Analysis of the Impact of logistical and geopolitical uncertainties (Red Sea, Strait of Malacca, Panama Canal) on the resilience of global maritime supply chain

Ourssoula SIKAL[1], *Abdellah ZAMMA*[1], and *Mohamed EL KHAILI*[2]

[1] Laboratoire M2S2I, ENSET Mohammedia, Université Hassan II, Casablanca, Maroc
[2] Laboratoire IESI, ENSET Mohammedia, Université Hassan II, Casablanca, Maroc

Abstract. Strategic maritime chokepoints—especially the Red Sea/Suez system, the Strait of Malacca, and the Panama Canal—concentrate a disproportionate share of seaborne trade and therefore transmit shocks widely when disrupted. From 2000 to 2025 the literature evolved from network/port-system perspectives (e.g., port regionalization, connectivity indices) to event-based impact assessments (piracy, canal blockages, climate-driven restrictions), complemented by operational metrics such as schedule reliability and delay days. This article integrates those strands in a hybrid framework (AIS trajectory analysis + connectivity indices + event studies) and shows that shocks at chokepoints materially degrade reliability, extend transit times, and inflate costs, yet the magnitude and duration of those impacts depend on network structure (redundancy), governance, and timely operational responses.

Keywords— Geopolitical Uncertainties, Logistical Uncertainties, Maritime Supply Chain, Resilience.

1 Introduction

Global supply chains rely on a handful of sea lanes. UNCTAD highlights how pressures on Suez/Red Sea and Panama have recently lengthened routes, raised costs, and strained logistics; over 80% of world trade by volume still travels by sea. The Strait of Malacca remains a core artery for Asia–Europe energy and container flows. Such concentration means localized disruptions propagate system-wide, reducing reliability and increasing emissions through longe reroutings [1][2].

2 Literature review (2000–2025)

Corresponding author: sikal.ourssoula@gmail.com

2.1 Network structure, port regionalization and connectivity

Foundational work by Notteboom & Rodrigue (2005) reframed seaports as regionalized systems knit to inland hubs, shaping how corridor shocks ripple beyond coastlines. In parallel, UNCTAD's Liner Shipping Connectivity Index (LSCI, since 2004) provided a tractable measure of how countries/ports are embedded in liner networks and, indirectly, how exposed they may be to chokepoint dependencies [1][3].

2.2 Security shocks and piracy (2008–2015)

Empirical studies showed that Somali piracy raised shipping costs materially—often cited in the 8–12% range on exposed routes—and imposed broader welfare losses through insurance premia, rerouting and delay externalities. Southeast Asian piracy—including in/around Malacca—fell in the mid-2000s with coordinated policing but never disappeared entirely [3][4][5][6].

2.3 2021–2025: High-impact events and fragile reliability

2.3.1 Suez/Red Sea system:

The Red Sea crisis (late-2023 onward) pushed Far East–North Europe rates sharply higher (Xeneta data) and forced widescale Cape of Good Hope detours. The volume of crude/petroleum crossing Bab el-Mandeb fell >50% in Jan–Aug 2024 [7][8].

2.3.2 Panama Canal:

Prolonged drought (2023–2024) led to draft limits and booking rule changes, reducing daily transits and adding delays. ACP advisories and operations summaries document the measures and their trade significance [9][10].

- *Operational reliability:*

Operational reliability refers to the ability of maritime transport systems to maintain predictable schedules and stable service performance under varying conditions. In the context of choke-point disruptions (e.g., Suez or Panama), reliability becomes a proxy for both logistical efficiency and systemic vulnerability.

Between 2018 and 2025, global schedule reliability fluctuated sharply — dropping from over 80% pre-COVID to around 50–55% in 2024 (Sea-Intelligence, 2025). These variations illustrate how localized shocks propagate through global supply chains, affecting port congestion, carriers alliance, and cost structures.
Integrating operational reliability into the analytical framework thus allows quantifying the tolerance threshold of maritime networks — the point at which delays cascade into broader systemic inefficiencies [11].

3 Analytical framework and hypotheses

3.1 Analytical framework

(i) **AIS (Automatic Identification System)** data to compute extra nautical miles, transit times, rerouting patterns [1][2][11].
(ii) **LSCI (Liner Shipping Connectivity Index)** to capture structural connectivity [1][2][11].
(iii) **Event windows** around disruptions (Panama drought 2023_2024; Red Sea escalation late -2023 to 2025) and compare exposed vs non-exposed trades using difference-in-differences [1][2][11].
(iv) **Operational KPIs** (schedule reliability, delay days...) [1][2][11].

3.2 Hypotheses

- **H1 (Reliability):** Chokepoint shocks significantly reduce schedule reliability and increase delay days on exposed routes [11].
- **H2 (Structure):** Higher LSCI centrality without alternative arcs amplifies shock impacts; redundancy dampens them [1].
- **H3 (Governance/response):** Flexible booking/governance (e.g., ACP rule changes) and fast rerouting shorten recovery times [8].

4 Case evidence

4.1 Red Sea / Bab el-Mandeb (2024–2025)

4.1.1 The crisis triggered network re-wiring:

frequent Cape detours increased ton-miles, fuel use, and crew time; insurance premia rose; and freight rates on Asia–Europe spiked in tandem with capacity withdrawals and pre-CNY surges [7]. UNCTAD estimates that by mid-2024, rerouting away from Red Sea and Panama lifted global vessel demand ~3% and container-ship demand ~12% versus a no-disruption baseline—an economy-wide stress indicator [12]. Energy flows confirmed the scale: EIA tracked >50% drop in crude/products through Bab el-Mandeb in the first eight months of 2024 [8].

4.1.2 Resilience signal:

Despite higher costs and longer voyages, available ocean capacity and carrier alliance structures allowed rapid tactical rerouting, limiting outright supply failure—but at the expense of reliability (late arrivals) and price volatility borne by shippers [11].

4.2 Panama Canal (2024–2025)

4.2.1 Freshwater constraints

Severe freshwater constraints forced the ACP (Autoridad del Canal de Panama) to tighten drafts and modify booking rules, reducing transits and causing queues; ACP reports emphasize water-resource prioritization and long-term adaptation (e.g., additional reservoirs). The Canal still handles a material slice of global trade and links 180 routes/1,900+ ports; capacity controls thus reverberate far beyond the Isthmus through schedule cascades and transshipment rotations [9][10].

4.2.2 Resilience signal:

Transparent, time-bound rules and a reservation system helped stabilize throughput under constraint and provided shippers with planning anchors, supporting quicker re-normalization once hydrological conditions improved [8].

4.3 Strait of Malacca (2000–2025)

Malacca's salience is long-standingin both energy security (the "Malacca Dilemma") and maritime security debates [14]. Earlier 2000s research mapped the costs of impeding shipping and the trade-offs of alternative tanker routes, while empirical work on piracy quantified transport-cost uplifts and insurance effects. While Malacca did not experience a single blockbuster disruption in 2024–2025, the corridor's systemic centrality makes it a latent risk amplifier; coordinated patrols have contained (not eliminated) piracy risks in the 2000s–2010s [4][5][13][14].

Table 1. Major Maritime Events and Impacts (2000–2025).

Year/Period	Event	Main Impact	Source
2008–2012	Somali Piracy	Freight rates +8–12%, higher insurance premiums, rerouting	Martínez-Zarzoso & Bensassi (2013), Besley et al. (2015)
2005–2015	Piracy in the Malacca Strait	Security costs, rerouting, insurance surcharges	Lanteigne (2008), Rimmer (2007)
2021	Suez Canal blockage	~USD 9.6 billion/day trade delayed, 300+ ships queued	UNCTAD (2024), Lloyd's List
2023–2024	Panama Canal drought	Draft restrictions, reduced daily transits, queues	Panama Canal Authority (2023–2024)
2024–2025	Red Sea/Bab el-Mandeb crisis	Cape rerouting, >50% drop oil flows, insurance premiums 0.5–1%	Notteboom et al. (2024), EIA (2024), UNCTAD (2024)

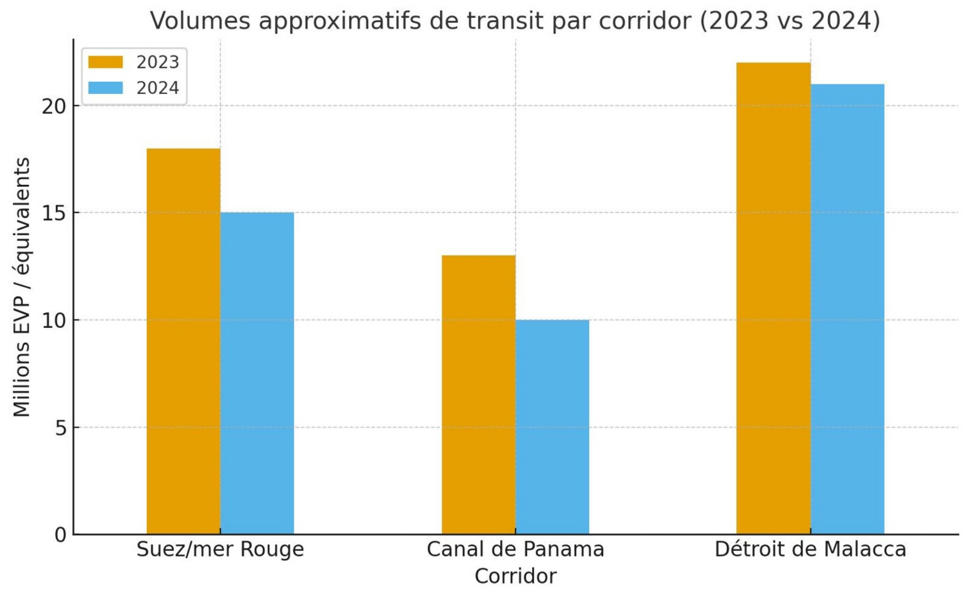

Fig. 1. Transit Volumes Through Strategic Corridors 2023 vs 2024 (Source: UNCTAD (2024), EIA (2024), Panama Canal Authority) [1][8].

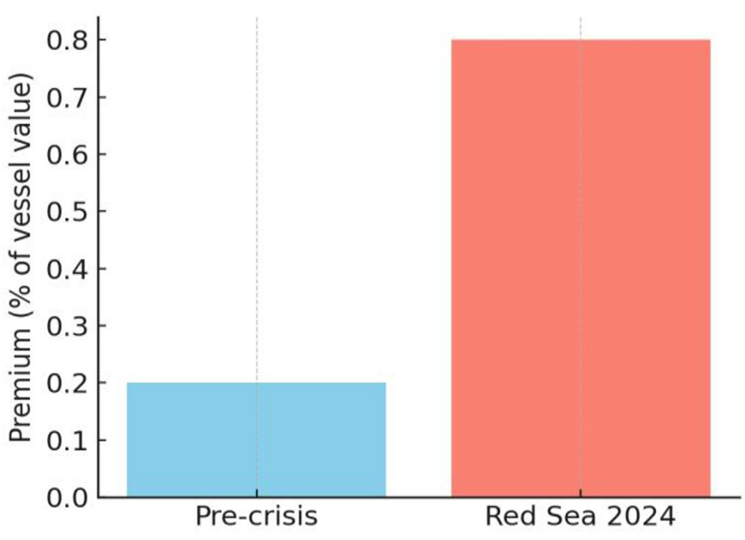

Fig. 2. Insurance Premiums under Chokepoint Disruptions (Source: Notteboom et al. (2024), Maritime Economics & Logistics) [1][7][8].

5 Cross-corridor synthesis: what drives resilience?

5.1 Concentration versus redundancy

The more single-corridor dependent a trade is, the larger the reliability hit when shocks occur; trades with viable alternates (longer, costlier, but available) exhibit faster functional recovery even if cost/emissions rise in the short run [12].

5.2 Limited systemic reliability

System-wide schedule reliability ~50–55% (2024) shows limited buffer; shocks push reliability down and delay days up, stressing berth windows, hinterland trucking, and inventory plans [11].

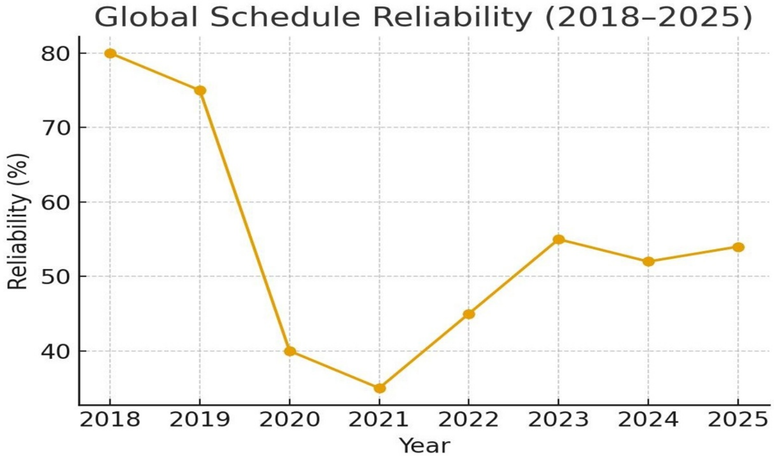

Fig. 3. Global Schedule Reliability 2018–2025 (Source: Sea-Intelligence (2025), Global Liner Performance Report) [1][2].

5.3 Governance and information

ACP's booking/draft policy changes and UNCTAD's chokepoint monitoring underscore how transparent rules and timely data reduce uncertainty and shorten recovery cycles [9][12].

6 Managerial and policy implications

6.1 Pre-planned rerouting and muti-carrier contracting

To reduce single-corridor exposure (Red Sea/Panama lessons) [12].

6.2 Corridor-level KPI dashboards

(reliability %, delay days, queue length, blank sailings) tied to automatic triggers for allocation and pricing responses [11][15].

6.3 Invest in resilient connectivity:

Backup gateways, inland links, and climate adaptation for water-constrained canals/ports (storage, watershed management) [9].

6.4 Multilateral transparency

On chokepoint conditions (security/hydrology) through UNCTAD/EIA style monitoring to inform shipper and carrier decisions [10][16].

Table 2. Key Indicators of Supply Chain Resilience.

Indicator	Definition	Value/Trend (2018–2025)	Source
Schedule Reliability (%)	Share of vessels arriving on time	Declined from ~80% (2018) to ~50–55% (2024)	Sea-Intelligence (2025)
Average Delay (days)	Late-arrival delays beyond schedule	~5.3 days (Dec 2024)	Sea-Intelligence (2025)
Global Vessel Demand (%)	Extra capacity needed due to rerouting	+3% vessels, +12% container ships (2024)	UNCTAD (2024)
Oil Transit (Bab el-Mandeb)	Share of oil/products crossing Red Sea	>50% decline (Jan–Aug 2024)	EIA (2024)

7 Future Prospects

7.1 Geopolitical Realignments

The expansion of alternative trade routes (e.g., Arctic passages, Belt and Rad maritime projects) may provide redundancy but also introduce new environmental and political risks.

7.2 Climate and Environmental Pressures

Investment in adaptive infrastructure and sustainable water management will become essential for corridor resilience.

7.3 Digitization and Artificial Intelligence

Wider adoption of AI-driven predictive analytics and Digital Logistics Platforms (DLPs) will improve visibility, schedule reliability, and risk anticipation.

7.4 Resilience-Oriented Governance

- Multilateral organizations (UNCTAD, IMO, OECD) are likely to play a greater role in coordinating real-time monitoring of chokepoints, publishing transparent data, and establishing resilience benchmarks.
- Regional agreements may focus on joint security patrols (as in Malacca) and cooperative water management (as in Panama).

7.5 Tanger Med Case Study

8 Conclusion

The management of logistical uncertainties is today a central issue for the resilience of maritime supply chains. The cases of the Panama Canal, the Red Sea, and the Strait of Malacca show that any local disruption can have systemic effects on global flows. Managing these uncertainties does not solely rely on responses, but on an integrated approach combining route diversification, digital innovation, climate adaptation, and cooperative governance. Strengthening logistical resilience thus involves anticipating crises, investing in infrastructure flexibility, and encouraging increased international coordination [17][18][19].

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