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Global Resilience in Transport and Logistics:

Navigating Disruptions With the GRIT Framework

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ABSTRACT

This study aims to develop the Global Resilience In Transport-and-Logistics (GRIT) framework designed to reinforce the resilience of global supply chains against a variety of disruptions, from pandemics to geopolitical tensions and environmental challenges. It facilitates devising robust, adaptable logistics and transportation strategies that help mitigate the challenges of supply chain disruptions. The research adopts a mixed-methods approach, combining a literature review with the conceptual foundation of the Stress and Strain model and the Theory of Graceful Extensibility. It adapts these concepts to the global transportation and logistics sector to develop the GRIT framework. The findings reveal the GRIT's potential in identifying critical areas for strategic intervention and thus enabling logistics managers to adeptly navigate disruptions. Through its application in a real-world scenario, the framework demonstrates its applicability and effectiveness in mitigating the impact of supply chain disruptions.

KEYWORDS

Global Logistics, Logistics Network Planning, Resilience, Supply Chain Disruption, Transport

INTRODUCTION

Recent years have seen significant supply chain disruptions—the COVID-19 pandemic, the Suez Canal blockage, port congestions, the Ukraine war, Middle Eastern conflicts, and the Houthi blockade of the Red Sea. These events reinforce the need for improved disruption management in supply chains to ensure continuity, highlighting the prominent theoretical trend of resilience planning (Grzybowska, 2021). The expansive structure of multiple nodes linked by transportation makes global supply chains vulnerable (Grzybowska & Stachowiak, 2022). Disruption at one point creates a ripple effect downward and across other supply chains. A lack of empirical data presents a unique challenge in estimating probabilities and magnitudes (Monostori, 2021). The aggregative effect of supply chain disruption increases shipping times, raises prices, and causes stock outs, especially for goods relying on delayed inputs. It significantly slows down the economy and is not fully offset by the recovery boost from faster shipping (Alessandria et al., 2023).

Logistics and transportation between nodes are critical in managing disruptions through geographical differences, varying regulations, and environmental standards. It requires sophisticated logistics planning and compliance (Bookbinder & Matuk, 2014). Global logistics and transportation are interconnected cyber-socio-technical systems that are maneuvered in their entirety when managing

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disruptions. Supply Chain Resilience (SCRes) is its adaptive capability of readiness, response, and recovery, ensuring operational continuity (Ponomarov & Holcomb, 2009). The principles of resilience include "control" in managing actions within the network, "coherence" or understanding disruptions, and "connectedness" of people uniting during crises. Flexibility, agility, and risk-sharing are associated with response and coherence.

With several global disturbances, 2022 revealed supply chain issues as a predominant vulnerability. It became the prime focus of corporate and investment strategies (EBRD Transition Report 2022-23 Business Unusual, 2022). Industry 4.0 technologies impact SCRes and enhance related key performance indicators (KPIs) (Marinagi et al., 2023). Companies have preferred maintaining their existing supplier relationships and network configurations, choosing tactical adjustments to improve resilience and competitiveness in managing risks (de Lucio, et al., 2023). The improvised solutions to the immediate issues of recent disruptions highlights the need for robust responsiveness in the present logistics market. This study introduces the GRIT framework, aimed at assisting in a thorough investigation of Performance Indicators (PIs) for addressing disruptions and reinforcing resilience. Grounded in Global Transport and Logistic (GTL) principles and business sustenance, the GRIT framework is designed to be a preliminary tool that could evolve into a widely accepted industry standard.

Objective

Global logistics face a myriad of disruptions, highlighting the complex challenges of supply chains and the need for resilient, adaptive strategies. The objective of this study is to establish a knowledgebase for identifying critical areas for strategic intervention and developing a framework to guide logistics managers in resilience planning. The GRIT framework embodies resilience—toughness, determination, endurance—a tool for addressing immediate issues and enhancing system resilience. It is a strategic, informed approach to managing and mitigating the effects of supply chain disruptions.

Research Method

The mixed-method research approach is used in developing the GRIT framework. This method combines elements of both qualitative and quantitative research along with a case study analysis.

LITERATURE REVIEW

Supply Chain Disruption

Global supply chains are governed by international trade regulations, depend on local infrastructure, and serve diverse stakeholders. Functioning in tandem globally, the systemic risks of interconnectivity are addressed through transparency, inclusivity, and resilience (Goldin & Mariathasan, 2014, pp. 325–327). Logistics enhancements notably boost the competitiveness and efficiency of international trade (Ma et al., 2021).

Informed decision-making underlines the benefits and vulnerabilities of global networks, balancing their risk and profitability, and accurate risk assessment incorporates both direct and indirect measures. Complex interdependencies within supply chains advocate exhaustive analyses of broader economic impacts and strategic risk management to enhance resilience in a globalized economy (Baldwin & Freeman, 2022). Consequently, a country's logistics performance is measured by the quality of services like tracking, timeliness, customs, and infrastructure (Shikur, 2022).

Research shows that a network-centric approach supports mitigation of disruption and recovery mechanisms, identifying bottlenecks, comprehending the ramifications, and implementing network resilience. Furthermore, a broader base of stakeholders, especially government agencies, fortifies resilience (Hong et al., 2023). Furthermore, predictive disruption assessments allow companies to strategically position inventory, minimizing disruption impacts, and risk management efforts can be guided during disruptions by identifying critical suppliers or installations that impact supply chain performance (Gao et al., 2016).

The COVID-19 pandemic exposed the vulnerabilities of geographically-dispersed supply chains, highlighting their risks and prolonged recoveries. For instance, long lead time networks showed that they are particularly prone to disruptions and instability. The resultant hidden costs of additional safety stock, obsolescence, and diminished demand response offset the cost-saving logic, demanding reassessment of their economic viability (Graves et al., 2022).

According to Yan, Chen, et al. (2023) Information Processing Theory and Technology Collaborative Innovation enhance supply chain agility through innovative product development cycle, reducing the time-to-market and costs. Closed Engineerable Systems focus on fail-safe designs with rapid survival and return to equilibrium. Open Socio-Ecological Systems emphasize long-term adaptability and evolution. Given the complex and evolving nature of supply chains, a collaborative approach integrating engineering efficiency and socio-ecological flexibility ensures robustness (Wieland & Durach, 2021).

Research has also pointed out that environmental factors impacting supply chains comprise a complex interconnection of different organizations, government regulations, and markets. Understanding these dynamics provides insights to anticipate unforeseen events and fortify resilience (Herold & Marzantowicz, 2023). Flexibility, visibility, collaboration, and adaptability augment the supply chain's capacity to absorb impacts, recover from disruptions, and maintain operational continuity (Pettit et al., 2010).

Solutions, such as the game model, advocate strategic investments in supply chain recovery and supply capacity enhancements to lower costs and improve recovery through coordinated approaches and strategic resource allocation in supply chain management (Yan, Li, et al., 2023).

Additionally, port disruptions have a prolonged economic and logistical impact, causing delays in shipping, increased transportation costs, and coordination issues. Resilience requires upgraded infrastructure, alternative logistics routes, and technology for real-time tracking and response (Verschuur et al., 2020).

Post-COVID-19 Studies

Despite the intensity of COVID-19 during its second wave, foreign trade figures have improved. Earlier disruptions brought valuable learnings and adjustments, like manpower management, smaller maritime vessels, and supply chain automation. Centralized decision-making has streamlined responses, better coordinating supply chains (Ekinci et al., 2022). Deng and Noorliza (2023) purport that resilient logistics mandates collaborative relationships with external entities, including suppliers and customers, for a seamless flow of information and resources across organizations. Furthermore, visibility and redundancy in transportation reinforce SCRes. Visibility enables strategic decision-making through real-time tracking, and redundancy builds buffers against disruptions. This enhances rapid response and operational sustainability (Azadeh et al., 2013).

Craighead et al. (2020) suggest a 10-theory toolbox to leverage diverse perspectives to mitigate `disruptions and reinforce resilience. It develops a "transilient" strategy to restore supply chains to their pre-disruption state while adapting to new realities. Cajal-Grossi et al. (2023) recommend the use of detailed, transaction-level sourcing data— international and domestic— as a powerful analysis tool to aid researchers and businesses in mapping responses to market challenges. According to Fu et al. (2010), data-driven analysis offers valuable insights into optimizing supply chains against unexpected disruptions. Non-financial KPIs impacting SCRes are vital for managing disruptions across stages, facilitating preemptive management, immediate response, and post-event recovery, according to Karl et al. (2018), and advanced technologies and information-sharing reinforce SCRes, ensuring agility, transparency, and effective disruption response through visibility and collaboration among stakeholders (Katsaliaki et al., 2021). Supply chain recovery is a significant, evolving, and multifaceted thematic block within supply chain management, with theoretical foundations still being consolidated (Castillo, 2022). Existing literature supports the idea that integrating non-financial KPIs with advanced technologies significantly boosts SCRes, ensuring adaptability and sturdiness against disruptions.

METHODOLOGY—DEVELOPMENT OF THE FRAMEWORK

Woods and Wreathall (2008) compare resilience to the stress-strain plots from materials engineering, distinguishing predictable responses in the uniform region from strategies added in the X-region, emphasizing organizational standardisation and resilience indicators. Additionally, Hollnagel (2011) proposed the Four Cornerstones of Resilience—monitoring, responding, learning, and anticipating. Dinh et al. (2012) introduced six resilience strategies in industries: minimizing failures, early detection, increasing flexibility, reinforcing controllability, limiting disruption effects, and enforcing administrative controls and five factors reinforcing resilience: process design, detection capabilities, emergency preparedness, human involvement, and safety management, advocating proactive safety and operational stability.

David Woods' (2018) theory of graceful extensibility describes a system's stretchability beyond its usual limits in unexpected circumstances, without failing. Even with limited resources, the system exhibits finite adaptability, responds to surprises, and coordinates within networks to handle stress. It balance regular operational capacity with adaptive extendibility, ensuring sustenance. Krauter (2020) reiterates that adaptive strategies developed through recognizing stressors, understanding strain effects, and assessing power dynamics, coupled with resilience promotion and support-seeking behaviors, effectively navigate disruptions.

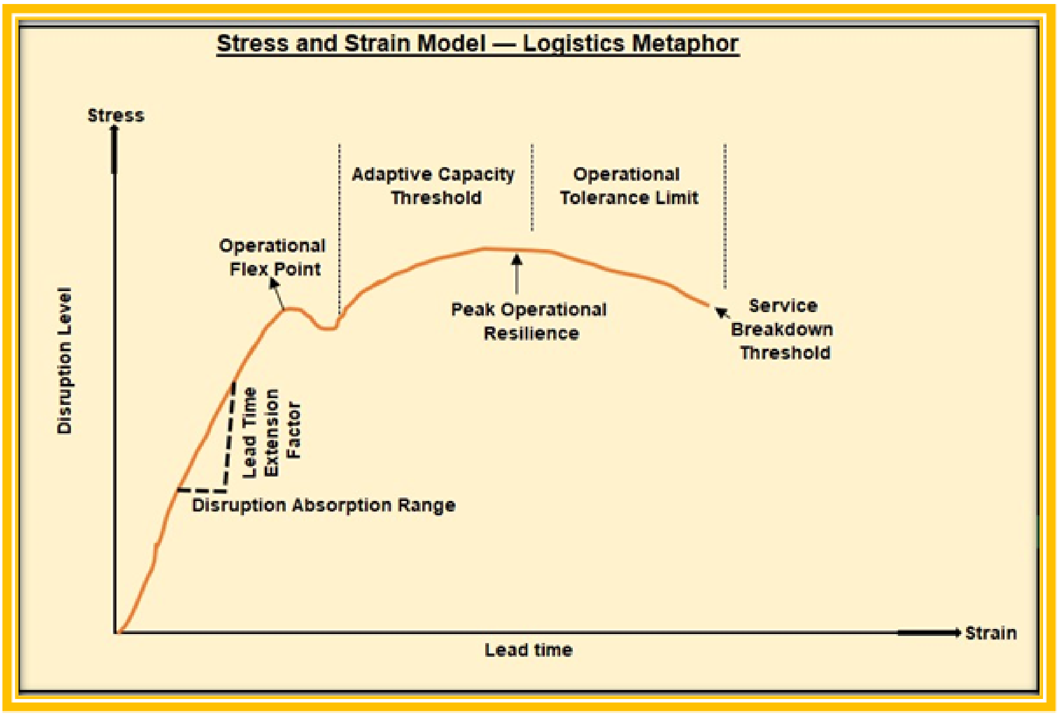
The MARLIN method by Colabianchi et al. (2023) enhances resilience through warehouse KPIs by identifying impact areas, defining emergencies, and specifying state variables for targeted responses against disruptions. Focussed on warehousing, the MARLIN method is a conceptual precursor to our GRIT framework, which focusses on resilience in GTL.

The strategic integration of the stress and strain model, the theory of graceful extensibility, and the MARLIN method provides a comprehensive framework of PIs addressing resilience to disruptions in logistics and transportation. The application and strategies of these methods are adapted to the global logistics and transportation sectors. Leveraging resilience engineering and proactive disruption management, this paper aims to uncover novel insights into supply chain adaptability and develop a robust framework to address supply chain vulnerabilities. It emphasises data-driven decision-making and strategic operational adjustments.

The Stress and Strain Model

1. Elastic behavior under design conditions: The foundation of logistics and transportation is a well-designed network, similar to the materials in mechanical engineering operating within their elastic limits. The system adapts seamlessly to shifts in delivery schedules and customer requirements without significant modifications in functioning or overall architecture. The safety margin absorbs these shifts gracefully within the constraints of their original design, like the materials that stretch under stress and revert to their original form.
2. Non-proportional stretching beyond design conditions: When demand exceeds design limits, significant modifications, like reallocating resources, adjusting workflows, and changing vehicle routes and shipping strategies, adjust to increased demand. This extends to adding more vehicles and personnel, reworking partnerships, streamlining customs processes (like preclearance and bonded operations), and seeking extensions for port operations. These prompt, strategic changes are essential for continuing efficient operations and meeting delivery commitments despite unexpected demand spikes.

Figure 1. GTL stress and strain curve



3. Potential for collapse or restructuring: If the stress on logistics and transportation increases, it faces a critical decision: Collapse? Or reorganize to achieve a higher performance? Similarly, materials either fail under stress or reorganize their internal structure. For logistics and transportation, this implies a fundamental rethinking of processes and network design, adopting new technologies, or a executing a strategic overhaul to meet the new demands.
4. Continuous adaptation and resilience: According to this model, logistics and transportation systems should undergo cycles of challenge, adjustment, and evolution, mirroring materials' cycles of stress and adaptation. Each cycle strengthens the network's resilience, preparing it for future demand modulations and disruptions.

In Figure 1, the stress-strain curve from material science is repurposed to the stages of supply chain responsiveness to disruptions.

The Stress and Strain Curve Charts

1. Operational Flex Point (Yield Strength): The critical threshold where systems begin to adapt to disruptions, accepting longer lead times as standard.
2. Adaptive Capacity Threshold (Strain Hardening): The phase where the logistics resilience adapts to sustain operations despite increased stress.
3. Peak Operational Resilience (Ultimate Strength): The maximum level of disruption logistics can withstand before functional lead times become unmanageable.
4. Operational Tolerance Limit (Necking): The extreme point of adaptability, beyond which disruptions risk system collapse or major bottlenecks.

5. Disruption Absorption Range (Run): The system's ability to handle disruptions with minimal operational impact.
6. Lead Time Extension Factor (Rise): The increased delivery times resulting from disruptions, highlighting the direct impact on service efficiency.
7. Service Breakdown Threshold (Fracture): The critical point of logistics failure or breakdown under the magnitude of disruptions.

Theory of Graceful Extensibility

The components of the Theory of Graceful Extensibility maintain operational continuity of logistics and transportation during disruptions, underlining the magnitude of resilience in the global supply chain. They are described as follows.

- Unit of Adaptive Behavior: These are critical entities, like customs, port operations, and suppliers, that adapt to changes independently, augmenting agility and responsiveness to disruptions.
- Adaptive Capacity: The two levels of Adaptive Capacities are as follows. Base capacity encompasses the system's ability to manage daily demands with the existing processes.
- Extensible capacity is the system's ability to stretch beyond normal to handle extraordinary situations with minimal performance loss.
- Capacity for Manoeuvre (CfM): This is the system's flexibility to adapt and restructure during disruptions, quantifying the buffer that prevents overwhelming and ensures continuity.

Coordinating frequent, critical trade-offs between adaptive capacity and operational efficiency maintains system balance through disturbances. Consequently, strategic decision-making navigates the complexities of resilience (Woods, 2019).

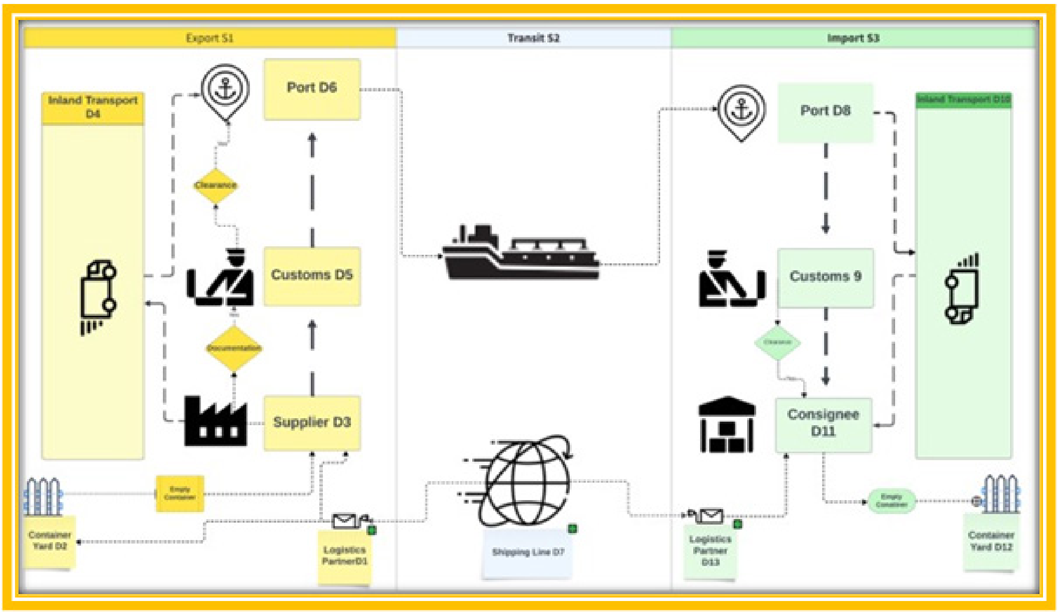
The 10 proto-theorems of the theory of graceful extensibility are outlined in Table 1 (Woods, 2018).

GRIT is an innovative approach to operational resilience of GTL through strategic insights and adaptive planning. The PIs employ a multi-phase approach, identifying impact areas (Unit of Adaptive Behavior), assessing base and extensible capacities, and defining system-specific state variables. Data collection and analysis ensures PIs meritoriously enhance logistics and transport performance and resilience to disruption. This novel integration enables a holistic understanding of the existing challenges within the supply chain domain while laying groundwork for practicable and customizable strategies toward resilience.

ANALYSIS AND FINDINGS—CONCEPTUALIZING THE GRIT FRAMEWORK

Organizations must proactively shape their futures through foresight, strategic planning innovation, and evolution to maintain a competitive advantage and SCRes (Hamel & Prahalad, 1994). Logistics is a key enabler of international trade and economic growth. Anticipating disruptions and developing unified response capabilities enhances resilience (Tang & Abosedra, 2019; Yeo & Deng, 2020). Global logistics seamlessly integrate key transitions from production to final delivery (Song, 2021). Interaction between customs and stakeholders can beneficially reduce customs processing time, labor intensity, and costs (Salimonenko & Stepanov, 2018). A hierarchical IT system harmonizing customs, port operations, and logistics enhances real-time container tracking and operational efficiency, while reducing costs and alleviating port congestion through constant monitoring (Caballini & Milena Benzi, 2023).

Figure 2. GTL map



The three operational segments within GTL are mapped in Figure 2. The export segment (S1) initiates the GTL sequence; the transit segment (S2) is the intermediate movement of goods; and the import segment (S3) concludes the journey. These segments have distinct nodes, D1 through D13.

Table 1. Applying graceful extensibility in global logistics operations

Theorem	Principle	Consequential Dynamics within GLT Processes
S1	Finite Adaptive Capacity	Ports and Customs optimize against capacity limits to prevent bottlenecks.
S2	Surprise is Inevitable	Suppliers and transporters adapt to sudden shifts, maintaining flow amid uncertainty.
S3	Risk of Saturation	Ports redirect ships and Customs accelerates clearance to manage unexpected volume surges.
S4	Need for Synchronization	Seamless cargo transition requires synchronized supplier-to-transport-to-port logistics.
S5	Influence of Neighbours	Port congestion impacts neighbouring facilities; collaboration is essential for fluidity.
S6	Adapting Goals	Suppliers shift production and ports adjust operations to meet evolving demands.
S7	Two Forms of Adaptive Capacity	Ports and transport enact standard and surge protocols to balance efficiency with emergency responsiveness.
S8	Every Unit is Local	Local constraints of ports, suppliers, and customs are built in their operations.
S9	Limited Perspective	Cross-sector sharing between suppliers, transport, ports, and Customs broadens operational perspectives.
S10	Risk of Miscalibration	Realistic capacity assessments by ports and customs optimize global cargo movement.

Critically examining the GTL structure through PIs provides a practicable, resilient framework that can withstand disruptions and adapt to the dynamic global marketplace. It translates theoretical resilience strategies to actionable plans.

Phase 1

Phase 1 of disruption management has the following steps:

1. Disruption identification: The affected segment and node are identified as $SiDi$.
2. Immediate rectification: Initiate remediation at $SiDi$.
3. Upstream revision: Engage in strategic revisions starting from $SiDi - 1$ backwards, to ensure stability and continuity in the preceding nodes of the GTL.

$Si(Di - 1) \rightarrow Si(Di)$ for upstream process

4. Downstream realignment: Progress with adjustments beginning at $SiDi + 1$ forwards, to maintain the flow towards the destination.

$Si(Di + 1) \rightarrow Si(Di)$ for downstream process

$min\,\Delta\,(Si(Di))$ is the disruption impact.

$\Delta\,(Si(Di))$ needs to be minimized, subject to upstream and downstream continuity.

Phase 2

Flexibility in the selection of ports of origin, shipping lines for transit, logistics partners, and destination ports optimizes the supply chain and prepares for potential disruptions. However, certain elements, specifically the choice of suppliers and consignees, are beyond the purview of logistics managers and deemed constant. Port connectivity determines the suitability of global shipping networks. Ports with higher connectivity contribute to reducing transportation time and increasing capacity, thereby being preferred by shipping lines and shippers (Jiang et al., 2015).

Logistics providers are broadly evaluated on five service qualities: reliability, responsiveness, tangibles, assurance, and empathy (Luyen & Thanh, 2022). The operational choices in the ports of origin, shipping lines, logistics partners, and destination ports provide strategic adaptability. Diversity within these nodes enables logistics managers to tailor their strategies based on cost, transit time, and other logistical considerations. The product of combinations, derived from multiplying the options across nodes, illustrates the GTL's dynamic disruption response capability and flexibility. It represents a complex adaptive system approach within the GTL, revealing its significant CfM.

Phase 3

Each combination is evaluated to ascertain which configuration minimizes the lead time or cost, or aligns with other logistical criteria, while also aligning with the principal business objectives. The primary objective of logistics management often centers on minimizing lead times, unless stated otherwise. This framework is designed to identify the optimal combination of logistics nodes that minimizes lead time.

Let *Xijkm* be a binary decision variable that equals to 1 if the combination of Origin Port *Oi*, Destination Port *Pj*, Shipping line *Lk*, and Logistics Partner *Mm* is selected for its minimal lead time. Otherwise, the value of *Xijkm* is 0. The aim is to minimize the overall lead time through the objective function represented in the following equation.

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{m=1}^{n} \left(O_i + P_j + L_k + M_m\right) \cdot X_{ijkm}$$

Subject to constraints:

$$\sum_{i=1}^{n} X_{ijkm} = 1 \quad \forall j,k,m$$

$$\sum_{j=1}^{n} X_{ijkm} = 1 \quad \forall i,k,m$$

$$\sum_{k=1}^{n} X_{ijkm} = 1 \quad \forall i,j,m$$

$$\sum_{m=1}^{n} X_{ijkm} = 1 \quad \forall i,j,k$$

$$X_{ijkm} \in \left\{0,1\right\} \quad \forall i,j,k,m$$

Phase 4

Meticulous evaluation of PIs across each segment and node enhances the robustness and adaptability of the systems towards various challenges and disruptions. A comprehensive list of PIs is built on a thorough research of basic operational assessments. Identifying and integrating these PIs into our resilience framework provides a quantitative and qualitative assessment primarily required for strategic decisions and actions. Data-driven planning enhances our capability to anticipate, respond to, and recover from disruptions, thereby safeguarding the continuity of operations.

Three Types of PIs (Badawy et al., 2016)

1. Lagging indicators provide consistent, foundational benchmarks for performance over time. They do not fluctuate frequently; they provide a reference for assessing trends and aligning with operational goals.
2. Leading indicators are responsive to operational activities, reflecting the efficiency of processes in real-time. They are highly sensitive to changes in workflow, productivity, and resource allocation and can be adjusted promptly to optimize operational performance.
3. Diagnostic indicators have a clear-cut correlation with critical outcomes, such as lead time. They directly measure factors that influence key objectives. They are essential for identifying and tracking the direct effects of operational decisions and processes on crucial performance metrics, enabling operational alignment.

Table 2 is a comprehensive and quite exhaustive list of PIs considered, emphasising the importance of empirical evidence and operational insights in building resilient systems.

The segment-wise distribution of PIs is:

- Exports has 27 PIs: 8 diagnostic, 9 lagging, and 10 leading.
- Imports has 14 PIs: 4 diagnostic, 3 lagging, and 7 leading.
- Transit has 5 PIs: 1 diagnostic, 2 lagging, and 2 leading.

To collate, there are 46 indicators: 13 diagnostic, 14 lagging, and 19 leading.

Performance Benchmark for PIs

Performance assessment against established benchmarks standardizes and ratifies the evaluation and aids in leveraging its optimal advantage. To elevate the quality and accuracy of our benchmarks, we have used yearly publications from renowned organizations, as indicated in Table 3. Conversely, the evaluation criteria for logistics partners and suppliers in the GTL are specific to each business. Acknowledging the uniqueness of each business, it is crucial for companies to develop customized benchmarks for their logistics partners and suppliers. Furthermore, while assessing the shipping lines, companies need to decide between direct and transshipment options. Each service type comes with its own set of advantages and disadvantages. This PI does not follow a traditional benchmark, as it essentially provides a binary answer to identify the type of service available for a route.

Phase 5

The operational PIs for each segment and node are methodically evaluated against established benchmarks. This involves a comparative analysis of current dynamic performances against strategic benchmarks and historical datasets, enabling a comprehensive, objective assessment across a spectrum of operational and strategic dimensions.

To accurately gauge the likelihood of success in our resilience strategy, it is essential to:

- Establish benchmarks: For each PI, a specific benchmark is established, drawing from industry norms, past performance metrics, strategic objectives, and analyses of competitive landscapes. These benchmarks act as pivotal reference points for evaluating success probabilities.
- Measure current performance: The latest performance metrics for each PI are systematically collated and analyzed. This includes the diligent collection, verification, and interpretation of data to precisely gauge the current state of operations.

A uniform statistical percentile is employed for the benchmarks. This standardizes the empirical distribution of each dataset and incorporates comparability across various analyses. For each dataset, the performance of all considered metrics is classified as High, Medium, or Low.

- Optimal performance (High) is attributed to values at or below the lower quartile, corresponding to the top-performing 25% within the respective metric. It indicates that the current performance meets or exceeds the benchmark, signifying that strategic objectives are being achieved or surpassed.
- Acceptable performance (Medium) corresponds to the interquartile range spanned from the 25th to 75th percentile, encompassing the middle 50% of the data spectrum. It signifies that current performance is close to, but not meeting, the benchmark, pinpointing areas where targeted improvements can elevate performance to meet strategic goals.
- Performance improvement needed (Low) is assigned to values above the upper quartile, indicating the lowest performing 25% of the evaluated measure. It indicates that current performance is

Table 2. Performance indictors in GTL resilience

GTL Segment	Designated Node	PI Code	Performance Indicator	Performance Indicator Type	Operational Definition	Strategic Resilience Significance
Export	Port	PI01	Rank in Container Port Performance Index	Lagging Indicator	Reflects port's robustness and competitiveness, influencing supply chain integrity and continuity	Tracks port performance to identify strong and competitive hubs, guaranteeing stability and ongoing flow in supply chain activities (Iyer & Nanyam, 2021; UNCTAD, 2023)
Import	Port	PI02	same as above	Lagging Indicator	same as above	same as above
Export	Port	PI03	Container Dwell Time (days)	Leading Indicator	The time a container spends within port premises pending clearance and awaiting loading onto a vessel for export	Monitors dwell time to streamline processing, lowering costs and increasing agility to respond to changes in demand or disruptions (Hassan & Gurning, 2020; Mustafa et al., 2021; UNCTAD, 2023)
Import	Port	PI04	same as above	Leading Indicator	The time a container spends within port premises pending clearance and subsequent delivery for imported goods	same as above
Export	Port	PI05	Vessel Dwell Time (days)	Leading Indicator	Total time that a vessel spends at a port	Monitors turnaround time to optimize port efficiency, minimizing lead times and enhancing resilience against disruptions within the supply chain (Ha & Yang, 2017; Gurudev, 2021; UNCTAD, 2023)
Import	Port	PI06	same as above	Leading Indicator	same as above	same as above
Export	Port	PI07	Port Waiting Time to Load (Hours)	Leading Indicator	Time a vessel is required to remain on standby before the start of loading operations	Tracks waiting time to optimize port operations, minimizing delays, and ensuring continuity (Ha & Yang, 2017; Gurudev, 2021; UNCTAD, 2023)
Import	Port	PI08	Port Waiting Time to Discharge (Hours)	Leading Indicator	same as above	same as above

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Table 2. Continued

GTL Segment	Designated Node	PI Code	Performance Indicator	Performance Indicator Type	Operational Definition	Strategic Resilience Significance
Export	Customs	PI09	Efficiency of the Customs Clearance Process	Diagnostic Indicator	Efficiency of the Customs clearance process	Assesses Customs efficiency, benchmarking, identifying and addressing bottlenecks to ensure smooth and uninterrupted operations thereby safeguarding operational continuity and efficiency (World Bank, 2023; Martincus et al., 2015; Hausman et al., 2013)
Import	Customs	PI10	same as above	Diagnostic Indicator	same as above	same as above
Export	Customs	PI11	The ease of arranging and conducting international shipments	Diagnostic Indicator	The availability of international shipping services, the quality of logistics services providers, and the accessibility of international trade documentation	Enhances economic stability, ensures supply chain reliability, and facilitates global trade integration (Gani, 2017)
Import	Customs	PI12	same as above	Diagnostic Indicator	same as above	same as above
Export	Inland Transport	PI13	Factory to Port Time	Lagging Indicator	Delivery time from the supplier premise to the port of export	Assesses efficiency in the transportation process, identifies bottlenecks, and optimizes the required timeline (Pérez-Mesa et al., 2020)
Import	Inland Transport	PI14	Port to Warehouse Time	Lagging Indicator	Delivery time from the port of import to the consignee warehouse	same as above
Export	Inland Transport	PI15	On-Time %	Diagnostic Indicator	Percentage of times goods reach the port according to the agreed timeline	Helps enable proactive risk management and ensure agile response to unforeseen challenges through monitoring (Olyanga et al., 2022)
Import	Inland Transport	PI16	same as above	Diagnostic Indicator	same as above	same as above

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Table 2. Continued

GTL Segment	Designated Node	PI Code	Performance Indicator	Performance Indicator Type	Operational Definition	Strategic Resilience Significance
Export	Inland Transport	PI17	Logistics Competence Score	Diagnostic Indicator	A country’s ability to provide quality logistics services, the availability of logistics service providers, and the competency of logistics operators	Enhances a country's ability to adapt to disruptions and maintain continuity of the supply chain; reinforces agility and responsiveness
Import	Inland Transport	PI18	Logistics Competence Score	Diagnostic Indicator	same as above	same as above
Export	Inland Transport	PI19	Transport Frequency	Leading Indicator	Reflects the availability of logistical infrastructure and the diversity of transport modes	Ensures timely movement of goods, improves supply chain predictability, and optimizes vehicle scheduling (Kurtuluş and Çetin, 2020)
Import	Inland Transport	PI20	Transport Frequency	Leading Indicator	same as above	same as above
Export	Supplier	PI21	Adherence to Delivery Dates	Lagging Indicator	Percentage of times a supplier provides goods on the agreed delivery date	Helps identify delivery deviations and facilitates corrective actions (Schmitz & Platts, 2004)
Export	Supplier	PI22	Delivery Discrepancies	Lagging Indicator	Percentage of correct items delivered out of total items ordered	Helps minimize errors in improving accuracy and operational weaknesses (Schmitz & Platts, 2004)
Export	Supplier	PI23	Delivery Flexibility	Diagnostic Indicator	Percentage of times that adjustments are made in quantity, location, or lead time	Helps in responsiveness to changing demands, optimizing and improving supply chain agility (Schmitz & Platts, 2004)
Export	Supplier	PI24	Adherence to Delivery Quantities	Diagnostic Indicator	Percentage of full quantity deliveries	Helps ensure stability mitigation, forecasting accuracy, and supplier performance management (Xu et al., 2023)
Export	Supplier	PI25	Loading-Unloading Time	Leading Indicator	Time it takes to load or unload a container	Helps optimize operational efficiency, reduce turnaround times, and improve transportation productivity (García-Arca et al., 2018)

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Table 2. Continued

GTL Segment	Designated Node	PI Code	Performance Indicator	Performance Indicator Type	Operational Definition	Strategic Resilience Significance
Export	Supplier	PI26	Transport Distance	Leading Indicator	Distance from the factory or supplier location to the port of export	Helps optimize route planning and lead time planning through tracking (García-Arca et al., 2018)
Export	Supplier	PI27	Vehicle Utilization	Lagging Indicator	Percentage of a vehicle's total carrying capacity that is used during transport operations	Helps maximize efficiency in fleet operations, reduces idle time, and optimizes resource allocation (García-Arca et al., 2018)
Export	Supplier	PI28	Processing Time of Order	Diagnostic Indicator	Time taken to process the order, post-production	Helps streamline order fulfilment processes, improves order cycle times, and enhances operational efficiency (Jothimani & Sarmah, 2014)
Export	Supplier	PI29	On-Time Performance	Diagnostic Indicator	Percentage of times that goods are ready for pick-up or loading as per agreed timeline	Ensures timely coordination in supply chain activities, minimizes delays, and maintains smooth logistics operations (Jothimani & Sarmah, 2014)
Export	Supplier	PI30	Fleet Size	Lagging Indicator	Number of fleet trucks owned or leased	Determines capacity for transportation, ensures adequate resources for delivery, and meets customer demand (Jothimani & Sarmah, 2014)
Export	Supplier	PI31	Fleet Size (3PL)	Lagging Indicator	Capacity of fleet contracted from the market	Supplement owned fleet capacity enhance flexibility in transportation operations and adapt to fluctuating demand (Jothimani & Sarmah, 2014)
Export	Supplier	PI32	Number of Daily Routes and Frequency	Lagging Indicator	Frequency of delivery and the number of daily routes	Ensures consistent supply chain operations through regular monitoring of delivery schedules and route optimization (Jothimani & Sarmah, 2014)

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Table 2. Continued

GTL Segment	Designated Node	PI Code	Performance Indicator	Performance Indicator Type	Operational Definition	Strategic Resilience Significance
Transit	Shipping Line	PI33	Direct or Transhipment	Lagging Indicator	Classification of a shipping service as either direct route or involving transshipment	Understands the routing and handling of shipments, optimizes logistics strategies, and selects the most suitable service (Tagawa et al., 2021)
Transit	Shipping Line	PI34	Schedule Adherence	Leading Indicator	Percentage of conformity to the pre-announced timetable for shipments	Helps ensure predictability, mitigates risks, and improves planning for disruptions (Yazar Okur & Tuna, 2022)
Transit	Shipping Line	PI35	Ranking	Lagging Indicator	Scale of operations, encompassing the total capacity in volume transported, fleet size, and expanse of the global network	Enables higher-ranking shipping lines with substantial volumes, extensive fleets, and global reach mitigate risks more effectively, ensuring supply chain continuity amidst diverse challenges because rank is reflected in its robustness and adaptability to disruptions (Wang et al., 2022)
Transit	Shipping Line	PI36	Transit Time	Diagnostic Indicator	Time required for the transport of goods from the port of export to the port of import	Pivotal for planning, risk assessment, and mitigation Ensures timely delivery and maintenance of operational continuity (Sun et al., 2020)
Transit	Shipping Line	PI37	Blank Sailing Percentage	Leading Indicator	Ratio of scheduled departures omitted by the carrier to the total scheduled sailings; reflects the frequency of service disruptions or strategic cancellations by the shipping line	Assesses disruptions in shipping schedules, understands potential delays in cargo transportation, and plans contingencies (Gul et al., 2022)
Export	Shipping Line	PI38	Empty Container Availability	Leading Indicator	Ease of obtaining empty containers for export or import, highlighting potential delays	Helps adjust to shipping schedules and resource allocation (Toygar et al., 2022)

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Table 2. Continued

GTL Segment	Designated Node	PI Code	Performance Indicator	Performance Indicator Type	Operational Definition	Strategic Resilience Significance
Export	Logistics Partner	PI39	Global Network Coverage	Leading Indicator	Extent and connectivity of logistics and transportation services across different countries and continents	Leverages global network to diversify shipping routes and ensure continuity, even in regions experiencing disruptions (Huang et al., 2019; Mohsen, 2023)
Import	Logistics Partner	PI40	same as above	Leading Indicator	same as above	same as above
Export	Logistics Partner	PI41	Intermodal Capability	Leading Indicator	Efficient combination of different modes of transport to complete deliveries seamlessly	Helps plan to switch transport modes swiftly in case of disruptions, ensuring timely delivery despite challenges in one mode of transportation (Mohsen, 2023)
Import	Logistics Partner	PI42	same as above	Leading Indicator	same as above	same as above
Export	Logistics Partner	PI43	Flexibility in Operations	Leading Indicator	Ability to adapt to customer needs and unexpected changes	Maintains operational flexibility to accommodate sudden changes in customer demands or unforeseen disruptions and ensures continuity and responsiveness within the supply chain (Huang et al., 2019; Mohsen, 2023)
Import	Logistics Partner	PI44	same as above	Leading Indicator	same as above	same as above
Export	Logistics Partner	PI45	Dependability and Reliability	Lagging Indicator	Trustworthiness in handling shipments and solving issues	Ensures prompt resolution of issues and consistent performance, thereby enhancing SCRes (Huang et al., 2019; Mohsen, 2023)
Import	Logistics Partner	PI46	same as above	Lagging Indicator	same as above	same as above

considerably below the benchmark, highlighting areas that require immediate attention and substantial improvements to align with strategic objectives.

This study introduces a novel performance integration framework for aggregated evaluation. The PIs are a composite indicator of the overall success of the organization. The evaluation functions on the premise that all PIs hold equal significance in the analysis. Therefore, the method abstains from associating weights and considers each indicator's contribution as uniformly impactful to the final assessment.

Table 3. PI benchmarks and performance

PI Code	Reference Benchmark Source	Benchmark Performance	Unit of Measure	Optimal Performance (High)	Acceptable Performance (Medium)	Performance Improvement Needed (Low)
PI01	Container Port Performance Index 2022 (Bank, 2023)	70	Number	<70	71 to 278	>278
PI02	same as above	70	Number	<70	71 to 278	>278
PI03	Supply Chain Tracking Data, Logistics Performance Index (LPI) (World Bank, 2023)	5	Days	<5.1	5.1 to 9.6	>9.6
PI04	same as above	5.5	Days	<5.7	5.8 to 11.5	>11.5
PI05	Vessel Dwell Time (UNCTAD, 2023)	0.75	Days	<.75	7.5 to1.26	>1.26
PI06	same as above	0.75	Days	<.75	7.5 to1.26	>1.26
PI07	Review of Maritime Transport (UNCTAD, 2022)	41.8	Hours	<41.8	41.8 to 87.6	>87.6
PI08	same as above	30.5	Hours	<30.5	30.5 to 87.9	>87.9
PI09	Logistics Performance Index—Customs Score (World Bank, 2023)	3.18	Number	>3.18	2.3 to 3.18	< 2.3
PI10	same as above	3.18	Number	>3.18	2.3 to 3.18	< 2.3
PI11	Logistics Performance Index—International Shipment Score (World Bank, 2023)	3.15	Number	>3.15	2.6 to 3.15	<2.6
PI12	same as above	3.15	Number	>3.15	2.6 to 3.15	<2.6
PI13	Logistic Performance Index Surveys: Lead time to export median days (World Bank and Turku School of Economics, 2018)	2	Days	<2	2 to 4	>4
PI14	same as above	3	Days	<3	3 to 4.8	>4.8
PI15	Logistics Performance Index—Timeliness Score (World Bank, 2023)	3.5	Number	>3.5	2.9 to 3.5	<2.9
PI16	same as above	3.5	Number	>3.5	2.9 to 3.5	<2.9
PI17	Logistics Performance Index—Logistics Competence Score (World Bank, 2023)	3.3	Number	>3.3	2.6 to 3.3	<2.6
PI18	same as above	3.3	Number	>3.3	2.6 to 3.3	<2.6
PI19	Logistics Performance Index—Infrastructure Score (World Bank, 2023)	3.2	Number	>3.2	2.4 to 3.2	<2.4
PI20	same as above	3.2	Number	>3.2	2.4 to 3.2	<2.4
PI21	Bespoke benchmarks	90%	Percentage	>82%	60% to 82%	<60%
PI22	Bespoke benchmarks	2%	Percentage	<2%	2% to 5%	>5%
PI23	Bespoke benchmarks	75%	Percentage	>75%	50% to 75%	<50%
PI24	Bespoke benchmarks	95%	Percentage	>95%	75% to 95%	<75%

continued on following page

Table 3. Continued

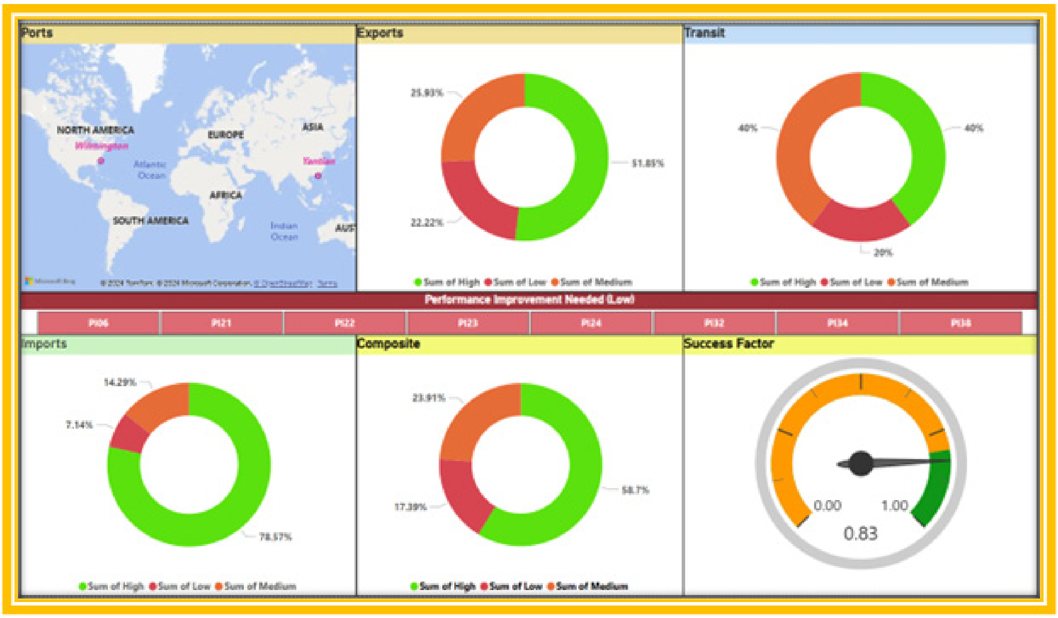
PI Code	Reference Benchmark Source	Benchmark Performance	Unit of Measure	Optimal Performance (High)	Acceptable Performance (Medium)	Performance Improvement Needed (Low)
PI25	Bespoke benchmarks	3	Hours	<3	3 to 5	>5
PI26	Bespoke benchmarks	500	Kilometres	<500	500 to 1000	>1000
PI27	Bespoke benchmarks	85%	Percentage	>85%	65% to 85%	<65%
PI28	Bespoke benchmarks	3	Hours	<3	3 to 6	> 6
PI29	Bespoke benchmarks	95%	Percentage	>95%	75% to 95%	<75%
PI30	Bespoke benchmarks	50	Number	>50	25 to 50	<25
PI31	Bespoke benchmarks	100	Number	>100	50 to 100	<50
PI32	Bespoke benchmarks	5	Number	>5	3 to 5	<3
PI33	Sea Intelligence GLP report (Murphy, 2023)	1	Binary	1		0
PI34	same as above	65%	Percentage	>65%	40% to 65%	<40%
PI35	Alphaliner Top100 (Alphaliner, 2023)	5	Number	<5	5 to 19	>19
PI36	Bespoke benchmarks	25	Days	<25	25 to 40	>40
PI37	Blank Sailing Percentage (xChange, 2023; Drewry, 2022)	10%	Percentage	<10%	10% to 25%	>25%
PI38	Empty Container Availability (xChange, 2021; xChange, 2024)	0.55	Number	>0.55	0.45 to 0.55	<0.45
PI39	Bespoke benchmarks	Yes	Binary	1		0
PI40	Bespoke benchmarks	Yes	Binary	1		0
PI41	Bespoke benchmarks	Yes	Binary	1		0
PI42	Bespoke benchmarks	Yes	Binary	1		0
PI43	Bespoke benchmarks	75%	Percentage	>75%	60% to 75%	<60%
PI44	Bespoke benchmarks	75%	Percentage	>75%	60% to 75%	<60%
PI45	Bespoke benchmarks	90%	Percentage	>90%	75% to 90%	<75%
PI46	Bespoke benchmarks	90%	Percentage	>90%	75% to 90%	<75%

The PIs of each segment and node of the GTL are evaluated. Their current performance clearly indicates the impact point of disruption. The likelihood and extent of success are based on the assessment of current operational performance against predefined benchmarks. A quantitative tally of PIs classifies them within the predefined success chances of High, Medium, and Low. The performance levels distributed across the spectrum of organizational activities are quantified to collate a foundational dataset for subsequent analysis. A proportional representation of the successful PIs against their universal set clearly illuminates the distribution of each High success category.

This will be further subdivided into segment aggregation before we calculate the overall success.

The crux of this process is to derive an overall chance of success. Quantifying the analysis makes it clearer and more practicable. Toward this goal, an Overall Chance of Success is deemed High if over 60% of the PIs are classified as High; Medium if the majority are Medium or there is an equal distribution between High and Medium with less than 20% classified as Low; and Low if over 20% of PIs are classified as Low, particularly in the absence of a predominant High or Medium majority.

Figure 3. GRIT dashboard of the case study (LaRocco, 2022)



This aggregation method not only facilitates a holistic assessment of the GTL network but also emphasizes the necessity of devising other alternatives.

Phase 6

Once all PIs are aggregated at both the segment and overall levels, the logistics manager can leverage the likelihood of success for the chosen combination of origin, port, destination, and shipping line. It should be duly noted that the performance of the supplier, their own warehouse (which is the consignee), and the logistics partners are independent of the PIs.

The analysis of the GRIT framework culminates in a dashboard with the aggregated scores of the Optimal (High) and Acceptable (Medium) PIs. The dashboard clearly indicates the likelihood of success in resilience planning. This innovative tool is preliminary to the development of a comprehensive resilience strategy, laying the groundwork for a more detailed plan and facilitating subsequent engagements with relevant stakeholders.

A dashboard revealing over 80% of PIs in Optimal and Acceptable performance brackets and implementing theoretical tenets of Redundancy and Robustness correlates to the system's enhanced capacity to sustain stress. This aligns with the high reliability theory of a system's potential to operate safely in complex environments. The substantial safety margin implies a robust buffer against disturbances suggested by the complex adaptive systems theory of adaptive components within operational dynamics. A High Adaptive Capacity to adjust potentially mitigates system failures, as proposed by the normal accident theory (Rijpma, 2002).

Thus, a cumulative score of the Optimal and Acceptable Performances surpassing the 80% threshold strongly predicts favorable outcomes, denoting a higher likelihood of success. Consequently, this assessment serves as a precondition for resilience planning.

A practicable dashboard of the GRIT framework, derived from a case study analysis, is illustrated in Figure 3.

DISCUSSION—APPLICATION OF THE GRIT FRAMEWORK: CASE STUDY

To illustrate the GRIT framework, we selected a past news report (LaRocco, 2022). The GRIT framework analyzed an empirical case study on the accumulated shipping containers at the Port of New York and New Jersey using real-world evidence and synthetic datasets, presuming that a USA-based logistics manager is importing goods from China. This context evaluates the performance of the framework within the GTL domain and reinforces its real-world applicability. The empirical dataset comprises PIs PI01 to PI20 and PI33 to PI38, the selection of data for the 2022 case study, based on authoritative sources mentioned in Table 3.

Simulated Data

With proprietary constraints and a lack of direct measurement, empirical data for PI11 to PI32 and PI39 to PI46 was unavailable. This gap was addressed with simulated data derived from commonly accessible online information, operational norms, and acclaimed literature from Özkanlısoy and Bulutlar, 2023; Sakas et al., 2023; Min, 2013; Mitra and Bagchi, 2008; Woschank et al., 2022; Aharonovitz et al., 2018, and Utama et al., 2021.

The dataset was created using stochastic simulation, employing pseudo-random numbers to replicate real-world variability. Refinements were made after reviewing relevant literature, ensuring the data accurately reflected the real operations of suppliers and logistics. Instead of statistical calculations, the process relied on documented patterns, expert assessments, and theoretical frameworks, keeping the values within plausible ranges. Each value's rationale is supported by cited literature. While this approach introduces subjectivity, it allows for a preliminary investigation through the GRIT framework, suggesting future replacement with empirical data as it becomes available.

Phase 1: Disruption Identification and Management

A disruption is noted at the Import Segment S3 Node D8 (S3D8), the New York port. Immediate remedial action at Shipping Line S2D7 (D8-1) reroutes the in-transit cargo. Undeparted shipments from the origin point, Export S1D6, are pre-emptively redirected through alternate supplier channels. Concurrently, alternate transportation arrangements and documentation are adjusted at Customs S3D9 (D8+1). This integrated response mitigates the impact of the disruption at D8, maintaining the integrity of the supply chain.

Phase 2

The logistics manager evaluates alternatives for the D9 New York port within the Import S3, upstream logistics partners and ports in Export S1, and shipping lines in Transit S2. For this instance, logistics flow can be redirected to four possible ports in China and four on the US East Coast, with a CfM of 16 options (4 x 4). The origin and destination ports are the primary influences. The shipping lines and logistics partners are evaluated based on internal criteria. Structured evaluation reinforces resilience planning, sustaining operational integrity through port-specific disruptions.

Phase 3

A selection matrix of four Chinese and four US ports generates the optimal shipping route from Yantian Port to Wilmington Port, using the services of CMA CGM, which is one of the top three shipping lines in the world. With a projected minimal lead time of 25 days, logistics partner B is the preferred collaborator. A methodical evaluation of logistics configurations within theoretical constructs aligns remedial actions within operational parameters.

Phase 4

A systematic evaluation of the PIs pertinent to the chosen ports, shipping service, transport, Customs, logistics partner, and supplier ensues in context to 2022.

Table 4. GRIT output on various examples

Scenario Number	Disruption Details	Ports	Disruption Point	Success Factor
1	Shenzen Lockdown (Campbell, 2022)	Qingdao–New York	D6	74%
2	West Coast Lockdown (Eshkenazi, 2022)	Yantian–New York	D8	67%
3	Trucker Strike at Oakland (LaRocco, 2022)	Yantian–Los Angeles	D10	89%
4	Panama (News, 2022)	Shanghai–Los Angeles	D7	80%
5	Customs (Brexit) issue (Globalia Logistics Network, 2022)	Shanghai–Antwerp	D9	87%
6	The Freedom Convoy (Trucker) Belgium (Times, 2022)	Mumbai–Antwerp	D10	85%
7	Custom Network Issue Nhava Sheva (Lennane, 2022)	Chennai–New York	D5	76%
8	Shanghai Lock down (Magill, 2022)	Ningbo–Los Angeles	D6	57%
9	US West Coast Labour Union Issue (Garland, 2022)	Ningbo–New York	D8	76%
10	Container Shortage (Newton, 2022)	Shanghai–New York	D2	72%

Phase 5

The assessment of PIs for the ports, CMA CGM, transport, US and China Customs, logistics partner, and supplier against benchmarks reveals 27 PIs with Optimal Performance, 11 with Acceptable Performance, and eight with Performance Improvement needed. Within the Performance Improvement category, the three leading indicators and two diagnostic indicators offer a clear directive to initiate focused enhancements. Meanwhile, the two lagging indicators require reflective, strategic planning rather than immediate intervention.

Phase 6

The aggregated values of PIs indicate success probabilities of 78% for export, 93% for import, and 80% for transit. On a composite level, the overall success probability is 83%.

A graphic representation references all metrics. The chromatically-differentiated donut charts demarcate operationally sound PIs. PI06 in import; PI21 to PI24, PI32, and PI38 in export; and PI34 in transit require strategic intervention. The needle gauge quantitatively reflects the aggregate success factor.

The GRIT framework dashboard in Figure 3 distinctly achieves the objectives of this study. The Performance Improvement Needed PIs clearly identify the critical areas for strategic interventions, while the Success Factor gauge provides a realistic aggregated assessment required for resilience planning.

The GRIT framework equips logistics managers with an analytical dashboard for informed decision-making on network viability. If the dashboard deems a network inept, managers can promptly assess alternatives. It facilitates immediate, heuristic evaluations, founded on PIs assessments. Essentially, the GRIT framework is a preliminary step in strategic resilience planning.

The GRIT framework was tested in 10 real-life disruptions of 2022. It accurately assessed diverse scenarios, identifying strengths, improvement areas, and success probabilities. Table 4 illustrates the GRIT framework's output for these cases.

The GRIT framework analyzes through diverse disruptions, identifies vulnerabilities within the GTL, and prioritizes interventions to enhance overall resilience.

CONCLUSIONS

Theoretical Implication

The GRIT framework offers an intuitive, user-friendly tool that diagnoses and preemptively addresses GTL challenges. By theoretically leveraging the Stress and Strain model and the MARLIN method for a better understanding of the dynamic pressures and adaptive responses, it incorporates operational buffers from the Theory of Graceful Extensibility. These theories reinforce adaptive resilience concepts within the GTL. The GRIT framework translates theory into actionable strategies, empowering logistics managers to address disruptions with continuous monitoring and adaptive planning. It is a pragmatic application of resilience engineering principles in the context of global logistics management.

Managerial Implication

Logistics managers must ensure timely product delivery and availability, despite disruptions. Our research leverages PIs for proactive system adjustments to navigate through varying disruptions across diverse logistics networks. The data-driven approach reinforces agility and adaptability in networks to maintain continuity and optimal lead times. Relevant to an array of global supply chains, this research highlights the role of GTL in addressing the effects of global disruptions.

This GRIT framework proposes conceptually sound, practicable solutions to manage various disruptions and maintain continuity and cohesion throughout operational networks. While effective, it is not a universal solution; its success depends on the quality and granularity of supply chain data and is complemented by supplier and logistics partnerships. GRIT integrates sophisticated theories into practical logistics management, promoting resilience in GTL operations. However, data limitations and qualitative PIs, mostly Customs PIs impacting ports, present challenges.

FUTURE SCOPE

Rapid advancements, like analytics (Xu et al., 2024), AI (Toorajipour et al., 2021), and Machine Learning (Hathikal et al., 2020; Yang et al., 2023), allow better access to data on port operations, carrier performance, and the Logistics Performance Index. An Integrated Logistics Platform would empower logistics managers to leverage the GRIT framework across varied global supply chains, reinforcing operational resilience through disruptions.

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PROCESSING DATES

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