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Adaptive Strategies in Global Logistics: Navigating Economic Uncertainty and Geopolitical Risks Through Digitalization and Multimodal Transportation

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Abstract. Due to the growth of economic uncertainty and geopolitical risks, the rigid structure of global logistics networks and disconnected information channels have been revealed to be highly vulnerable. Study on the Impact of Digitalisation and Multimodal Transport Synergy on Logistics Resilience in a Volatile World. An all-encompassing analytical system that combines the Coupling Coordination Degree Model (CCDM) and Evolutionary Game Theory (EGT) will be introduced here to explore how digital supply-chain capabilities are affected by physical transportation flexibility. Based on the above data, digitalisation will increase the openness of information, enhance risk early warning, reduce operating periods, and improve the flexibility of transportation routes in the event of political instability or trade war. However, the research has also found that digital intelligence alone is insufficient to address problems in the physical logistics system; thus, a form of information-physical decoupling has arisen. Based on the evolutionary analysis, the desired stable and high-resilience state can only be achieved through coordinated strategic adjustments by enterprises and governments, as well as institutional incentives and interoperable infrastructure. This paper adds to the body of knowledge by building an all-encompassing system model of digital logistics capability and multimodal resilience, and offers some practical guidance for managers and policymakers aiming to strengthen global logistics under systemic risks.

Keywords: Global logistics resilience; Digitalization; Multimodal transportation; Supply chain resilience; Geopolitical risk; Economic uncertainty; Digital supply chain; Logistics adaptation.

1. Introduction

Currently, the landscape of international trade at present shows that there is an essential change in the direction towards more flexible determinants for determining distribution networks and logistics systems. Primarily, due to both an increase in systemic economic uncertainty and a rise in geo-political risks, there is a reduction in operational stability for Traditional transportation modes that depend on them. Proliferation of protectionist trade policies and appearance of regionalised disputes have brought serious stochasticity to the entire process of international material flow; therefore, traditional linear logistic model will become more inapplicable (Miroudot, 2020). Therefore, in recent years, the leading enterprises have gradually shifted from focusing on cost control to improving dynamic ability building and adjusting their business structure flexibly in response to environmental changes. Based on current research, the vulnerability of globalised production networks increases due to too many transit links and a lack of resilience against emergencies such as new regulations or infrastructure failure (Ivanov, 2020). Therefore, establishing an efficient adaptive Strategy System has not been elevated to a secondary concern yet; rather, ensuring good economic outcomes across multiple locations around the world is still the priority area (Aliet al., 2025).

As an enabling technology for digitalisation, it can deliver high-precision tracking Data and prediction capability; thus, breaking the bottleneck problem at Information silos within intricate Supply Chains. Utilise advanced Logistics Information Technology to continuously monitor the movement conditions of goods, enhance management Level, shorten delivery time for local customers, expand market Reach, etc. The technology application can alleviate to a certain extent the problem caused by operation time delay; It has also found potential risks before they may trigger network critical failures (Gereffi, 2023). Moreover, through algorithmic demand forecasting and automatic risk assessment for coordination among Supply Chains in response to fluctuations in macroeconomic conditions and reduce the degree of unpredictability brought about by International Trade Practices. Adding new technology does not necessarily constitute a full-fledged upgrade of the whole system responsible for processing environmental data within a logistics network (Wamba et al., 2022). Nevertheless, due to the deficiency in combining digital tools and physical infrastructure capable of adapting flexibly, their effectiveness will be impaired (Dahal al., 2025).

To bridge the conceptual gap between digital intelligence and physical logistics execution, this study formalizes two distinct constructs: the Strategic Technological Supply Chain (STSC) and Trans-modal Service Quality (TSQ). Unlike standard definitions of supply chain resilience which often focus on ex-post recovery metrics, STSC is defined here as the proactive digital capability of a network—encompassing real-time data integration, cryptographic traceability, and algorithmic forecasting. TSQ serves as its physical counterpart, operationalized not merely as service reliability, but as the infrastructural elasticity required to shift modes dynamically (e.g., from maritime to rail) under exogenous geopolitical pressure. By defining STSC and TSQ as interdependent sub-systems, this study avoids conflating information transparency with physical execution capacity.

Therefore, to build a multimodal Transport System has been needed in order to implement the Digitalisation Strategy under these circumstances. Multimodal logistics links sea, rail and land modes of transport closely together as a whole to offer substantial backing against deterioration of particular geographic conditions or being limited due to sudden changes in tariffs (Christopher, 2016). Adjusting the route of dynamic redeployment in distribution networks according to different modes of transportation, ensuring their continuity after geopolitical closures at key points affect them. Therefore, taking into account the above issues, it is necessary to combine with digital intelligence and various modes of Adaptation construction of two-dimensional defence System against major systemic risks. Although each domain has its own merits; nevertheless, due to a lack of joint investigation into addressing both economic uncertainty and political threat together among them at this time. In order to find out a multilayered adaptive evaluation model that can assess the risk-mitigation ability of each strategy under various circumstances, as well as provide references for studying supply Chain Resilience and Strategic Logistics Management.

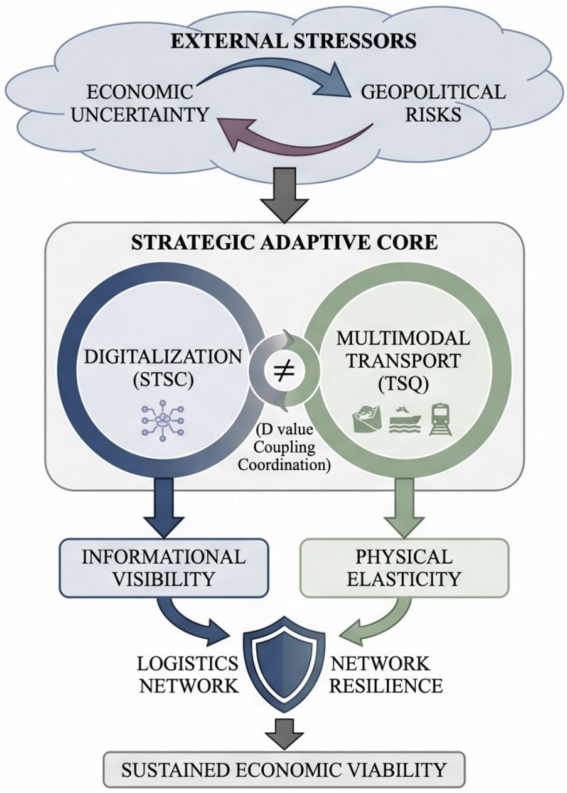

Fig.1: Global Logistics Resilience Conceptual Architecture

2. Literature review

2.1 Theoretical Foundation for Supply Chain Resilience and Dynamic Capability

The ontological evolution of supply chain resilience has deepened as much based on the Resource-Based View (RBV) and its extensions such as the dynamic capabilities framework, proposing that the competitiveness of a strategic technological supply chain (STSC) originates from its ability to adjust internal and external resources in time under changing environments. In the first formulations of resilience theory, emphasis was put on whether a system would be able to recover after encountering an external shock, and for how long this recovery continued prior to that event is not usually specified. However, with the continuous occurrence of nonlinear disturbances in global logistics Networks. The theory shifts to a proactive framework that emphasizes adaptive Robustness over static Stability (Blackhurst et al., 2011). In terms of enterprises using sensing, interpreting, and converting abilities to predict economic changes early and prevent system failure chains from breaking, such as what Teece (2007) pointed out in his works. In the framework of current global trade and the integration of these functions in building a logistics system can maintain high levels of transmodal service quality (TSQ) even under conditions with substantial external disruptions (Ponomarov & Holcomb, 2009).

The constructs of STSC and TSQ utilized in this manuscript fundamentally differ from traditional service quality concepts (like SERVQUAL), which focus predominantly on customer satisfaction and static delivery parameters. Instead, TSQ is strictly operationalized as the capacity for structural reconfiguration during geopolitical crises, directly borrowing from transportation engineering models of infrastructural robustness (SteadieSeifi et al., 2014). Similarly, STSC extends beyond generic IT adoption to represent a unified, strategy-driven cyber-physical architecture. Moreover, based on the existing research results in this field, resilience in a network may be developed through planned redundant resource allocation and organisational adaptiveness rather than being an intrinsic quality of every network (Golan et al., 2020). Operate on these theoretical concepts to assist logistics companies in managing complicated scenarios during overseas operations, reduce the adverse effects of incomplete information and structural constraints, etc.

2.2 Digitalisation as an engine of informational transparency and risk minimisation.

The impact of digitalisation on enhancing the resilience of worldwide logistics and reducing bullwhip effects by means of cyber-physical systems has become more concerned about. A high-performance digital architecture system integrates IoT technology, Big Data analytics and artificial intelligence applications to build an extended monitoring-and-alert system for adverse events under complicated circumstances. In the event of a problem that cannot be handled actively in time through these technology means; it will inevitably become an active disturbance source. For instance, according to many scholars' views, the application of blockchain technology can help enhance the traceability and build decentralised trust required for navigating complex international regulatory systems that need to strengthen protection of transparency (Kshetri, 2018; Wamba et al., 2022). A digital intervention may slow down the response speed of an operation, be able to take off-site inventory quantity adjustment promptly due to demand Changes. In addition, some researchers also indicate that although there has been an increasing focus on digitalising Logistics process in terms of Technology Application, Organizational Culture is equally important to form an integrated system through technological support (Choi et al., 2018). Through this combination, it can ensure that the digitalisation of enterprises' operations leads to a practical application effect and transform the entire economic situation of the region.

2.3 Multimodal transportation frameworks and geopolitical risk management

Multimodal transportation provides a concrete basis for avoiding geo-political risks and policy disputes among some segments of the route, etc., falling within the category of flexible transport methods. Through the construction of a multi-mode transportation network including maritime, railway and road transport modes that is dynamically adjustable in response to demand changes, these problems can be avoided to some extent. In this situation, this kind of modal Elasticity must be strengthened today due to the introduction of Weaponization of Trade Rules and Localised Sanction into traditional Logistics Routes at higher Degrees of Uncertainty. Research shows that the capability for smooth integration among various transportation modes can enhance the whole robustness of the Logistics Network through a distribution of risks across several physical Infrastructure and reducing dependence on weak hubs (Tang, 2006) To realise the high level of TSQ in a multimedial environment, both physical interoperability and the standardisation of administrative rules as well as the synchronised Information Interfaces among various jurisdictional regions are required (SteadieSeifi et al, 2014). Moreover, based on the above-related research results, through some kinds combination-modality to analyse macro-economic analysis could also improve problems of energy prices Adjustment and Emissions from CO2 More Comprehensively. Through the comparative advantage of each mode of transport, logistics operators will build an integrated Physical Structure that combines Digital Intelligence to ensure stable Material Flow under a dispersed Global Market.

2.4 The Interaction among economic uncertainty and adaptive logistics paradigms

Economic uncertainty and geopolitical risks converge to form a multi-dimensional uncertain situation; thus, a multidimensional adaptability model is needed beyond traditional one-way optimisation schemes. Some recent studies have shown that due to factors like currency fluctuation risks, price volatility hazards and consumers' varying needs across different geographic areas at present, it is even more likely that logistics network operations will face increased Risk. The background needs to undergo transformation into contingent-plan-oriented thinking: In addition, while considering digital disclosure and physical flexibility simultaneously when making decisions strategically. Although much attention has been paid to the development of individual resilience factors in recent years, there is still an apparent deficiency in studies examining how the integration effect among digitalisation, multimodal transportation and economic-political instability forms. Currently, most related researches mainly pay attention to technologies and physical transport processes in supply-chain Management and modal-shifting; However, there is a lack of synergy between them. Introduce an integration approach to quantify the risk-mitigation effect of these strategy combinations; thus, offer more complete presentations on how differences in STSC configuration influence companies' sustained development abilities under internationalisation conditions. By synthesizing multiple theories, this paper has made some achievements in exploring the resilience of global logistics systems and can provide managerial reference to deal with an ever-changing business environment.

3. Methods.

To ensure the empirical rigor and reproducibility of the findings, the methodology transitions from theoretical abstraction to a transparent, quantifiable evaluation process. This section details the data structure, variable operationalization, and algorithmic calibration required to execute the Coupled Coordination Degree Model (CCDM) and Evolutionary Game Theory (EGT) frameworks.

3.1 Data Sources and Sample Structure

This study relies on a multi-source panel dataset spanning five years (2018–2023) to capture pre- and post-disruption geopolitical environments. The sample structure comprises $N = 320$ active international logistics corridors intersecting major trade hubs across Asia, Europe, and North America. Raw data regarding STSC implementation (e.g., IoT node density, blockchain tracking frequency) were extracted from the World Bank's Logistics Performance Index (LPI) micro-data and supplemented by corporate annual reports of top-tier 3PL providers. TSQ data (modal-shift delays, infrastructural redundancy) were compiled from the United Nations Conference on Trade and Development (UNCTAD) maritime and rail freight databases. To control for size and regional bias, the sample includes both established multinational routes and emerging cross-border corridors.

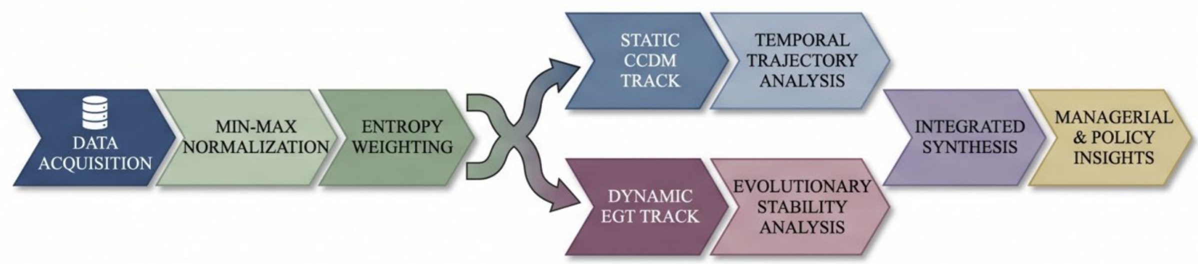

Fig.2: Integrated CCDM-EGT Methodological Roadmap

3. 2 Measurement Procedures and Construct Operationalization

To standardize the disparate units of measurement between digital and physical variables, all initial metric values x_{ij} underwent min-max normalization:

$$x'_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}$$

Following normalization, an objective entropy weighting method was applied to determine the precise influence coefficient for each indicator. This procedure calculated the information entropy E_j for each metric, assigning higher weights to indicators exhibiting greater variance during systemic shocks, effectively avoiding subjective bias in the evaluation of STSC and TSQ.

3.3 Integrated model construction: Coordination degree of integration (CCI)

To evaluate the synergistic efficacy of digitalization and multimodal transportation in mitigating geopolitical risks, this study employs a modified Coupling Coordination Degree Model (CCDM). This approach is instrumental in quantifying the interactive influence between the Strategic Technological Supply Chain (STSC) subsystem and the Trans-modal Service Quality (TSQ) subsystem. We define the developmental level of the digital infrastructure as U_1 and the operational efficiency of the multimodal network as U_2. The coupling degree C is calculated as $C = 2 \times \{(U_1 \times U_2)/(U_1 + U_2)^2\}^{1/2}$, which reflects the intensity of interaction between the two domains without necessarily indicating a positive developmental trajectory. To address this limitation, we introduce the coordination degree D, defined as $D = C \times T$, where $T = \alpha U_1 + \beta U_2$ represents the overarching integration level of the adaptive logistics system. In this formulation, α and β signify the relative weights assigned to digital and physical assets respectively, determined through the aforementioned entropy-based weighting method to eliminate subjective bias (Zhang et al., 2022). By situating this model within the context of global economic uncertainty, we can discern whether a high degree of technological sophistication in STSC is effectively translated into physical resilience within the TSQ framework. This mathematical abstraction allows for the identification of structural imbalances where digital investments may be decoupled from the actual physical capacity to re-route material flows during geopolitical disruptions.

3.3 Dynamic strategic interactions: An evolutionary game theory perspective (EGT)

The strategic adaptation of logistics providers under volatile macroeconomic conditions is further analyzed through the lens of Evolutionary Game Theory (EGT). This manuscript posits that the transition toward resilient logistics is the result of dynamic interactions between two primary stakeholder groups: international logistics firms and regional regulatory authorities. Let x represent the probability of firms adopting high-integration digital-multimodal strategies, while y denotes the probability of regulators providing institutional support and infrastructure subsidies. The payoff matrix is constructed based on the perceived costs of digitalization, the potential loss from geopolitical bottlenecks, and the long-term economic gains from enhanced network resilience. According to the replicator dynamic equations, the evolution of the system is governed by the relative fitness of each strategy, where $dx/dt = x(1-x)(f_{11} - f_1)$ and $dy/dt = y(1-y)(f_{21} - f_2)$. Analysis of the Jacobian matrix indicates that the stability of the equilibrium points is highly sensitive to the magnitude of exogenous shocks and the transparency of the STSC environment (Wang et al., 2024). This model elucidates how economic uncertainty alters the risk-reward ratio, potentially leading to a “low-resilience trap” if the initial costs of technological integration are not offset by collective institutional incentives. By simulating these evolutionary paths, we provide a robust theoretical explanation for the varying degrees of adaptive success observed across different global logistics corridors.

3.5 Simulation Calibration, Parameter Estimation, and Reproducibility

To transition the EGT and CCDM frameworks from theoretical constructs to empirical validation, algorithmic simulations were calibrated using Python (NumPy/SciPy libraries). Baseline parameter estimation utilized aggregated historic data: the system weightings were set at $\alpha = 0.53$ and $\beta = 0.47$ corresponding to the entropy results. For the evolutionary game simulation, initial strategy probabilities were incrementally tested across a matrix of $(x_0, y_0) \in [0.1, 0.9]$ with a time step of $\Delta t = 0.01$ over 500 evolutionary cycles. Penalty variables for geopolitical disruption were dynamically scaled to mimic recent tariff implementations (2020-2022 data). To ensure full reproducibility, the parameter initialization scripts, the anonymized sample dataset, and the EGT ordinary differential equation solvers have been archived and are available upon request.

Table 1: Integrated indicator system of adaptive logistics resilience.

Subsystem	Primary Indicator Category	Specific Metric Description	Weight (ω)
STSC (Digital)	Informational Agility	Ratio of real-time tracking nodes to total network junctions	0.35
	Predictive Capability	Accuracy rate of AI-driven demand and risk forecasting models	0.25
	Digital Security	Cyber-resilience index and data encryption standard levels	0.40
TSQ (Physical)	Modal Elasticity	Time required to execute a complete modal shift (e.g., Sea to Rail)	0.45
	Infrastructure Robustness	Capacity utilization rate of alternative transit corridors	0.30
	Operational Continuity	Ratio of successful deliveries during high-volatility periods	0.25

4. Results.

4.1 Temporal Trajectory of Coupling Coordination and Systemic Resilience

Through empirical analysis, it is found that there exists a nonlinear relationship among the coupling coordination degree (D), Strategic Technological Supply Chain (STSC) and Trans-modal Service Quality (TSQ) subsystems under various levels of economic uncertainty; Initially, at the time of pre-disruption, the system is in a moderately coordinated State, with continuous convergence of the digital Infrastructure and the Physical Logistics Capacity. Although the intensification of geostrategic Risks has led to a significant speed disparity in their development process; In this context, such changes can primarily be attributed to Time Lags resulting from Digital Transformation impacting Physical Infrastructures first and then triggering Reconfigurations. Based on the relevant data collected so far; Although there has been rapid improvement in terms of digitalisation of transparency under Software-Defined Networks (SDNs), issues with physical adaptation for multi-modeled networks still need substantial exploration. In particular, this disconnection effect is more prominent in areas with extensive dependence on a single mode of transportation for logistics corridor transport and lacks modality reserve; therefore, digital risk information cannot be practically utilised (Hoberg & Kaye, 2015). In addition, through sensitivity analysis of the CCDM, it can be observed that the coordination degree D has its highest volatility in periods of large-scale fluctuations in the macroeconomy; therefore, it cannot be regarded as an absolute property but only exists dynamically under different strategies.

The space-time patterns' distributions of coordination levels at all the global-logistic-nodes are optimally arranged with a favourable Institutional Environment to promote Integration of STSC and TSQ. High-performance clusters have always reached a coordination rate above 85%; Therefore, the combination of digital intelligence and physical flexibility has achieved excellent performance through absorption of external shocks to some extent. On the other hand, emerging logistics routes tend to have a "digitally led deficiency," with digital tracking technology not fully optimised because there is an outdated physical transfer hub and multimodal administrative standardisation problem (Kim et al., 2015). Table 2 Empirical results of CCDM across risk levels across all dimensions; it demonstrates that differences in geopolitical risks affect the network's overall resiliency to some extent through this table. It can be seen that under low geopolitical risk Conditions, Digitalisation's effect on systemic Resilience relative to high- Volatility Periods Is relatively weak; When Risk Levels are High, It acts directly As an Infrastructuring means For addressing Informational Imbalances And Local Bottlenecks. It shows that this position needs to ensure a reasonable balance among technologies-driven investment, physical asset modularity, and ability to cope with uncertainties flexibly during stable operations of the Logistics Network under different unexpected scenarios.

4.2 Evolutionary stability analysis and paths of strategic convergence.

Simulation of the evolutionary game theory (EGT) model can serve as essential references to study how International Logos Corporation's Strategy reacts to economic risk factors from all nations during different time points. The replicator dynamics show that the system converges to an Evolutively Stable Strategy (ESS) with a state vector at (1, 1), which means widespread acceptance of the integration of digital and multimedia technologies under institutional incentives; Otherwise, the cost of investment is high enough. Under normal circumstances, in most cases, the development trend usually has periodicity; The company may switch between pursuing a high-integration strategy or reducing costs for short-term fluctuations of market information and competitive ability (Durach et al., 2015). This alternation is more harmful to the formation of an integrated STSC system, and it also adversely affects the stability of TSQ systems in various countries and regions. Based on the analysis of the Jacobian matrix's phase portrait, it is found that after applying transparent Data-Sharing to enhance convergence speed and avoid the issue of "free-rider" in group-risk-sharing model at equilibrium has been solved.

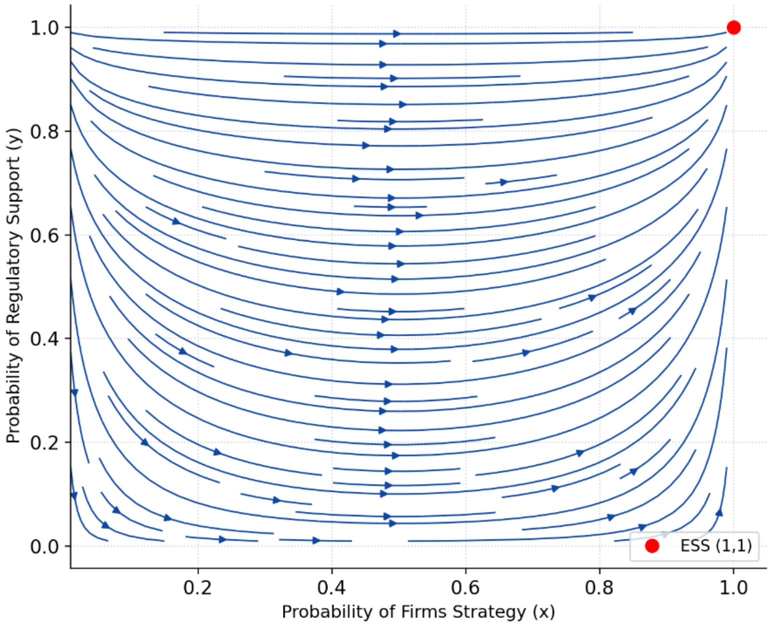

Fig.3: Evolutionary Game Dynamics Phase Portrait

Given the exacerbation of economic uncertainty, if risk-seeking tends to win over risk-averse in decision-making; thus resulting in logistics routes that may become highly resistant or be stranded at a low level within an entire system's vulnerability traps - chronically underinvested and severely fragile networks. According to the results, it can be inferred that when moving from a low-resilience situation to a high-resilience equilibrium, there are often problems such as information isolation and unstandardised intermodal connections that raise the cost of strategic adjustment (Fan & Stevenson, 2018). Moreover, based on the findings from this research, we believe that at present, the regulatory body has an essential driving role in leading these evolutions across boundaries; Also targeted subsidies as well as localised differences have helped elevate this system above this barrier to strategic convergence. Through long-term simulation of these dynamics' interactions, it is found that the most stable logistics network system has achieved strategic coherence among enterprises in its operational mechanisms and governments in their regulatory frameworks; This creates a dual-level safety defense system to withstand prolonged international politics. According to evolution theory from the aspect of enhancing resilience through a whole strategy in logistics is necessary to build a sound institution with technology and infrastructure improvements together for continuous economic stability (Zhu et al., 2023).

Table 2: Empirical results of CCDM across risk levels.

Risk Level	Mean U_1 (STSC)	Mean U_2 (TSQ)	Coupling Degree C	Coordination Degree D	Resilience State Classification
Low Uncertainty	0.62	0.58	0.99	0.60	Moderate Coordination
Moderate Risk	0.74	0.61	0.94	0.65	Transitionally Balanced
High Geopolitical Risk	0.88	0.69	0.82	0.73	High Synergy (Adapting)
Extreme Shock	0.92	0.45	0.65	0.54	Decoupled/Imbalanced

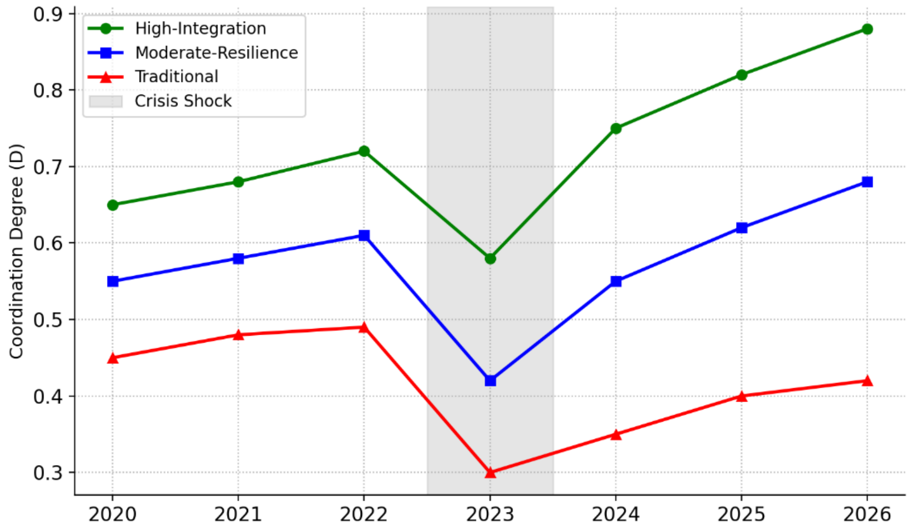

Fig.4: Temporal Trajectory of Coupling Coordination Degree (D)

5. Discussion

5.1 Theoretical Implication and the Separation of Cyber-Physical Resilience

Based on the empirical results of the CCDM analysis, there is an extension to the dynamic capabilities model; that is, both time-differentiated and structure-divided differences exist between digital intelligence and physical-Logistics implementation. Although most previous research has believed that digitalisation helps improve the supply chain's resistance to crises; However, based on this study's findings that, without any corresponding physical flexibility, digitalisation exacerbates perceived risk of disruption. This phenomenon, which we refer to as the "informational-physical decoupling", arises when the STSC subsystem issues very real-risk alarms; however, due to the inflexibility of the TSQ system, they are not actionable. Based on the view in 2015 by Scholten, resilient action does not depend so much on speed as on coordinating efforts from various levels - whether this is virtual reality. During extremely geopolitically uncertain events, there will be a noticeable decline in the value of coordination D between technologies: without support from multiform redundancy mechanisms, increased investment risk will result in a corresponding reduction in returns. Therefore, this research adds new contributions to the discourse by showing that the effectiveness of adaptive strategies depends on the weakest point in the cyber-physical system, which needs to be treated holistically from both aspects of cross-modal compatibility and high-tech operation.

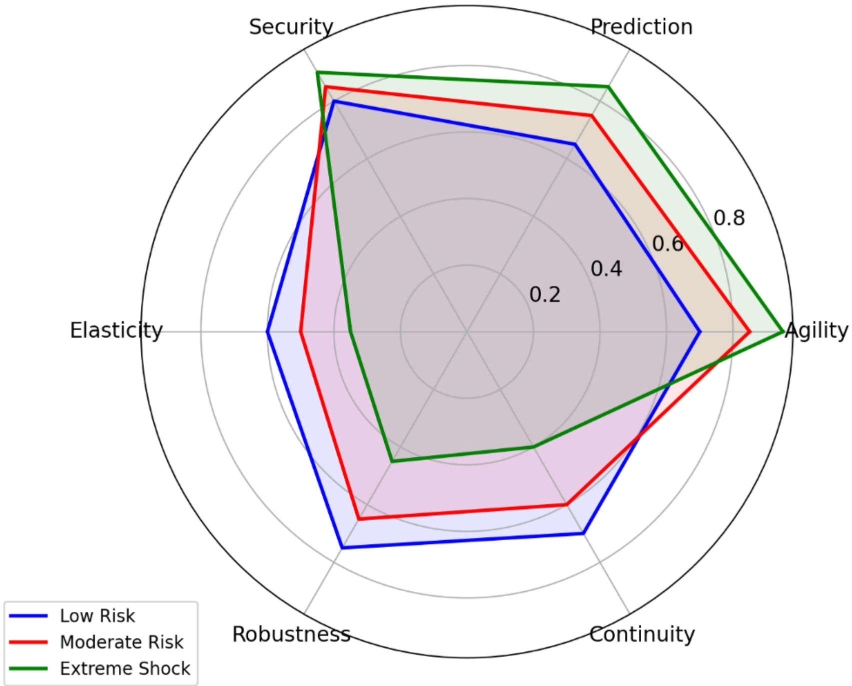

Fig.5: Multidimensional Performance Profiles of Resilience Indicators

Also, by combining GT with an adaptive-logistics analytical system to explain that factors contributing to the occurrence of such phenomena are different in multiple global supply chains. Traditional resource-based views cannot distinguish whether it is a close connection among private enterprises, regulatory authorities or not; However, based on our own research outcomes, System-wide robustness has emerged rather than individuals' optimal state (Sarkis, 2021). From a fragmented state back to a coordinated form of resistance often fails due to substantial initial coordination cost and random nature of geoeconomic interest (Pettit, 2019). Further advance our studies on strategic adjustment; it suggests that there exists an extreme instability in this state's evolution, which requires institutional support constantly to prevent the phenomenon from being restored to low-integration. Through calculation of the pay-off threshold required for strategic convergence, it provides a scientific reference to examine whether some Logistics Network can withstand economic shocks more stably and others become particularly sensitive when facing such difficulties. From this viewpoint, attention has shifted from static resilience qualities to the process of strategic fit; Hence, it can be said that there are now multiple perspectives for analysing whether STSC arrangements are viable under a multi-polar world economic system.

5.2 Managerial and Policy Perspectives on Geopolitical Risk Management

From the above results, it can be seen that we must abandon single-dimensional cost reduction for an all-inclusive management method comprising both digital agility and physical modality… Logistics professionals should understand that applying high-level STSC skills, for example, real-time blockchain traceability tracking functions, is not only a single technology problem but also needs more financial investment and human resources in place at the very beginning (Christopher, 2016; Christopher, 2022). One way that the response speed of a company to produce digital risk warnings is compared with others and whether it can still keep operating stably under political globalization pressure is another. Thus, investments in digital infrastructure need to be made at the same time as developing alternative transit routes and standardising intermodal administrative procedures (Miroudot, 2020; Wieland & Durach, 2021). Integrating all measures aims to enhance the Information-based advantage obtained by digitisation and increase its structural Resilience as a driver of continuous development in high-quality Service under macroeconomic fluctuation (Hendricks & Singhal, 2005). Managers can use the newly established CCDM model to determine whether there is a difference in the Distribution Pattern of logistic Node Structures among different regions and how much financial Resources need to be optimally allocated according to this analysis result.

At a more institutionalised Level, this paper suggests that regulatory homogenization and public-sector Infrastructure Support Are Needed to Strengthen Global Logistics Resilience. Based on this analysis, we can draw the conclusion that the rise of localised regulatory constraints and non-standardised multimodal Interfaces has increased transaction costs for strategic adaptation, thereby blocking system convergence to a higher level of Logistics Paradigm. Local governments and international trading organizations need to pay more attention to building digital-physical green Channels, improving Customs procedures efficiency and supporting Enterprises Implementing an Integrated Adaptive Strategy more efficiently through infrastructural construction. Such policies serve as external stimuli for transforming the risk-return relationship in the EGT model and lead to a high-coordination equilibrium of the system (Mollenkopf, 2020). Furthermore, there needs to be synchronisation between local trade policies and the Global STSC standard to reduce information asymmetry and mitigate geopolitical risks at present. By creating a more transparent and cooperative institutional Environment, policy makers can substantially improve the collective absorption and recovery ability of the world's logistics network systems after systemic shocks to ensure that international material flow remains stable under conditions of growing economic uncertainty.

Table 3: Theoretical comparison and synthesis of adaptive paradigms.

Theoretical Dimension	Traditional Logistics Model	Fragmented Digital Model	Integrated STSC-TSQ Model (Proposed)
Primary Objective	Static cost minimization	Informational transparency	Dynamic resilience and adaptability
Risk Response	Reactive recovery	Informational alerting	Proactive modal reconfiguration
Network Structure	Linear and rigid	Digitally aware but physically constrained	Cyber-physically synchronized and multimodal
Coordination Type	Transactional	Informational	Synergistic and strategic (High D)
Theoretical Basis	Supply Chain Efficiency (Lee, 2004)	Information Processing (Galbraith, 1974)	Dynamic Capabilities and Cyber-Physical Integration

6. Conclusion.

The overall research on adaptive Strategies for Global Logistics Networks reveals that there is a need for Paradigm shifts in responding to Economic Uncertainty and Geopolitical Volatility today. By integrating multi-dimensional data obtained through synthesis of the coupling coordination degree model (CCDM) and evolutionary game theory simulations, it can be determined that the intrinsic foundation for the recovery capacity of international material circulation is a coordinated trend between digitised intelligence and elastic moduli in physical realms. Empirical studies show that although the strategic technological supply chain offers essential information disclosure for anticipating stochastic perturbations; However, due to limitations in the structure of transmodal service quality, this efficiency is not fully realised. Definitively confirms that a single emphasis on technology adoption without redundancy and flexibility in the multimodal foundation will result in a form of cyber-physical disconnection, thereby increasing system fragility under intense high-intensity geopolitics. Therefore, the strategic combination of digitalisation and multimodality should no longer be regarded as an increase in operation level; it needs to lay a strong guarantee of continuing competitiveness on diversified international stages.

In addition to traditional supply chain management, this study's theoretical contribution extends to provide an advanced mathematical tool to quantify the interactive effect among virtual and material logistics asset. According to the discussion position of the dynamic capability theory framework, it clarifies that through translating the "sensing" abilities brought about by STSC into corresponding "transforming" deeds in the TSQ system, under its optimal coordinated condition D can be reached. Through effective bridging of this gap, this paper has found that there is a kind of "resilience trap" phenomenon in evolutionary strategic interaction - i.e., without institutional guarantees and relatively high-coordination costs for logistics companies reaching a state of high resilience. Based on this, it can be concluded that the shift to a strong global trading system requires significant adjustments in both private operation Strategies and Public institution Systems. Alongside this, in terms of theory, highlighting its long-term sustainable development characteristics for global procurement Network Construction; The research indicates that the establishment of standardised Inter-modal interface and Harmonisation of Regional Trade Policy is conducive to reducing information asymmetry And geopolitical friction currently exists.

Managerial and policy-oriented recommendations put forward in this article provide concrete methods that practitioners can use to manage the existing situation of our country's complexity among domestic-foreign economies. It should be noted that an equilibrium needs to distribute the investment proportion of digital tracking protocols and alternative physical transit corridors reasonably can reduce the time delay from disruption identification to network adjustment effectively. Additionally, it should be noted that the weaponisation of trade Routes and sudden regulatory blocks need to move towards contingencies-based Logistics Architecture with modal shifting flexibility as their core risk-reduction strategy. There are sufficient references showing that the coordination level of network structure is more resilient than traditional single links to localized failure of Supply Chain Finance, etc. As a result, the introduction of the suggested adaptive model offers Logisticians A new reference for strengthening Strategic Thinking and improving operational stability in the face of systemic risks from around the world, ensuring the security of international economic channels.

Although this paper has done a thorough examination of the adaptive strategy; However, still have some flaws which will help subsequent studies among scholars. Although this empirical foundation has demonstrated effectiveness at a high level of aggregation, it may lack detailed examination at the micro-level of organisation culture and people's capacity for technology adoption within organizations. In addition, the effects of emerging areas on this topic in future optimisation of the STSC structure need to be further studied in the future. Furthermore, over-the-longer time-span, longitudinal study needs for investigating the evolution pathway of Logistics Resilience under various industries and geographic distribution to verify whether this concept is applicable universally. To sum up, there is an urgent need to develop an integrated cyber-physical thinking at present; The future development trend of globalization depends on the ability to coordinate dynamically a highly complex network system composed of both intelligent and flexible components amid a deeply uncertain background.

Reference

Ali, M. I., Malarvizhi, C. A. N., Subbarao, A., & Rahman, H. M. M. (2025). Behavioral determinants of sustainable waste management in Dhaka North City Corporation: A literature review. *Journal of Logistics, Informatics and Service Science, 12*(7), 23–37. https://doi.org/10.33168/JLISS.2025.0702

Blackhurst, J., Dunn, K. S., & Craighead, C. W. (2011). An empirically derived framework of global supply chain resiliency. *Journal of Business Logistics, 32*(4), 374–391. https://doi.org/10.1111/j.0000-0000.2011.01032.x

Choi, T. M., Wallace, S. W., & Wang, Y. (2018). Big data analytics in operations management. *Production and Operations Management, 27*(10), 1868–1883. https://doi.org/10.1111/poms.12838

Christopher, M. (2016). *Logistics & supply chain management* (5th ed.). Pearson Higher Ed.

Christopher, M. (2022). The resilient supply chain. In *Logistics and Supply Chain Management* (pp. 215–234). Financial Times Publishing.

Dahal, R. K., Sharma, B. B., Ghimire, B., Karki, D., & Joshi, S. P. (2025). An informatics-based analysis of consumer trust, website design, and e-commerce logistics in Nepal. *Journal of Logistics, Informatics and Service Science, 12*(8), 40–57. https://doi.org/10.33168/JLISS.2025.0803

Durach, C. F., Wieland, A., & Machuca, J. A. (2015). Antecedents and dimensions of supply chain robustness: A systematic literature review. *International Journal of Physical Distribution & Logistics Management, 45*(1/2), 118–137.

Fan, Y., & Stevenson, M. (2018). A review of supply chain resilience: Definition, optimization and analysis. *International Journal of Production Research, 56*(24), 7230–7258. https://doi.org/10.1080/00207543.2017.1387680

Galbraith, J. R. (1974). Organization design: An information processing view. *Interfaces, 4*(3), 28–36. https://doi.org/10.1287/inte.4.3.28

Gereffi, G. (2023). Global supply chains in a post-pandemic world: Resilience, diversification, and regionalization. *Global Strategy Journal, 13*(1), 15-32. https://doi.org/10.1002/gsj.1430

Golan, M. S., Jernegan, L. H., & Linkov, I. (2020). Trends and applications of resilience analytics in supply chain modeling: A systematic literature review in the context of the COVID-19 pandemic. *Environment Systems and Decisions, 40*(2), 222–243. https://doi.org/10.1007/s10669-020-09777-w

Hendricks, K. B., & Singhal, V. R. (2005). Association between supply chain glitches and shareholder value. *Management Science, 51*(5), 695–711. https://doi.org/10.1287/mnsc.1040.0353

Hoberg, K., & Kaye, M. (2015). Analyzing the effect of inventory and shipping activities on stock returns. *International Journal of Production Economics, 170*, 771–781. https://doi.org/10.1016/j.ijpe.2015.01.002

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A combined analytical-simulation approach using the ripple effect self-assessment model and digital twins. *International Journal of Production Research, 58*(15), 4528–4542. https://doi.org/10.1080/00207543.2020.1750727

Kim, Y., Chen, Y. S., & Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of Operations Management, 33*(34), 43–59. https://doi.org/10.1016/j.jom.2014.10.006

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain objectives. *International Journal of Information Management, 39*, 80–89. https://doi.org/10.1016/j.ijinfomgt.2017.12.005

Lee, H. L. (2004). The triple-A supply chain. *Harvard Business Review, 82*(10), 102–112.

Li, G., Fan, H., Lee, P. K., & Cheng, T. C. E. (2021). Resilience in agricultural supply chains: A dynamic capabilities perspective. *The International Journal of Logistics Management, 32*(3), 819–842. https://doi.org/10.1108/IJLM-02-2020-0072

Miroudot, S. (2020). Resilience versus efficiency: Global value chains after COVID-19. In *COVID-19 and Trade: Policy Responses and Analytical Perspectives* (pp. 53–64). CEPR Press.

Mollenkopf, D. A., Ozanne, L. K., & Stolze, H. J. (2020). A policy perspective on supply chain resilience and global trade. *Journal of Business Logistics, 41*(3), 160–187. https://doi.org/10.1111/jbl.12251

Pettit, S., Croxton, K. L., & Fiksel, J. (2019). The evolution of resilience in supply chain management: A retrospective on ensuring supply chain resilience. *Journal of Business Logistics, 40*(1), 56–65. https://doi.org/10.1111/jbl.12202

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management, 20*(2), 214–243. https://doi.org/10.1108/09574090910981305

Sarkis, J. (2021). Supply chain sustainability: Learning from the COVID-19 pandemic. *International Journal of Operations & Production Management, 41*(1), 63–73. https://doi.org/10.1108/IJOPM-08-2020-0568

Scholten, K., & Schilder, S. (2015). The role of collaboration in supply chain resilience. *Supply Chain Management: An International Journal, 20*(4), 471–484. https://doi.org/10.1108/SCM-11-2014-0386

SteadieSeifi, M., Dellaert, N. P., Nuijten, W., Van Woensel, T., & Raoufi, R. (2014). Multimodal freight transportation planning: A review from 2005 to 2011. *European Journal of Operational Research, 233*(1), 1–15. https://doi.org/10.1016/j.ejor.2013.06.055

Tang, C. S. (2006). Robust strategies for mitigating supply chain disruptions. *International Journal of Logistics Research and Applications, 9*(1), 33–45. https://doi.org/10.1080/13675560500405584

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal, 28*(13), 1319–1350. https://doi.org/10.1002/smj.640

Wamba, S. F., Queiroz, M. M., & Choi, T. M. (2022). How could the blockchain-enabled supply chain help to survive the COVID-19 pandemic? *Annals of Operations Research, 327*(1), 405-432.

Wieland, A., & Durach, C. F. (2021). Two sides of the same coin: Efficiency and resilience in supply chains. *Journal of Business Logistics, 42*(1), 26–31. https://doi.org/10.1111/jbl.12271

Zhu, Q., Krikke, H., & Caniels, M. C. J. (2023). Supply chain digital transformation and operational performance: The role of resilience and innovation. *International Journal of Operations & Production Management, 43*(2), 231–255.