuralgic points of the world trade and a need for agile adaptations. Additionally, the AI-led technology revolution aiming to increase efficiency of maritime trade placed additional stress on suppliers struggling to navigate the constantly changing political and security paradigm. The present article analyses the evolving intricacies of maritime supply chain logistics in the context of geopolitical uncertainty and AI-uptake, and proposes a conceptual framework for an AI-powered tool, which can be adopted by logistics providers to navigate them. The research methodology includes a dual quantitative-qualitative approach, including statistical analysis for measuring strategic traffic patterns, as well as applied intelligence analysis methods such as the trend impact analysis, stakeholder mapping, and case study analysis for understanding political and commercial nuances of maritime trade challenges. By offering a brief panorama of the geopolitical risks and a concept for AI potential use on shipping, this research aims to provide a strategic framework for businesses to navigate these challenges effectively, ensuring continuity and efficiency in global supply chains.*

Keywords: maritime trade, AI, geopolitical risk

1. Introduction

In recent years, the resilience of maritime trade supply chains was tested continuously by an array of high-impact political, economic, security and technological global evolutions. The dynamic pace of subsequent routes and logistics changes, set by events such as the COVID-19 pandemic, multiple military conflicts, Houthi rebellion, ISIS, US-China trade wars, brought under the spotlight key vulnerabilities of so-called neuralgic points of the world trade and a need for agile adaptations. Additionally, the AI-led technology

revolution aiming to increase efficiency and performance of maritime trade placed additional stress on freight forwarders struggling to navigate the constantly changing political and security paradigm. Key applications under testing include time, cost- and fuel-efficient navigation routes, real-time decision support systems, risk analysis, resource management, predictive maintenance.

The present paper forms part of a larger study, and aims to analyse the evolving intricacies and challenges of maritime supply chain logistics in the context of geopolitical uncertainty and AI-uptake.

Furthermore, it explores potential uses of AI in forecasting geopolitical risks and provide early-warning alerts to logistics providers working in maritime shipping based on a select number of indicators. Indicators are pre-set in accordance with industry specificities and relevance, and are adjustable based on the vessel's pavilion, logistics supplier size and trade flow levels. As global geopolitical volatility increases, the current research explores the merits of incorporating AI into risk management tools and its value to providing early warning signals of new challenges ahead. This serves a foundation for logistics suppliers' business continuity plans, helps them foresee new challenges, and allows companies to build their resilience on the short, medium and long term.

In continuation of this paper, we will briefly showcase the strategic importance of maritime trade logistics, in particular shipping, and its close dependency on the geopolitical climate for optimal transit routes.

2. Maritime Supply Chains in the Disruptions Era

Maritime supply chains, with shipping at the core, constitute the backbone of the world economy and its international trade flows. According to CSIS, sea freight forwarding accounts for approximately eighty percent of global trade by volume, and seventy percent by value. [1]

Numerous researchers have emphasized the importance of optimizing maritime transport for national economies, and mapped the political influence gained by those controlling strategic trade routes, straits, canals, ports. As Sopford showed, maritime transport efficiency transport can reduce transaction cost, increase competitive advantage, and integrates peripheral economies into the global trade market.[2] Mahan's classical sea power concept from the 19th century argued that control over maritime routes ensure maritime dominance, and implicitly,

economic gains. Mahan outlined six main conditions that reportedly influenced the so-called sea-power of a nation: geographical position, physical conformation, territory size, population size, national character and government character. [3] In recent literature, Till expanded the six conditions to include maritime domain awareness, cyber control of port infrastructure, and militarization of artificial islands in disputed waters such as the South China Sea [4]. Rodrigue and Notteboom found that a country's trade competitiveness can be directly correlated to the quality of the port infrastructure set-up on its shores [5]. Hall and Jacobs showcased that the port-city interface and connectivity can drive regional development and foreign investment. Strategic shipping nodes such as Rotterdam or Shanghai positioned themselves as economic clusters, as they provide not only logistics services, but also financial, manufacturing, energy distribution connected services [6]. Furthermore, political actors with control over maritime crossings such as the Suez Canal, Panama Canal, Hormuz Strait, have had a strong upper hand in regional power struggles along the years. Kraska reported that nations with strong naval power and control over such crossings often use this as leverage to gain geopolitical disproportionate influence, making shipping subject to sometimes unpredictable new economic or political demands. Disruptions caused in these situations often can affect global markets, particularly in regards to energy and agriculture supply [7]. One recent example can be found in the Russian-Ukraine's conflict and its effect on disrupting grains export supply chains from Europe to African states, de facto challenging the continent's food security. After initially blocking Ukrainian grain's export shipping through the Black Sea to Africa, to increase its political influence, Russia reportedly had sent out 200,000 tonnes of free grain shipments to countries such as Somalia,

Central African Republic, Mali, Burkina Faso, Zimbabwe [8]. In exchange for the support, Russian forces were allowed deployment in Burkina Faso, Central African Republic, and Russia gained additional economic advantages such as a Russian-built oil refinery in Mali [9]. Another example of a country using maritime shipping to increase its political influence in other regions is the initiation of the Belt and Road Initiative, China's flagship global infrastructure project, that uses port development for influence projection [10]. As Heath and Erickson showed, Chinese investments in foreign ports are often tied to economic advantages, and political alignment [11].

However, despite its strategic importance for economic and political actors all around the world, maritime trade has been facing numerous challenges. The dynamic pace of subsequent routes and logistics changes, set by events such as the COVID-19 pandemic, Houthi rebellion, multiple military conflicts, ISIS, Panama Canal takeover, US-China trade wars, brought under the spotlight critical vulnerabilities of so-called neuralgic points of the world trade and a need for agile adaptations.

Researchers Bueger and Edmunds showcased how governance gaps are identified in fragile regions, affected by corruption and weak rule of law, exposing maritime routes to issues such as terrorism, piracy, and smuggling. [12] For example, Houthi rebel activities on the African East Coast initially brought all-across challenges to transport costs and logistics efficiencies due to attacks on merchant ships in the Red Sea, as ships access from Asia to Europe turned arduous. Political actors had to step in to safeguard the passage of ships sailing under their pavilions. For instance, to protect its own interests, according to Alastar [13] and Karnitschnig [14], China began financing Houthi activities and supporting Iran's operations against US vessels, thus further deepening the ongoing US-China trade war. Freight forwarders'

safe passage in the area remains directly dependent on the political actor supporting them. Across the globe, to secure US vessels' seamless transit through the Panama Canal, President Trump's administration took a hard approach including launching discussions of US takeover of the canal, justifying it as a way to curb Chinese influence in the region against US interests. [15] According to Atlantic Council experts, the majority of cargo transported through the Panama Canal was shipped from or to the US, with the Canal being a key point of LNG transfer from the US and Brazil to Asia [16].

These incidents led throughout the years to the rise of geopolitical risk as one of the key challenges for maritime supply chain management, and one of the core facets to tackle to build resilient trade flows. According to CSIS (2024) significant disruptions, often interconnected, also included piracy, or environmental threats such as climate change and port infrastructure/logistics [1]. Psaraftis showed that maritime transport is a major contributor to global emissions, which would only be tackled by politically agreed upon sustainable logistics and green port policies such as fuel innovation, slow steaming and emission trading schemes [17].

Additionally, the AI-led technology revolution aiming to increase efficiency and performance of maritime trade placed additional stress on freight forwarders struggling to navigate the constantly changing political and security paradigm. Alternative technologies developed, including blockchain technology and digital trade platforms development in container transport. Durlík researched how AI tools are being currently developed to enhance maritime safety and risk management. Key applications include efficient navigation systems, real-time decision support systems, risk analysis, crew resource management, hazardous materials handling, predictive maintenance [18]. However, other researchers such as Notteboom

emphasized the risks of over technologization and AI-use, signalling that new vulnerabilities, specific to digital technologies, could pose national security risks [19]. As we are currently activating in a so-called “Era of Disruption”, an era in which technology evolves at a more rapid pace than businesses and economies, and in which it is often weaponized for economic or political gains, it is essential for actors to understand how to use it to their advantage [20].

In the following section we will briefly introduce the methodological approach utilized to analyse ways AI can be used to enhance maritime supply chain’s resilience to political risks.

3. Methodological Approach

The research methodology includes a dual quantitative-qualitative approach. Quantitative methods comprise statistical analysis such as time series analysis for pattern identification and anomaly detections, network analysis for event impact analysis and predictive modelling for measuring maritime transport routes efficiency. Qualitative methods include applied intelligence analysis methods such as stakeholder mapping and analysis, and case study analysis for understanding political and commercial nuances of maritime trade challenges. By offering a complex panorama of the geopolitical risks and AI impact on shipping, this research aims to provide a strategic framework for businesses to navigate these challenges effectively, ensuring continuity and efficiency in global supply chains.

4. AI-use for Political Risk Supply Chain Resilience Building

4.1. Shipping Disruptions and Early Warning Needs

Maritime shipping remains at the foundation of supply chain logistics as the world economies’ interconnection evolved, with supply chains nodes becoming intricately linked across many far-away geographical locations. As it proved to be

reliable, flexible in adjusting routes when needed, and capable of moving large amounts of goods in a cost-effective way, maritime shipping was favoured above alternative means of transport. However, as freight forwarding crosses neuralgic checkpoints and contested borders, shipping remains exposed to political unrest and other geopolitical threats.

Strategic trade corridors, including shipping routes, have been vulnerable to military or political conflicts for centuries – nowadays there is no exception. Research suggests that key elements that have a direct and significant impact on shipping include military actions, political instability and its associated linkages (corruption, ship safety, harassment, theft risks), maritime chokepoints power struggles, economic blockades, sabotage of port facilities and threats to the safety of passing vessels. Connected political measures also implicitly affect the global flow of goods such as sanctions, embargoes, trade restrictions, fuel prices, insurance premiums, and increased rerouting costs [21]. One recent example is the continuous conflict in Ukraine, which highlighted the vulnerability of Black Sea shipping routes, after a series of blockades, drone assaults on port facilities, and vessels’ safety threats led to significant disruptions in the region. The opening of the Arctic area, which provides fresh trade routes as the local ice melts, is yet another illustration [21]. However, ongoing discussions over the sovereignty of the Arctic region indicate the risk of new conflicts appearing over trade control and thus, sets the need for logistics providers to monitor and safeguard against their ramifications as time goes on.

Logistics companies often need to have business continuity plans set in place to respond to shipping disruptions. The adoption of smart shipping technologies can help companies optimise routes in a dynamic way to ensure delivery. However, there is a research gap in effective early warning of new political risks that may

impact the decision to maintain a route or change it.

4.2. AI: Political Risk Early Warning Uses in Shipping

As part of the present research, the following section introduces the concept of an AI tool that helps logistics supplier respond as early as possible to changes in the political environment in which it operates.

Requirements

The first step is to clearly map the user requirements. Desk research conducted as part of a wider study of the paper author suggest that the following key elements should be included in such a tool:

1. Dynamic Route Assessment (to flag signs of instability along the ship's route). Data sources may include Sentiment Analysis on news outlets or social media channels, AIS data, OSINT for port monitoring (this may include satellite imagery for destination port).
2. Pre-determined Country Risk Profiles (to flag country/ regional score based on political risks identified). Data sources may include sanctions and embargoes lists, port unrest reports, government stability indicators, military conflict indicators.
3. Predictive Analytics for Strategic Planning (to allow time for alternative plans in case of disruptions). Data sources may include historical political and economic data analysed through a time-series forecasting for long-term fleet deployment modelling.

Architecture

Based on the requirements mapped, the proposed architecture overview would include five layers:

1. Data Collection (continuous collection of real-time data)
2. Data Analytics (time series analysis for pattern identification and anomaly detections, network analysis for event impact analysis and predictive modelling for measuring maritime transport routes efficiency)
3. Risk Assessment (Score level of risk

for transit and destination country/port/route average with danger nodes)

4. Alerting and Decision Layer (incident alerts, risk mitigation suggestions)

5. User Interface (API/ user dashboard)

AI Components suggested:

1. Geopolitical Event Classifier (technique – BERT); Anomaly Detection (technique- Clustering and Isolation Forest)
2. Trend Forecasting (technique -time series analysis);
3. NLP (topic modelling).

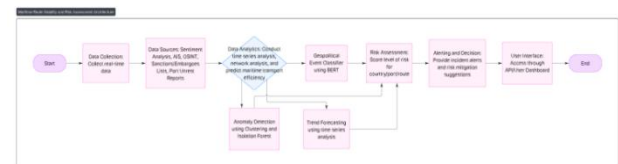


Figure 1: Author-generated

The final concept's benefits could include: shipping decreased response time and costs, increased personnel, vessel and merchandise safety, decreased insurance premiums, efficient strategic fleet operational planning. The concept's drawbacks may include high costs of use (especially for satellite imagery processing), threat alert missing for vessels with AIS turned off).

4.3. Recommendations

This section aims to provide brief recommendations for logistics suppliers wishing to deploy an AI-tool for political risk early warning.

To start, users of any AI tool developed for shipping should start by proactively planning the route with the support of any available risk map and predictive route planner made available. Chokepoints should be avoided when risk trends begin rising. Additionally, a balance should be maintained between the costs of any route deviation and the risks identified. Routes planned for countries with a low governance quality score, or active security threats, should be reassessed with a high frequency.

Moreover, real-time alerts should be activated for high-risk ports and regions, especially when there are known planned events tracked (e.g., upcoming elections or protests).

Sensitive routes that may require special insurance coverage or premiums should be cross-references with supplier and cargo exposure.

Dedicated political risks tool should be integrated in the supplier's Transport Management System to ensure proper vessel scheduling and allocate time for deviations, if necessary.

5. Conclusions

As global geopolitical volatility increases, this paper explores the concept of integrating AI to support political risk

management into more traditional risk management tools and its value to providing early warning signals of new challenges ahead. This serves a foundation for logistics suppliers' business continuity plans, helps them foresee new challenges, and allows companies to build their resilience on the short, medium and long term.

By providing a conceptual framework for AI-based political risks applications in shipping, the paper aims to facilitate ongoing risk management automation processes in shipping.

The present paper forms part of a multiple series of studies in the area of maritime logistics resilience building that will be published in the following years.

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