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A Conceptual Framework for Multi-Tier Supply Chain Network Architecture and Resilience

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Abstract: Introduction: SCN have become very strategic and intricate structures in contemporary operations management; they function both as a vector for vulnerabilities and an essential force driving competitive advantage. Being multi-tiered systems composed of nodes and links that stretch across nations and institutions' jurisdictions, such networks contain profound vulnerabilities that pose significant challenges to firm-level resilience paradigms. Objective: This paper aims at conducting an SLR of existing scientific studies that analyze the structural properties of SCNs, outline the structural mechanisms of multi-tier disruption propagation within these networks, and assess how digital technologies can be used to increase their resilience. Methodology: Employing SLR methodology in its entirety, the present study analyzes peer-reviewed papers dedicated to this problem from 2020 to 2026. Conceptual integration will be conducted using Network Theory, SCRES Theory, and Dynamic Capabilities Theory. Results: It has been found that the main structure-based predictor of disruption cascade effects in SCNs is network topology defined by such metrics as node degree distribution, geographic clustering, and multi-tier visibility depth. Importantly, it has been demonstrated that the use of digital twins, decentralized nodes, and E2E visibility contributes significantly to enhanced disruption absorption and time-to-recovery (TTR). Originality/Value: This work adds value to the field of operations management research through the formulation of a conceptual model for Digitally Enabled Supply Chain Network Resilience, which is a synthesis of the relationship between structural network topology and digital technology adoption. The final section of the paper applies these learnings to provide six practical recommendations for building resilient supply chains in the face of macroeconomic disruptions.

Keywords: Supply Chain Resilience, Network Topology, Digital Twin Technology, Disruption Spread, Multi-Tier Transparency, Systematic Literature Review.

INTRODUCTION

The global supply chain network (SCN) is considered to be the physical and digital backbone of today's macroeconomy. Rather than being elementary or linear in terms of a series of dyadic interactions between the buyer and seller, contemporary supply chain networks are advanced, non-linear and multi-level networks of nodes and interconnections, through which not only physical matter but also capital and information flow (Hosseini & Ivanov, 2022). It is important to note that the structure of the SCN, namely the density of nodes, degree distribution, concentration of productive capacities geographically and extent of information exchange among different tiers, plays the defining role in initiating and responding to disturbances.

From the years 2020 to 2025, there has been an exceptional increase in systemic instability, which is characterized by the greatest and longest-lasting disruption climate within global networks in recent times. The systemic shocks generated by the onset of the

COVID-19 crisis led to cascading failures in the auto, pharmaceutical, semiconductor, and agrifood industries, revealing the weaknesses inherent in lean, efficient, and just-in-time models (Paul et al., 2021). The fragility in supply chains was further accentuated by long-term shortages of semiconductors, which paralyzed downstream production of consumer electronics, and geopolitics, including the war between Russia and Ukraine, which disrupted fertilizer, fuel, and grain transportation networks. Taken together, the systemic crises showed that it is vital to assess SCN structural vulnerability and its impact on the economy.

In reaction to this extended period of volatility, the implementation of sophisticated digital technologies within supply chain networks became exponentially greater. The fusion of artificial intelligence, block-chain based ledgers, IoT sensor network technology, multi-level data structures hosted in the cloud, and digital twinning simulations have now created the technological foundation necessary for achieving full end-to-end network visibility and disruption telemetry (Ivanov & Dolgui, 2021). Recent empirical evidence from crisis situations shows that companies utilizing such integrated digital platforms exhibited significantly improved abilities for absorbing disruptions and recovering much faster than their technology-deficient rivals, thereby demonstrating strong positive relationships between digital network integration and organizational resilience.

In order to bring together the above-mentioned issues, this study analyzes the connection between SCN topology, the process of disrupting multiple tiers and digitalized approaches to building resilience. The structure of the current paper is organized in the following way: Chapter 2 provides a systematic literature review on issues related to SCN architecture and disruption processes; Chapter 3 defines the theoretical background; Chapter 4 explains the research methods applied; Chapter 5 discusses the results achieved; Chapter 6 presents some recommendations.

LITERATURE REVIEW

Supply Chain Networks: Concept and Architecture

On a graph, supply chain actors such as suppliers of raw materials, manufacturers of components, assembly facilities, distribution centers, logistics companies, retailers, and final consumers are represented by nodes, and the financial, material, and information flows that connect these actors are represented by links (Hosseini and Ivanov, 2022). This graph-theoretic conceptualisation of supply chains, which is based on Network Theory, allows researchers and practitioners to evaluate supply chain vulnerability, identify critical nodes, and assess the systemic implications of individual node or link failures with much greater analytical rigour.

The supply chain network designs of various industries and product categories range significantly. An exceedingly small number of tier-one systems integrators receive input from tens of thousands of tier-two and tier-three component suppliers, who then supply final assembly activities. Deep, multi-tiered hierarchies are characteristic of automotive supply networks. In contrast, fast-moving consumer goods networks typically have shorter tier structures and more parallel supply paths, which reduce the danger of a single point of failure and offer structural redundancy. Alikhani, Torabi, and Altay (2021) demonstrated through stochastic optimisation modelling that network design choices, particularly the location of safety stock, the number of sourcing options, and the degree of facility fortification, have first-order effects on a network's ability to absorb and recover from disruptions.

The concept of network complexity is one of the primary concerns in contemporary supply chain research. The three interconnected dimensions of supply chain network complexity are the number of nodes and links in the network; the variety of actors, relationships, and product flows; and the dynamic interactions among network elements that result in emergent properties not predictable from the characteristics of individual nodes or links in isolation (Wieland, 2021). High-complexity networks provide the advantages of redundancy and flexibility, but they are also more difficult to coordinate, monitor, and manage in the case of a disruption. The conflict between complexity and resilience is one of the main strategic problems in contemporary supply chain network architecture.

Disruption Propagation and the Ripple Effect in Supply Networks

The phenomenon whereby a localised disruption at one node in a supply chain network causes a cascade of operational failures and performance degradations at other network nodes, frequently propagating in directions and with amplitudes that could not have been predicted from analysis of the initially disrupted node alone, is known as the "ripple effect," which was first introduced by Ivanov, Sokolov, and Dolgui (2014) and extensively developed in subsequent literature. The severity of the ripple effect, which turns a point disruption into a network-level catastrophe, is closely correlated with the network's structural features.

To measure supply chain resilience with explicit ripple effect considerations, Hosseini and Ivanov (2022) created a Bayesian network framework. They showed that analysing the robustness of individual nodes in isolation is insufficient to determine a network's resilience. Because of their structural position as vital links between network modules, nodes with moderate individual vulnerability profiles could cause disproportionately large ripple effects when disrupted, according to their empirical application to a car manufacturing supply network. The most hazardous nodes are those whose failure would most seriously impede network connectivity, not necessarily those with the highest potential of failure. This discovery has significant implications for supply chain risk management.

Network Topology and the Ripple Effect

The issues related to the supply chain recovery after the outbreak of the coronavirus disease were assessed by Paul et al. (2021), who identified twenty-three recovery issues in the context of the ready-made garment industry of Bangladesh. Causative and resultant types of recovery issues were identified during the study using the grey DEMATEL methodology. As per the results of the study, transportation disruptions, working capital constraints, and lack of raw materials were causally antecedent to various performance issues.

The multi-level, multi-country network structure examined by Paul et al. (2021) provided empirical evidence to back up the hypothesis that, despite the lack of direct sourcing connections, disruptions in geographically distant tiers of the supply network have dire implications on downstream organizations. Some factors from the literature associated with structural characteristics of supply chain networks have been linked to the occurrence of significant ripple effect intensity. Geographic concentration refers to the clustering of supply capability for an important material or component group in a particular country or region, making the structure fragile, thus allowing limited geopolitical or climate-related shocks to create international disruptions. Single source dependencies at vital network nodes negate redundancy to monitor failures without creating disruptions downstream. Just-in-time systems with little inventory buffer are characterized by strong coupling among network nodes, negating the presence of buffering that stops ripple effect propagation before reaching downstream nodes (Zhao et al., 2023).

Network Design Strategies for Resilience

The architecture of supply networks, including the number and location of facilities, the structure of supplier relationships, the configuration of inventory and capacity buffers, and the design of information flows across network tiers, is decided by organisations in the strategic decision-making domain of supply chain network design. To find network architectures that strike a balance between the resilience goals of disruption absorption and recovery capacity and the efficiency goals of cost minimisation and asset utilisation, resilience-oriented network design incorporates disruption risk considerations into these choices (Alikhani et al., 2021).

Three types of resilience strategies can be incorporated into network architecture, according to the scholarly literature on robust supply chain network design. Facility fortification, supplier development and qualification, geographic sourcing diversification, and the construction of safety stock buffers at key network points are examples of initiative-taking methods that lessen the likelihood or impact of disruptions before they happen (Alikhani et al., 2021). Pre-negotiated backup supplier agreements, reserved capacity arrangements, emergency coordination protocols, and inventory sharing systems among network partners are examples of reactive methods that lessen the effects of interruptions after they have already happened (Alikhani et al., 2021).

Network Design Quality and Synergistic Resilience Portfolios

The structure features of the network like the degree of modularity of the network, the presence of alternative routes from the origin of the supplies to the destination of demand, and multi-tier visibility to identify emerging threats are included in the set of network design quality features (Alikhani et al., 2021). One important research domain is the interaction effects of resilience approaches. In certain circumstances, the use of combinations of resilience techniques may generate synergies which make their impact on the overall resilience greater than the sum of individual effects, (Alikhani et al. ,2021). This holds particularly true when different proactive and reactive measures are used in combination as complementary actions and not as substitutes.

According to their stochastic programming model, even if the total spending on resilience efforts was the same for each organization, organizations which utilized multiple simultaneous resilience measures performed better than organizations that pursued any single approach, (Alikhani et al. ,2021). This strongly supports the idea of applying the portfolio approach in managing risks through resilience efforts which cover the range of proactive, reactive, and network design quality aspects.

Digital Technologies as Network Resilience Enablers

The utilization of digital technology is making the supply chain network more resilient. Ivanov and Dolgui(2021) proposed the concept of digital supply chain twin as an important development of supply chain network resilience through digital technology. Companies can monitor the status of their supply chains continuously, predict the impact of possible disruptions on the network before the actual occurrence of the disruption, and assess plans for responses through quantitative measurements by applying the digital supply chain twin, which is a computational simulation of the network's status in real-time operations (Ivanov and Dolgui ,2021).The application of the digital twin concept in supply chain network risk management has resulted in a qualitative transformation in approach, from reactive crisis management to pro-active scenario planning based on real-time information about the current status of the network. Through empirical study, Belhadi et al. (2021) proved how innovation through artificial intelligence improves the resilience of the supply chain by analysing enormous data on supply network dynamics at scales beyond human capabilities.

Artificial intelligence can be used to monitor the risk of the supplier by analysing the performance data of the supplier, their financial health, geopolitical risks, and climate risks of the supplier in real time. It is worth noting that this system is quite effective in the case of multi-tier supply chains, According to Belhadi et al. (2021), the use of AI to enhance the resilience of the multi-tier supply chain will be highly effective when there is dynamic change in the network. The blockchain technology will address the most persistent problem in the case of multi-tier supply chains, which is lack of trusted information about the material.

Blockchain and Digitalisation: Enhancing Performance and Resilience Through Information Sharing

As per empirical analysis by Fosso et al. (2020), there exists a positive association between supply chain performance and the use of blockchain technology. Fosso et al. (2020) noted that the relationship was partially mediated by the extent of cooperative information sharing by actors within the supply chains. Blockchain technology makes supply chain network actors from various network layers willing to share information that may be withheld owing to liability or competitiveness, hence fostering "trust infrastructure" within the network layer (Fosso et al., 2020). The net effect would be enhanced visibility of the state of the network as well as its information flow (Fosso et al., 2020). According to the multi-mediation model proposed by Zhao et al. (2023), supply chain digitalization can help build network resilience and performance through three mechanisms, namely recovery capability (enhanced ability to restore the network following disruptions at minimized costs); response capability (enhanced speed of implementing network mitigation strategies) and absorptive capability (enhanced capacity to quickly acquire and process network state disruption-related.

This means that due to the fact that response optimization driven by artificial intelligence is based on the infrastructure created by the former, priorities for investment in absorption capacity must include priority for investing in multilevel visibility systems and data integration systems in real-time, among others (Zhao et al., 2023).

THEORETICAL FRAMEWORK

Supply Chain Resilience Theory

The main theory guiding this research is that of Supply Chain Resilience Theory, which was developed initially by Serhiy Y. Ponomarov and Mary C. Holcomb in 2009, describing resilience as the adaptability of a supply chain to prepare for unforeseen contingencies, respond to disturbances, and recover from the disturbances to continue operating effectively within a level of connectivity and control. Expanding on this theoretical concept, Dmitry Ivanov in 2020 presented the viability paradigm, whereby supply chain resilience theory was redefined to represent a systems property that encompasses agility, resilience, and sustainability. According to this theory, resilience is described as the adaptive capacity of a supply system to detect disruption indicators, initiate appropriate actions aimed at minimizing or recovering from disruption disturbances and ultimately emerging more resilient (Wieland, 2021; Chowdhury and Quaddus, 2021).

The element of transformation in resilience, referring to the capacity of network agents to make use of disruptions to initiate changes in their network structures and capabilities, has been identified with advances in theories of supply chain resilience (Wieland, 2021). The perspective on resilience as transformation has some significant implications in relation to organizational network design, which rather than seeing disruptions as something deviating from an optimal stable situation should be addressed, suggests organizations establish networks that have sufficient organizational and structural flexibility to change in line with disruptions.

Network Theory and Complex Systems

Network Theory, the basic principles of which have been mathematically formulated by Leonhard Euler in his 1736 paper on graph theory and later developed in the complex systems context by Albert-László Barabási and Réka Albert (1999), is the structural theoretical framework that underpins the analysis in this paper. The discovery by Barabási and Albert (1999) of the inherent scale-free nature of networks, including supply chains, has revealed that the heterogeneity in the distributions of node connectivity properties of real-world networks, not their randomness, plays an important role in disrupting network functioning. Building on this and the subsequent research into applications of Network Theory to supply chains (e.g., Hosseini & Ivanov, 2022), the current paper examines such core Network Theory concepts as path length, a measure of the average number of network links between two randomly selected nodes in the network; modularity, a measure of the extent of the division of a network into self-contained modules through which disruptions can propagate only weakly; network density, a measure of the proportion of possible links that are actualized; and node centrality, a measure of the criticality of particular actors within a supply chain network.

Significant empirical findings about the relationship between network topology and network resilience can be attributed to the application of network theory in supply chain research. Although they exhibit relatively high resilience to random node failures, scale-free networks where there are few highly connected hubs that contribute significantly to overall network connectivity tend to be vulnerable to disruptions of these hubs. As per Hosseini and Ivanov (2022), firms need to invest heavily in the resilience of their supply network hubs since disruptions at such hubs carry a lot of potential to disrupt networks across the board. This conclusion is one of the valuable lessons drawn from complex systems research and has a clear implication for supply chain risk management.

Dynamic Capabilities Theory

Dynamic Capabilities Theory provides an organisational-level framework that can be used to understand the development, renewal, and restructuring of the capabilities required by the players within the supply chain network to operate their network positions under conditions of fast-changing environments. The theory was first introduced by David J. Teece, Gary Pisano, and Amy Shuen in 1997 in their groundbreaking paper titled 'Dynamic Capabilities and Strategic Management', while it was further developed by David J. Teece in 2020 through adding open innovation and competition through platforms to the theory's purview. Among dynamic capabilities are the sensing capabilities of an organisation, its ability to seize new opportunities and disruptions within its network, and the reconfiguration capabilities of the network.

In the context of supply chain networks, dynamic capabilities show up as an organization's capacity to adapt to new disruption patterns by redesigning network structures, renegotiating supplier relationships, integrating new digital monitoring tools, and creating new cooperative protocols with network partners (Chen et al., 2026; Li, 2026). According to the theory, companies with strong dynamic capabilities will exhibit better network resilience outcomes not because they encounter fewer disruptions, but rather because they can react to disruptions more quickly and efficiently when they do occur and use those experiences to gradually improve their network architectures and resilience capabilities (Li et al., 2026; Odamtten, 2025). The actual data examined in this research supports this prediction.

METHODOLOGY

Research Design

The chosen methodology for conducting the primary research will be a systematic literature review. The systematic literature review has been chosen to be the best fit for the methodology since the main purpose of the research to explore the structure of the supply chain network, its vulnerability to disruptions and the way digital technologies can increase the resistance of the network cannot be achieved using new primary empirical data generated in a particular context but, instead, by summarizing current academic knowledge obtained from various streams of research. Through ensuring that the review procedure is transparent and complete, the systematic literature review eliminates the issues with bias associated with non-systematic narrative reviews (Tanfield, et al, 2003).

Considering the issue of relationships within supply chain network structures, this research uses the interpretivist approach due to the fact that the relationship of interest is highly embedded in organizational, technological, and environmental dynamics which cannot be easily described by means of any positivist framework (Gligor et al., 2020; Saunders et al., 2023). Following the interpretation approach, the systematic literature review is considered an organized interpretive process (Denyer & Tranfield, 2009; Snyder, 2019). It systematically gathers relevant evidence by selecting a representative sample of peer-reviewed articles, identifying patterns, contradictions, and convergences within this evidence, and creating a more comprehensive understanding from the results, compared to what can be provided by each individual article separately (Snyder, 2019; Xiao & Watson, 2019). These insights are expected to lead both academic and managerial thinking related to designing and managing supply chain networks.

Search Strategy and Inclusion Criteria

In order to obtain all-inclusive literature that covers the area of Operations Management, Logistics, Information Systems, and Supply Chain Management, the literature search included four important database resources, namely, Google Scholar, Web of Science, Scopus, and Emerald Insight (Ghadge et al., 2020; Snyder, 2019). It is worth noting that these databases are home to most of the peer-reviewed articles related to network architecture and supply chain resilience (Xiao & Watson, 2019). Specific keywords were created through the use of Boolean logic operators AND and OR; main keywords include the following: "supply chain network," "supply chain network design," "supply chain network resilience," "disruption propagation," "ripple effect supply chain," "multi-tier supply chain," "digital supply chain network," "blockchain supply chain," "artificial intelligence supply chain resilience," and "supply chain digital twin" (Ivanov & Dolgui, 2021; Katsaliaki et al., 2021).

In order to provide exhaustive coverage of all relevant literature related to operations management, logistics, information systems, and supply chain management, the literature review relied on four key academic databases, namely, Google Scholar, Web of Science, Scopus, and Emerald Insight (Kavota et al., 2024; Shishodia, n.d.). These sources combined contain almost all the existing scholarly studies devoted to the topic of SCN design and resilience (Shishodia, n.d.). Specific search strings were designed with the use of Boolean logic (AND, OR); the main search keywords used for searches include "supply chain network, supply chain network design, supply chain network resilience, disruption propagation, ripple effect supply chain, multi-tier supply chain, digital supply chain network, blockchain supply chain, AI supply chain resilience, and supply chain digital twin (Ivanov, 2020, 2023).

Data Extraction and Synthesis

Extracting the information from the articles selected for the body of literature was done based on a template designed specifically for that purpose (Denyer & Tranfield, 2009; Snyder, 2019). All essential aspects, including the conclusions arrived at through the research, the problem definition and objectives, theories employed, research method, and the potential implications for practical applications mentioned by the authors, have been extracted using the template designed (Durach et al., 2017). The use of the template facilitated the process of extracting the information systematically and comparably, thereby ensuring the quality of analysis.

The approach to synthesis used for this paper is thematic synthesis, based on the methodology outlined by Thomas and Harden (2008). Thematic synthesis entails three stages, namely: coding of individual study results; identification of descriptive themes, which help to code results in an analytical structure; and development of analytical themes, which transcend the results of each individual study in order to create new insights.In the current paper, the descriptive themes relate to the four sections of the literature review, while the analytical themes are addressed and synthesized within the context of the conceptual framework presented in the discussion section. Evaluation of the quality of the papers used in this paper relied on the mixed-methods appraisal tool, where the criteria considered were methodological rigour, clarity of theoretical grounding, and specificity and empiricism of the claims.

Network Topology and Disruption Vulnerability

Indeed, there is a direct and consistent relationship between supply chain network topology and disruption vulnerability, as highlighted in the synthesised literature. Supply chains that are made up of highly concentrated geographical distribution of supply capacity, highly dependent single sourcing at critical network nodes, and lack of structural modularity tend to be more disruptive than networks whose topologies involve geographical dispersion, diversification, and modularity which prevent cross-module disruption. The topology of supply chains is no coincidence but deliberate decisions made over time to cut down on costs and increase economies of scale.

The example of the coronavirus outbreak, along with the semiconductor shortage, emphasized the vulnerability caused by geographic clustering and dependency on one source (Paul et al., 2021). Automotive suppliers had to shut down when consumer electronics received priority at semiconductor manufacturing facilities. Such vulnerability underscores that both the severity of disruption and the recovery period of the network depend on network structure. With the help of Bayesian network modeling, Hosseini and Ivanov (2022) proved that the structural centrality of a node in a network is a more accurate indicator of potential damage than its individual risk level. Modern supply networks have to be managed according to this principle, thus requiring companies to focus on protecting strategically important nodes instead of addressing isolated weak links. It is possible that an individual node is not very vulnerable; nevertheless, the risk of disruption will still significantly affect the stability of the network as a whole due to its structural importance.

Multi-tier Visibility and the Information Deficit Problem

Most companies do not have much visibility beyond their immediate relationships with tier-one suppliers, based on the recurring theme noted from the literature synthesis exercise. Given that disruptions normally originate from tier-two, tier-three, or even further down in the supply network levels prior to their detection by focal firms via the influence they exert on tier-one suppliers, inadequate multi-level visibility cannot merely be viewed as a hindrance. In fact, it presents itself as a basic challenge in managing network resilience since it severely limits the window for action as well as the effectiveness of intervention measures taken once focal organizations rely on their tier-one supplier relationships for recognizing the developing disruption. Digital supply chain twin technology directly addresses the multi-level visibility issue through the provision of a real-time computation-based representation of the entire supply network in which nodes and links at all tiers are represented simultaneously, as demonstrated by Ivanov & Dolgui (2021).

By integrating the use of IoT systems, artificial intelligence for detecting anomalies, and cloud services, digital twins help firms detect and deal with signals of upstream disruption much quicker compared to the past, as shown in simulations by Ivanov and Dolgui (2021), indicating that quick detection results in up to a 35% reduction in overall disruption impacts on performance metrics. Even though the benefits are apparent, the ability to see the entire network remains constrained due to a joint technological and relational lack of information wherein suppliers refuse to disclose sensitive information out of competitive, regulatory, and reputational concerns (Ivanov & Dolgui, 2021). Blockchain technology directly addresses the problem of relational friction by providing a trust infrastructure through the transparency of a distributed ledger that prevents any form of data manipulation, which traditional relational and contractual frameworks cannot achieve.

Digital Technologies and Network Resilience Outcomes

This synthesis of existing literature offers clear empirical support of the hypothesis that the investment made towards digitalisation of the supply chain network capabilities leads to better network resilience results. For example, Belhadi et al. (2021) using structural equation modeling with data from 279 firms from different sectors and nations found that AI innovation positively impacts supply chain efficiency directly and indirectly, the latter happening through improved network resilience. Similarly, Zhao et al. (2023) used this research model to show that the digitalisation of supply chains increases resilience through three subsequent stages: increased absorptive capacity facilitating quicker processing of disruption-related network information; increased response capacity leading to prompter execution of mitigation actions; and greater recovery capacity enabling the rapid and inexpensive restoration of the disrupted network. Network resilience resulting from investments in digitalisation can be rather substantial. Specifically, according to the estimation provided through the use of simulation modeling by Ivanov and Dolgui (2021), digital supply chain twin capability led to reducing the loss of efficiency due to disruptions by 22 to 35 per cent. However, Belhadi et al. (2021) discovered that the positive influence of investments in artificial intelligence on resilience becomes more pronounced in case of the high level of dynamism within the supply chain, which is exactly what is present in the period from 2020 to 2025. Furthermore, Zhao et al. (2023) concluded that maximum performance can be achieved through the combination of technologies and organisation skills, namely, the maturity of data management, cross-functional digital teams, and collaborative partnerships with suppliers.

Barriers to Digitally Enabled Network Resilience

The challenges that may prevent organizations from realizing the benefits of digital network resilience have been highlighted in the synthesised literature as well. First, the already existing base of technologies that supports supply chain management and ERP in the manufacturing and logistics sectors cannot operate in the new cloud-based, API-driven architecture of data that contemporary multi-layer visibility and digital twin technologies are based upon. Sometimes, legacy challenges prevent organizations from incorporating their existing systems into the new data environment due to high costs and complex legacy system modernization. Even after spending considerable resources on modern technologies, organizations face the issue of having siloed data as a result (Zhao et al., 2023).

Regarding the use of digital networks in corporate operations, the role played by human capital in terms of the network resilience of an organization is continually overlooked, thus acting as a bottleneck to effective technology adoption (Kavota et al., 2024). Effective utilization of technologies such as AI anomaly detection, digital twins, and blockchain requires employees who have both digital analytics skills and knowledge on the operations of a company. Due to the shortage of this kind of professional skills globally, companies that invest heavily in digital infrastructure end up having poorly utilized assets (Kavota et al., 2024).

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study frames supply chain networks as intricate multi-tier systems where resilience outcomes are mutually determined by structural topology, disruption propagation dynamics, and digital capabilities. The synthesized literature demonstrates that architectural features—specifically geographic concentration, single-source dependencies, structural modularity, and multi-tier visibility depth are the primary determinants of how disruptions initiate and propagate, proving that networks optimized solely for cost efficiency through lean, just-in-time models are systematically vulnerable to cascading shocks. Conversely, emerging digital enablers like cloud visibility systems, blockchain tracking, AI demand sensing, and digital twins offer a qualitative leap forward, allowing organizations to detect early disruption signals and simulate response options against quantitative models before deployment. Empirical data confirms that firms leveraging these digital competencies consistently outperform technology-lagging peers in both disruption absorption and recovery speed. Ultimately, by theoretically integrating Supply Chain Resilience Theory, Network Theory, and Dynamic Capabilities Theory through a rigorous systematic literature review methodology, this paper establishes a robust, methodologically sound analytical architecture that explains how organizations systematically develop and sustain network resilience within complex, resource-constrained environments.

Recommendations

1. For network topology risk assessments, it is vital for companies to go past their tier-one connections and use network centrality metrics to reveal geographical and structural weaknesses. Such systematic assessments need to drive investments into critical network nodes.
2. For multitier supply network visibility solutions, the companies have to implement cloud infrastructure solutions that will integrate flow streams between tier-one, two, and three partners. Otherwise, it would be impossible to identify any signals indicating the potential disruptions and take action on time.

3. For digital twins for supply chains, firms should consider employing digital twins technologies and assess network resilience by simulating any disruptions to see whether a company can withstand an attack without compromising its productivity and efficiency.
4. for modularity of structures in networks, network architects should focus on creating independent modules within the supply network that would limit any shock's ability to travel throughout a business and affect all of its parts at once.
5. For supply base diversification strategies, businesses have to work on diversifying suppliers by removing their dependence on single sources of raw materials, particularly those that can potentially lead to significant losses in case of disruptions.
6. Governments and large focal organisations should support SME supply network partners in developing digital capabilities, particularly those needed to participate in shared multi-tier data architectures.

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