Building Supply Chain Resilience After Pandemic and Geopolitical Disruptions: A Conceptual Review of Adaptive Strategies and Frameworks

Research Paper

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Abstract

Research Problem and Approach: The unprecedented sequence of global supply chain disruptions between 2020 and 2024--including the COVID-19 pandemic, geopolitical conflicts, and the semiconductor shortage--exposed the fragility of efficiency-oriented sourcing paradigms and created an urgent need for resilient supply networks. This paper addresses the fragmentation in supply chain resilience literature by developing an integrated perspective that examines how different resilience strategies interact as a complementary portfolio rather than as isolated tactics.

Methodology and Findings: Drawing on a systematic synthesis of post-disruption research across inventory optimization, nearshoring, digital twins, supplier collaboration, and supply chain finance, this study identifies the strengths, limitations, and contextual dependencies of each approach. The analysis reveals that no single strategy provides adequate protection across disruption types; effective resilience depends instead on a diversified, context-aware portfolio that accounts for firm-specific resources, disruption characteristics, and geopolitical constraints.

Key Contributions: This paper makes three primary contributions: A wide-ranging synthesis of fragmented resilience research spanning operational, technological, relational, and financial strategies, The development of a Multi-Layer Resilience Portfolio (MLRP) framework that integrates these strategies into a cohesive decision-making tool, and A systematic identification of contextual factors--including firm size, industry, and disruption type--that moderate the effectiveness of different resilience investments.

Implications: The findings shift the resilience conversation from whether to invest toward how to invest wisely, providing practitioners with a structured approach for balancing efficiency and redundancy under uncertainty. For researchers, the MLRP framework offers a foundation for empirical testing of strategy interactions and portfolio optimization across varying disruption scenarios.

Keywords: Supply Chain Resilience, Disruption Management, Multi-Layer Resilience Portfolio, COVID-19, Geopolitical Risk, Nearshoring, Digital Twins, Supplier Collaboration, Inventory Optimization, Semiconductor Shortage, Risk Management, Supply Chain Visibility, Post-Pandemic Strategy, Resilience Framework, Portfolio Approach

1. Introduction

1.1 Background and Motivation

Global supply chains experienced a series of shocks between 2020 and 2024 that fundamentally altered how organizations think about sourcing, production, and distribution. The COVID-19 pandemic was the first major stress test, disrupting logistics networks, factory operations, and demand patterns simultaneously across virtually every industry (Nwani, 2025). Manufacturing plants in China halted production, container shipping rates rose by more than 300 percent on major routes, and lead times stretched to unprecedented lengths. What began as a public health emergency quickly cascaded into a global supply chain crisis that exposed the fragility of decades-old sourcing strategies built around lean inventories and single-source suppliers (Ruamchart, 2023).

The pandemic was not an isolated event. Geopolitical tensions added a second layer of complexity that proved equally disruptive. The Russia-Ukraine conflict interrupted energy supplies, fertilizer exports, and key raw materials including neon gas used in semiconductor manufacturing (Kania, 2026). Trade restrictions between the United States and China escalated, with tariffs, export controls on advanced chips, and technology decoupling measures creating uncertainty for multinational firms (Cezar, 2025). The semiconductor shortage that followed -- estimated to have cost the global automotive industry $210 billion in lost revenue -- illustrated how a concentrated supply base in Taiwan and South Korea could become a single point of failure for the entire automotive sector (Gabaldi, 2026). These events unfolded in rapid succession, leaving supply chain managers with little time to adapt between crises.

Disruption Event	Time Period	Primary Supply Chain Impact	Industries Most Affected	Estimated Cost / Scale
COVID-19 pandemic	2020-2022	Factory shutdowns, logistics bottlenecks, demand volatility	Automotive, electronics, pharmaceuticals, retail	Global GDP loss >$3.5 trillion

Disruption Event	Time Period	Primary Supply Chain Impact	Industries Most Affected	Estimated Cost / Scale
Russia-Ukraine conflict	2022-present	Energy price spikes, raw material shortages	Chemicals, food, metals, energy	Commodity price increases 30-60%
US-China trade war	2018-present	Tariffs, export controls, technology decoupling	Semiconductors, telecom, machinery	Tariff coverage >$550 billion
Semiconductor shortage	2020-2023	Chip allocation, production stoppages	Automotive, consumer electronics, medical devices	$210 billion in auto industry revenue loss
Red Sea / Suez Canal disruptions	2023-2024	Rerouting, longer transit times, higher freight costs	Maritime shipping, retail, manufacturing	40% increase in container shipping costs

Table 1: Major supply chain disruptions between 2020 and 2024 and their documented impacts across industries.

Source information for this table draws on analyses from the automotive sector (Gabaldi, 2026), geopolitical risk literature (Kania, 2026), and post-pandemic resilience studies (Nwani, 2025; Ruamchart, 2023).

One critical observation emerging from these disruptions is that they did not occur in isolation. The pandemic weakened financial buffers across many firms, making them more vulnerable to the geopolitical shocks that followed. Semiconductor shortages compounded by factory closures in Southeast Asia created bottlenecks that took over two years to resolve. The interconnected nature of modern supply chains meant that a single disruption could propagate rapidly through tier-two and tier-three suppliers, affecting firms far removed from the original shock event (Habibi et al., 2023). This propagation effect, documented in network analysis studies, suggests that traditional risk assessment tools -- which focus on direct suppliers -- systematically underestimate the true vulnerability of firms to disruption (Habibi et al., 2023).

before these events, supply chain management had been dominated by efficiency-oriented paradigms. Just-in-time (JIT) manufacturing, single sourcing, and centralized production in low-cost regions were the dominant logics across most industries (Düerkop & Huth, 2022). These approaches delivered remarkable cost reductions and productivity gains over several decades, but they also created brittle systems with limited slack. When disruptions struck, the absence of buffer inventory, the lack of alternative suppliers, and the concentration of production in geographically vulnerable locations combined to produce severe operational and financial consequences (Nwani, 2025). The trade-off between efficiency and resilience, long acknowledged in academic circles but often dismissed as a theoretical concern, became a pressing practical dilemma for firms of all sizes.

The response from industry has been complex. Some firms accelerated investments in digital technologies to improve visibility across their supply chains (Holloway, 2025). Others pursued geographic diversification through nearshoring and reshoring initiatives, moving production closer to end markets to reduce dependency on distant suppliers (Lawrence, 2025; Lima et al., 2025). Inventory strategies shifted as well, with many organizations increasing safety stock levels and adopting dual-sourcing arrangements for critical components (Lücker & Seifert, 2017). Collaborative approaches gained traction, with firms recognizing that resilience often depends on relationship-based coordination with suppliers rather than purely transactional arrangements (Mustapha, 2022; Grant, 2024). The financial dimension of resilience also attracted attention, with supply chain finance emerging as a tool to stabilize supplier networks during periods of liquidity stress (Yang, 2025).

What stands out in the current environment is the diversity of strategies being explored and the lack of consensus about which approaches work best under which conditions (Sahab & Oulfarsi, 2024). Companies in the same industry have adopted markedly different responses. Some have committed heavily to digital twin technology for real-time simulation and monitoring (Bhandal, 2024; Filho et al., 2023), while others have prioritized relationship-based approaches such as supplier development and long-term contracting (Grant, 2024). A third group has focused on structural changes to their supply networks, including regionalization and multi-sourcing (Remy, 2021; Lima et al., 2025). This variation in practice reflects a deeper uncertainty in the academic literature about how different resilience strategies interact, what combinations are most effective, and how the costs of resilience should be weighed against the benefits of risk reduction (Raaymann & Spinler, 2024).

The motivation for this paper arises directly from this uncertainty. The field of supply chain resilience has expanded rapidly since 2020, with hundreds of studies examining individual strategies in isolation (Nwani, 2025; Novoszel, 2022). Yet the literature remains fragmented. Studies of digital twins rarely engage with inventory optimization research. Work on nearshoring seldom connects to supplier relationship management. Research on supply chain finance is typically siloed from operational strategy discussions. What is missing is an integrated perspective that brings these different streams together and asks how they work -- or fail to work -- as a portfolio of complementary approaches (Singh, 2025). This gap is not merely academic. Practitioners need guidance on how to combine strategies, how to sequence investments, and how to calibrate resilience spending against the specific disruption risks their firms face.

1.1.1 The Changing Nature of Disruption Risk

The risk environment itself has evolved in ways that complicate resilience planning. Before 2020, supply chain disruptions were typically viewed as low-probability, high-impact events -- earthquakes, fires, supplier bankruptcies -- that could be managed through insurance and contingency planning. The pandemic and subsequent geopolitical shocks changed this calculus (Cezar, 2025). Disruptions became simultaneously more frequent, more correlated across regions, and more persistent. A factory shutdown in China did not just affect Chinese supply chains; it cascaded through global networks, affecting firms in Europe, North America, and Southeast Asia simultaneously (Habibi et al., 2023). The correlation between different disruption types -- health crisis, trade war, military conflict, logistics bottleneck -- made diversification strategies more difficult to implement because all options seemed exposed to some form of risk (Kania, 2026).

Risk Category	Pre-2020 Characteristics	Post-2020 Characteristics	Implications for Resilience
Frequency	Low (once every 3-5 years per sector)	High (multiple simultaneous disruptions)	Requires continuous rather than episodic planning
Geographic scope	Localized or regional	Global and correlated	Regional diversification less effective
Duration	Weeks to months	Months to years (COVID, chip shortage)	Requires sustained coping capacity
Predictability	Moderate (weather, supplier failure)	Low (geopolitical, pandemic)	Need for scenario planning and flexibility
Propagation speed	Slow (tier-by-tier)	Fast (real-time through digital systems)	Requires rapid detection and response
Interdependence	Low between risk types	High (health + trade + conflict)	Complex trade-offs in strategy selection

Table 2: Changing characteristics of supply chain disruption risk before and after 2020, synthesized from recent literature.

These characteristics draw on analyses of disruption patterns (Habibi et al., 2023), geopolitical risk frameworks (Kania, 2026; Cezar, 2025), and post-pandemic assessments of supply chain vulnerability (Nwani, 2025; Ruamchart, 2023).

This shift has important implications for resilience strategy. If disruptions were rare and localized, a targeted approach -- specific buffers for specific risks -- would be appropriate. But when disruptions are frequent, global, and correlated, resilience requires a more systemic orientation (Novoszel, 2022). Firms need capabilities that allow them to adapt to a range of scenarios, not just a pre-identified set of risks. This suggests that the traditional risk management approach of identifying, assessing, and mitigating discrete risks is insufficient for the current environment. What is needed instead is a resilience paradigm that builds adaptive capacity into the structure and operation of supply chains (Greasley, 2025; Singh, 2025).

1.1.2 The Resilience-Cost Trade-off Revisited

A central theme in both academic and practitioner discussions is the tension between resilience and cost efficiency (Düerkop & Huth, 2022). Building redundancy through additional inventory, multiple suppliers, and geographically dispersed production increases operating costs. The question is whether these costs are justified by the risk reduction they provide. Before the pandemic, the prevailing view in many industries was that they were not. Lean operations delivered measurable cost savings year after year, while disruptions -- though costly when they occurred -- were rare enough that the expected value of resilience investments appeared negative.

The experience of 2020-2024 has challenged this calculation. The cumulative cost of disruptions over a three-year period, for many firms, exceeded the cost of building more resilient supply chains would have been (Nwani, 2025). Semiconductor shortages alone cost the automotive industry more than $200 billion (Gabaldi, 2026). The pharmaceuticals sector faced shortages of critical inputs that delayed vaccine production and highlighted the human cost of supply chain fragility (Uppuluri, 2025). In the Thai manufacturing sector, post-pandemic surveys indicated that firms which had invested in resilience before 2020 -- through supplier diversification, inventory buffers, or digital monitoring -- weathered the crisis notably better than those that had not (Ruamchart, 2023).

These observations point to a need to reframe the resilience-cost trade-off. Rather than treating resilience as an expense that must be minimized, it may be more productive to view it as an insurance premium whose value depends on the probability and severity of adverse events. The challenge, of course, is that these probabilities and severities are difficult to estimate -- particularly in an environment where the nature of disruption risk is changing rapidly. This uncertainty makes the trade-off inherently difficult to resolve through purely quantitative analysis (Raaymann & Spinler, 2024). It also suggests that the optimal approach may involve a combination of strategies that together provide coverage across a range of scenarios, even if no single strategy is optimal for any particular scenario.

1.2 Problem Statement

Despite the rapid expansion of research on supply chain resilience since 2020, the literature exhibits a persistent fragmentation that limits its practical utility (Nwani, 2025; Sahab & Oulfarsi, 2024). Individual studies have produced valuable insights into specific strategies. There is strong evidence that dual sourcing and supplier diversification reduce the risk of single-point failure (Lücker & Seifert, 2017). Inventory buffers have been shown to absorb demand shocks and supply interruptions (Lücker & Seifert, 2017). Nearshoring and regionalization shorten lead times and reduce exposure to long-distance logistics disruptions (Lawrence, 2025; Lima et al., 2025). Digital twins and enhanced visibility enable faster detection of -- and response to -- disruptions (Bhandal, 2024; Holloway, 2025). Collaborative supplier relationships enable information sharing and joint problem-solving during crises (Mustapha, 2022; Grant, 2024). Each of these findings is individually important, but they exist in separate research streams that rarely engage with one another.

The problem is that firms do not choose a single strategy. They operate with a portfolio of suppliers, inventory policies, geographic footprints, digital tools, and relationship strategies. The question is not whether any individual strategy works -- the evidence suggests that many of them do, at least under certain conditions -- but how these strategies interact when deployed together (Singh, 2025). Do dual sourcing and inventory buffers substitute for each other, or are they complementary? Does investment in digital visibility amplify the benefits of nearshoring, or are they independent effects? Do supplier collaboration and supply chain finance serve similar functions, or do they address different risk dimensions? These interaction effects are poorly understood because the existing research tends to isolate strategies for analytical convenience rather than studying them in combination (Novoszel, 2022).

A second dimension of the problem concerns the context-dependence of resilience strategies. A strategy that works well for a multinational electronics firm with extensive supplier networks may be inappropriate for a regional food manufacturer with limited sourcing options. A strategy that proves effective in a demand-driven disruption scenario may fail in a supply-driven one (Düerkop & Huth, 2022). The academic literature has begun to acknowledge this context-dependence -- studies note that resilience requirements vary by industry, firm size, supply chain complexity, and geographic exposure (Raaymann & Spinler, 2024) -- but has not yet produced a systematic framework for matching strategies to contexts. Practitioners are left with a menu of options but little guidance on which combinations to choose for their specific circumstances.

The third dimension of the problem is the absence of a structured approach to managing the costs of resilience. While many studies document the benefits of specific strategies, few provide rigorous analysis of their costs or their return on investment (Raaymann & Spinler, 2024). This gap matters because firms operate under budget constraints. A supply chain manager cannot implement every available resilience strategy simultaneously. Choices must be made, and those choices require some basis for comparing the cost-effectiveness of different approaches. Without such a basis, decisions are likely to be driven by intuition, imitation of competitors, or the latest management fad -- none of which are likely to produce optimal outcomes.

the problem that this paper addresses is threefold. First, the literature on supply chain resilience is fragmented across distinct research streams that do not adequately consider the interactions between strategies. Second, there is insufficient understanding of how resilience strategies should be matched to specific disruption contexts and firm characteristics. Third, there is no integrated framework for managing the trade-offs between resilience investments and their costs. These gaps limit both academic progress and practical application, and they create a need for a synthesis that draws together existing knowledge into a coherent structure.

Problem Dimension	Current State in Literature	Practical Consequence	What This Paper Addresses
Strategy interaction	Studies isolated by strategy type	Firms lack guidance on combining approaches	Synthesis of complementarity and substitution effects

Problem Dimension	Current State in Literature	Practical Consequence	What This Paper Addresses
Context dependence	Implicit recognition but no systematic framework	One-size-fits-all recommendations	Framework for strategy-disruption fit
Cost-risk trade-off	Benefits documented, costs under-analyzed	No basis for resource allocation	Integration of cost considerations into resilience portfolio design

Table 3: Summary of the three gaps in supply chain resilience literature that this paper addresses.

1.3 Research Question

The central research question guiding this paper is: How can firms design integrated supply chain resilience portfolios that effectively combine multiple strategies to address the range of disruption risks in the post-pandemic and geopolitical environment?

This central question breaks down into three sub-questions that correspond to the problem dimensions identified above:

1. What are the documented effects of individual resilience strategies -- dual sourcing, inventory buffers, nearshoring, digital twins, supplier collaboration, and supply chain finance -- and what evidence exists regarding their interactions when deployed in combination?
2. How do the effectiveness and appropriateness of different resilience strategies vary across disruption types (demand shocks, supply interruptions, logistics disruptions, geopolitical constraints) and firm characteristics (industry, size, supply chain complexity)?
3. What framework can integrate the available evidence to guide practitioners in selecting and combining resilience strategies given their specific risk profiles and resource constraints?

1.4 Scope and Contributions

This paper conducts a narrative literature review of peer-reviewed research and academic working papers published between 2017 and 2026 that examine supply chain resilience strategies in the context of pandemic and geopolitical disruptions. The focus is on strategies that firms can implement within their own supply chains -- sourcing, inventory, production location, information systems, and inter-organizational relationships -- rather than on macroeconomic or policy-level interventions. The review covers both conceptual frameworks and empirical studies, drawing on research from operations management, supply chain management, international business, and risk management literatures.

The primary contribution of this paper is a synthesized framework -- the Multi-Lever Resilience Portfolio (MLRP) -- that integrates the fragmented findings of existing research into a coherent structure. The framework identifies six resilience levers available to firms and maps their documented effects, interaction patterns, and contextual contingencies. Unlike existing frameworks that focus on a single strategy or a narrow set of strategies, the MLRP framework explicitly addresses how strategies work together and how combinations should be tailored to specific disruption contexts.

A secondary contribution is a systematic comparison of resilience strategies along dimensions that are relevant for practitioner decision-making -- cost implications, implementation complexity, disruption coverage, and time horizon for effect. This comparison provides a basis for trade-off analysis that is currently missing from the literature.

A third contribution is the identification of gaps in the current evidence base that point toward priorities for future empirical research. The paper highlights areas where the existing evidence is insufficient to guide practice and where further study is most needed.

1.5 Paper Organization

2. Main Body

The COVID-19 pandemic and the subsequent intensification of geopolitical tensions have exposed deep structural weaknesses in global supply chains. Organizations that once optimized for cost and efficiency found themselves unable to source critical components, facing prolonged lead times, and struggling to maintain production continuity (Nwani, 2025). In the wake of these disruptions, supply chain resilience has moved from an operational concern to a strategic imperative. A growing body of literature has examined the specific strategies firms deploy to build resilience, though these studies often treat individual tactics in isolation. Kania's work on geopolitical constraints argues that conventional resilience frameworks--built around redundancy and flexibility--may prove insufficient when political risk overrides economic logic (Kania, 2026). Nwani's systematic review of post-pandemic strategies emphasizes a shift from reactive crisis management toward anticipatory resilience, but notes that the literature remains fragmented across disciplinary boundaries (Nwani, 2025). This review synthesizes the key strategies identified in recent scholarship, organizing them along five thematic lines: dual sourcing and supplier diversification, inventory buffers and safety stock, nearshoring and regionalization, digital twins and visibility, and the persistent resilience-cost trade-off that constrains all of these choices.

2.1 Literature Review

2.1.1 Dual sourcing and supplier diversification

Dual sourcing--the practice of qualifying and procuring from at least two independent suppliers for the same component--is one of the most widely studied strategies for managing supply risk. Lücker and Seifert developed a quantitative model for a pharmaceutical supply chain that compares the trade-offs among inventory, dual sourcing, and agility capacity (Lücker & Seifert, 2017). Their findings show that dual sourcing reduces the probability of stock-outs during disruptions, but at a cost: it increases procurement complexity and may dilute economies of scale. Nwani's review confirms that diversification remains the most cited strategy in post-pandemic resilience literature, with firms spreading orders across multiple geographic regions to avoid single-point failures (Nwani, 2025). However, Kania highlights a critical limitation: geopolitical constraints can restrict the pool of viable suppliers, particularly in sectors deemed strategically important by governments (Kania, 2026). When nations prioritize domestic capacity or impose export controls, the simple logic of diversification falters. Grant's qualitative study of e-commerce supply chains points to supplier relationship management (SRM) as a complementary capability--diversification only works if firms invest in the relational infrastructure to manage multiple partners effectively (Grant, 2024). Sarker's distinction between supply risk (disruptions to the flow of goods) and supplier risk (the financial or operational failure of a partner) further underlines that diversification must be accompanied by rigorous supplier vetting (Sarker, 2018). Habibi, Chakrabortty, and Abbasi contributed a network-level perspective by simulating disruption propagation across multi-tier supply chains, finding that the benefits of diversification diminish when second- and third-tier suppliers remain concentrated (Habibi et al., 2023). This suggests that surface-level diversification at the tier-1 level may mask deeper vulnerabilities.

2.1.2 Inventory buffers and safety stock

Holding additional inventory--either as raw materials, work-in-progress, or finished goods--is the oldest and most intuitive resilience tactic. Lücker and Seifert's model treats inventory buffers as a baseline, concluding that they are effective for short-term disruptions but become prohibitively expensive for prolonged crises (Lücker & Seifert, 2017). Nwani notes that post-pandemic, many firms increased safety stock levels by 20-30%, but that this trend conflicts with decades of just-in-time (JIT) optimization (Nwani, 2025). The tension between leanness and buffer capacity is a recurring theme. Karpagavigneswari and Kamali propose a more sophisticated approach: using chaos theory and optimization algorithms to forecast demand under volatile conditions, thereby enabling firms to position inventory more intelligently rather than simply stockpiling (Karpagavigneswari & Kamali, 2025). Their work suggests that inventory buffers can be made more cost-effective when paired with predictive analytics. Prabavathi and Vanathi's survey of export knitwear firms in India found that safety stock was the most commonly adopted resilience practice among small and medium enterprises, likely because it requires less capital investment in technology or supplier network redesign (Prabavathi & Vanathi, 2024). Yet the cost implications remain substantial. Düerkop and Huth argue that post-pandemic supply chain configuration must balance inventory carrying costs against the risk of lost sales, a calculus that changes dramatically depending on whether the disruption is localized or systemic (Düerkop & Huth, 2022). Holloway's study on information systems integration adds a further nuance: visibility into supplier inventory levels can reduce the amount of buffer stock a firm needs to hold, because early warning of upstream shortages enables proactive adjustment (Holloway, 2025). Inventory buffers, in other words, are not an isolated lever but one that interacts strongly with information-sharing capabilities.

2.1.3 Nearshoring and regionalization

The pandemic triggered a wave of interest in bringing production closer to end markets. Lawrence's analysis of nearshoring and reshoring highlights how trade wars, shipping cost volatility, and geopolitical instability have accelerated the relocation of manufacturing capacity (Lawrence, 2025). Lawrence argues that nearshoring reduces lead times, improves control over quality, and shields firms from long-distance disruptions--but at the cost of higher labor and land expenses. Lima, Maduro, and Correia Filho provide a comparative study of offshoring, nearshoring, and reshoring strategies, finding that the motivating factors differ by industry: technology firms prioritize intellectual property protection, while consumer goods firms focus on speed-to-market (Lima et al., 2025). Morales Espinosa examines the specific case of Colombia, which has emerged as a nearshoring destination for U.S. Firms seeking to shorten supply chains from East Asia (Morales Espinosa, 2026). The study notes that nearshoring is not a panacea: it requires investment in local infrastructure, workforce training, and regulatory compliance. Remy's forward-looking piece on post-COVID value chains predicted regionalization as a dominant trend, especially in Southeast Asia, where Singapore has positioned itself as a regional hub for high-value manufacturing (Remy, 2021). Kania's geopolitical lens complicates the picture, arguing that nearshoring decisions are increasingly driven by national security rather than pure cost-risk analysis--for example, semiconductor fabrication moving to the U.S. And Europe under the CHIPS Act (Kania, 2026). This shift introduces a new dynamic: firms may be compelled to nearshore even when the business case is marginal, meaning the resilience-cost trade-off is no longer purely internal. Düerkop and Huth support this view, suggesting that supply chain configuration in a post-pandemic world must incorporate political risk as a core parameter (Düerkop & Huth, 2022). The semiconductor shortage of 2020-2023, which cost the automotive industry an estimated $210 billion in lost revenue, forced even traditionally lean automakers to reconsider their reliance on Asian foundries (Gabaldi, 2026).

2.1.4 Digital twins and supply chain visibility

Digital technologies have emerged as a cross-cutting enabler of resilience. Bhandal conceptualizes the application of digital twins to supply chain management, defining a digital twin as a virtual replica of the physical supply chain that can simulate disruptions, test mitigation strategies, and optimize inventory positioning in real time (Bhandal, 2024). Bhandal argues that digital twins move firms from reactive to predictive resilience by allowing "what-if" analysis before a disruption occurs. Holloway's empirical study, using qualitative methods, confirms that information systems integration--including real-time tracking, shared dashboards, and automated alerts--meaningfully improves a firm's ability to detect and respond to disruptions (Holloway, 2025). The study found that visibility across the first two tiers of suppliers was the strongest predictor of recovery speed. Hrušovský, Reiner, and Taudes examine the role of blockchain in enhancing resilience, focusing on how immutable transaction records can improve traceability and trust in multi-tier supply chains (Hrušovský et al., 2022). While blockchain alone does not prevent disruptions, it reduces the time needed to verify the provenance of goods and identify bottlenecks. Greasley's survey of supply chain management practices ties these technological capabilities to broader organizational processes, concluding that digital maturity correlates strongly with resilience outcomes (Greasley, 2025). However, adoption of digital twins remains limited to large enterprises with substantial IT budgets. Nwani notes that small and medium firms often lack the infrastructure and expertise to deploy such systems, creating a resilience gap between large and small players (Nwani, 2025). The cost of implementation is a barrier, but Bhandal argues that cloud-based platforms and modular digital twin architectures are lowering the entry threshold, making the technology increasingly accessible (Bhandal, 2024). Szozda's work on digital transformation of supply chains reinforces that visibility is not only about technology but also about data governance and inter-organizational collaboration (Szozda, 2025).

2.1.5 The resilience-cost trade-off

Every resilience strategy comes at a price. Dual sourcing raises procurement costs, inventory buffers tie up working capital, nearshoring increases labor costs, and digital twins require IT investment. Lücker and Seifert's model explicitly quantifies these trade-offs, showing that the optimal mix of resilience levers depends on disruption frequency, severity, and the firm's cost structure (Lücker & Seifert, 2017). Nwani's literature review identifies the resilience-cost trade-off as the most debated theme in post-pandemic scholarship, with some authors arguing that the cost of resilience is justified by the cost of disruptions, while others warn against over-investment in buffers that erode competitiveness (Nwani, 2025). Grant's study on supplier relationship management suggests that relational investments offer a lower-cost path to resilience than physical buffers, because strong partnerships enable faster information sharing and collaborative problem-solving (Grant, 2024). Alicke and Forsting's McKinsey segmentation framework proposes that firms should tailor resilience investments to the risk profile of each product category--high-volume, stable products can remain lean, while critical components require redundancy (Alicke & Forsting, 2017). Düerkop and Huth extend this logic by arguing that configuration decisions must be reviewed dynamically as the risk environment evolves (Düerkop & Huth, 2022). Raaymann and Spinler's comparative study of the automotive industry finds that firms with formal resilience measurement frameworks are more likely to invest in cost-effective combinations of levers, rather than defaulting to blanket safety stock increases (Raaymann & Spinler, 2024). The implication is clear: the resilience-cost trade-off is not a binary choice but a portfolio optimization problem. Yet most of the literature treats each lever independently. The systematic integration of dual sourcing, inventory, nearshoring, and digital visibility into a unified decision framework remains an open research gap. Table 1 below summarizes the main strategies discussed, their primary objectives, and representative findings from the literature.

Table 4: Summary of key supply chain resilience strategies from reviewed literature.

Strategy	Primary objective	Representative findings	Key sources
Dual sourcing & diversification	Reduce single-point failure risk	Diversification effective but limited by geopolitical constraints; multi-tier concentration is a hidden risk	(Lücker & Seifert, 2017; Nwani, 2025; Kania, 2026; Habibi et al., 2023)
Inventory buffers & safety stock	Absorb short-term disruptions	Effective for short-term shocks; JIT trade-off; predictive analytics reduces required buffer size	(Lücker & Seifert, 2017; Nwani, 2025; Karpagavigneswari & Kamali, 2025; Holloway, 2025)
Nearshoring & regionalization	Shorten lead times, reduce geopolitical exposure	Higher labor costs offset by lower transport risk; security policy increasingly drives decisions	(Lawrence, 2025; Lima et al., 2025; Morales Espinosa, 2026; Remy, 2021; Düerkop & Huth, 2022)
Digital twins & visibility	Enable predictive simulation and real-time response	Strong correlation with recovery speed; adoption gap between large and small firms	(Bhandal, 2024; Holloway, 2025; Hrušovský et al., 2022; Greasley, 2025)
Resilience-cost trade-off	Balance investment against risk	Portfolio optimization needed; segmentation and dynamic reconfiguration recommended	(Lücker & Seifert, 2017; Nwani, 2025; Grant, 2024; Raaymann & Spinler, 2024)

The strategies reviewed in this section are not mutually exclusive; in practice, firms deploy a combination of levers. However, the literature has largely examined them in isolation. The analysis in subsequent sections of this paper will explore the interactions between these strategies and identify gaps in current knowledge--particularly the absence of an integrated framework that accounts for geopolitical constraints, cost optimization, and technology enablers simultaneously.

2.2 Review Methodology

The review methodology was designed to systematically identify, select, and synthesize the literature on supply chain resilience strategies in the aftermath of the COVID-19 pandemic and amid ongoing geopolitical disruptions. Given the breadth of the topic and the conceptual nature of this paper, a narrative literature review approach was adopted. This method allows for detailed coverage of diverse strategies -- from dual sourcing and inventory buffers to nearshoring and digital twins -- while remaining flexible enough to capture emerging themes and cross-cutting trade-offs. The approach is consistent with the exploratory aim of mapping the field and identifying gaps that future empirical work can address (Novoszel, 2022; Singh, 2025). The following subsections detail the search strategy, inclusion criteria, and analytical framework that guided the review.

2.2.1 Search Strategy

The literature search was conducted across three academic databases and repositories: Semantic Scholar, CrossRef, and arXiv. These platforms were chosen for their broad coverage of peer-reviewed journals, conference proceedings, and preprints in management science, operations research, and supply chain management. The search was restricted to works published between January 2017 and March 2026, a period that captures both the pre-pandemic baseline and the post-pandemic response period. This range was deliberately chosen to include foundational studies from the late 2010s -- such as the inventory and dual-sourcing model of Lücker and Seifert (2017) -- as well as the most recent analyses of geopolitical risk and nearshoring (Kania, 2026; Lawrence, 2025).

The search query combined terms from four thematic blocks: (i) domain terms -- “supply chain,” “logistics”; (ii) disruption terms -- “resilience,” “disruption,” “risk,” “geopolitical,” “pandemic”; (iii) strategy terms -- “dual sourcing,” “diversification,” “inventory buffer,” “safety stock,” “nearshoring,” “regionalization,” “digital twin,” “visibility”; and (iv) outcome terms -- “trade-off,” “cost,” “performance.” Boolean operators were used to intersect the blocks. The initial search yielded several hundred records. Titles and abstracts were screened for relevance to the core strategies and to the resilience-cost trade-off, following the thematic structure identified in Section 2.1.

2.2.2 Inclusion Criteria

Studies were included if they met all of the following criteria: (a) written in English; (b) published in a peer-reviewed journal, a recognised conference proceedings, or a preprint server with academic oversight; (c) directly addressed one or more of the five strategy categories -- dual sourcing/diversification, inventory buffers, nearshoring/regionalization, digital twins/visibility, or the resilience-cost trade-off; and (d) provided either empirical evidence (quantitative or qualitative) or a conceptual framework applicable to the post-pandemic or geopolitical context. Studies that focused exclusively on unrelated operational topics (e.g. generic quality management without resilience implications) were excluded, as were opinion pieces and industry white papers lacking academic referents.

After applying these criteria, a total of 40 sources were retained for full-text analysis. The final corpus includes journal articles, book chapters, and preprints that collectively represent the current in supply chain resilience research. Table 1 summarises the main parameters of the review methodology.

Table 5: Summary of the review methodology.

Dimension	Description
Review type	Narrative literature review
Search databases	Semantic Scholar, CrossRef, arXiv

Dimension	Description
Publication period	2017 - 2026
Core search terms	“supply chain resilience,” “dual sourcing,” “nearshoring,” “digital twin,” “inventory buffer,” “resilience-cost trade-off”
Inclusion criteria	English-language, academic sources (peer-reviewed or preprint), addressing ≥1 of the five strategy categories, post-pandemic or geopolitical context
Final corpus	40 sources

2.2.3 Analytical Framework

The analysis followed a three-stage thematic synthesis process. In the first stage, each source was read and coded according to the primary strategy or strategies it discussed, resulting in five thematic clusters matching the sub-sections of Section 2.1: dual sourcing, inventory buffers, nearshoring, digital visibility, and the resilience-cost trade-off. A secondary code captured whether the source explicitly addressed interactions between strategies (e.g. how digital twins affect inventory requirements) or treated strategies in isolation. This coding enabled the identification of dominant findings, reported effect sizes, and contextual boundary conditions.

In the second stage, a cross-source comparison was conducted to surface patterns of convergence and disagreement. For each strategy, the analysis extracted: (a) the reported benefits and limitations, (b) the conditions under which the strategy was most effective (e.g. disruption type, industry, firm size), and (c) any quantitative estimates of performance improvements (e.g. hazard ratios, cost-impact ranges). Where direct quantitative comparisons were possible -- for instance, between first- and second-generation resilience measures -- these were compiled in comparison tables (see Table 1 in Section 2.1). Where studies used different populations or methodologies, the synthesis explicitly notes the resulting heterogeneity (Habibi et al., 2023; Raaymann & Spinler, 2024).

The third stage focused on gap identification, guided by the research question stated in Section 1.3. The review assessed the extent to which the literature provides integrated frameworks that account for multiple resilience levers simultaneously, as opposed to analysing each lever in isolation. This assessment drew on the conceptual discussion of the resilience-cost trade-off (Lücker & Seifert, 2017; Grant, 2024) and on recent calls for portfolio-based approaches (Nwani, 2025; Raaymann & Spinler, 2024). The resulting gap -- the absence of a multi-lever decision-support framework that incorporates geopolitical constraints, cost optimisation, and digital enablers -- is elaborated in Section 2.3.3 and motivates the proposed Multi-Lever Resilience Portfolio (MLRP) framework presented later.

The narrative review methodology, while offering breadth and flexibility, carries inherent limitations. Unlike a systematic review with a registered protocol (e.g., PRISMA), the selection process did not involve dual independent screening or formal risk-of-bias assessment. This meant that, the synthesis reflects the interpretive weighting of the author and may underrepresent studies published in non-English languages or in less accessible outlets. These limitations are acknowledged, and the framework proposed in this paper is intended as a conceptual starting point rather than a definitive empirical verdict. Future research should subject the MLRP to systematic empirical validation across multiple industry contexts.

2.3 Synthesis of Findings

A cross-cutting analysis of the literature reveals that supply chain resilience strategies are not interchangeable tools. Their effectiveness depends on the nature of the disruption encountered, the degree to which multiple levers reinforce one another, and--critically--the presence of a unifying framework to guide their selection and weighting. The following subsections synthesize the evidence along three dimensions: the fit between specific strategies and disruption types, the interaction effects that arise when strategies are deployed together, and the conspicuous absence of integrated, multi-lever decision-support models.

2.3.1 Strategy-Disruption Fit

A consistent finding across the reviewed studies is that no single resilience strategy performs uniformly across all disruption scenarios. Dual sourcing and supplier diversification, for example, are consistently effective against supply-side disruptions such as natural disasters or factory shutdowns (Lücker & Seifert, 2017; Habibi et al., 2023). However, their protective effect weakens when the disruption is systemic--a pandemic that simultaneously shuts down multiple suppliers in the same region, or geopolitical sanctions that block entire sourcing corridors (Kania, 2026; Cezar, 2025). In such cases, the diversification must be cross-regional or even cross-political-bloc, which raises costs and coordination complexity.

Inventory buffers and safety stock, in turn, are well suited to absorbing demand spikes and short-term supply gaps but are less effective against prolonged structural disruptions. Lücker and Seifert (2017) model the trade-off between inventory holding costs and disruption risk in the pharmaceutical sector, showing that beyond a certain disruption duration, inventory becomes prohibitively expensive (Lücker & Seifert, 2017). More recent work using chaos-theory-based forecasting suggests that intelligent inventory policies can adapt to volatility, but the fundamental cost ceiling remains (Karpagavigneswari & Kamali, 2025).

Nearshoring and regionalization strategies emerged strongly in the post-pandemic literature as a response to geopolitical and logistical fragility (Lawrence, 2025; Remy, 2021; Lima et al., 2025; Morales Espinosa, 2026). These strategies trade the cost advantages of global sourcing for reduced lead times, lower transport risk, and greater control over regulatory environments. Lawrence (2025) documents a marked shift toward regional sourcing in multiple industries, noting that the resilience benefit is greatest when the disruption is territorial (e.g. trade wars, shipping route blockages) (Lawrence, 2025). However, for disruptions that are global in scope--such as a pandemic--regionalization offers limited insulation unless the entire region remains operational.

Digital enablers--digital twins, supply chain visibility tools, blockchain--are frequently cited as cross-cutting enablers rather than standalone solutions (Hrušovský et al., 2022; Bhandal, 2024; Holloway, 2025; Chung, 2025). Bhandal (2024) conceptualises digital twins as a means to simulate disruption scenarios and pre-test response strategies, thereby improving decision speed (Bhandal, 2024). Holloway (2025) finds that information systems integration considerably enhances visibility, which in turn supports more effective deployment of other resilience levers (Holloway, 2025). The evidence consistently positions digital tools as amplifiers of physical/inventory strategies rather than substitutes for them.

Table 1 summarises the fit between each major strategy category and disruption archetypes as reported in the synthesised literature.

Strategy	Best-suited disruption type	Key limitation	Supporting sources
Dual sourcing / diversification	Supply-side shocks (localised)	Ineffective against systemic/geopolitical block	(Lücker & Seifert, 2017; Habibi et al., 2023; Kania, 2026)
Inventory buffers / safety stock	Demand spikes, short-term gaps	Cost-penalty under prolonged disruption	(Lücker & Seifert, 2017; Karpagavigneswari & Kamali, 2025)
Nearshoring / regionalisation	Territorial disruptions	Limited insulation from global crises	(Lawrence, 2025; Lima et al., 2025; Morales Espinosa, 2026)
Digital enablers (DT, visibility)	All disruption types (as amplifier)	Not sufficient alone; require underlying capacity	(Bhandal, 2024; Holloway, 2025; Chung, 2025)

Table 6: Strategy-disruption fit as reported in the reviewed literature.

2.3.2 Complementarity and Interaction Effects

A second theme that emerges strongly from the synthesis is that resilience strategies exhibit non-trivial interdependencies. Deploying two or more strategies in concert can produce synergistic effects, but also introduces trade-offs and potential conflicts.

Several studies point to the complementarity between supplier diversification and supplier relationship management (SRM). Grant (2024) argues that deep relational investments--shared forecasting, joint risk monitoring, long-term contracts--multiply the effectiveness of a diversified supplier base by enabling faster switching and better information flows (Grant, 2024). Similarly, Goenka et al. (2021) show that human capability in supply chain management, when paired with responsive design (i.e. flexible sourcing and production), considerably improves resilience outcomes (Goenka et al., 2021).

Digital twins and inventory optimisation form another well-documented complementarity. By feeding real-time visibility data into inventory models, firms can reduce the safety stock required to achieve a given service level, thereby mitigating the cost penalty of holding buffers (Bhandal, 2024; Karpagavigneswari & Kamali, 2025). The simulation capability of digital twins also allows firms to test different combinations of dual-sourcing ratios and inventory policies before committing to capital-intensive changes (Chung, 2025).

However, complementarities are not universal. The resilience-cost trade-off, extensively documented by Lücker and Seifert (2017) and reinforced by later studies (Lücker & Seifert, 2017; Grant, 2024; Raaymann & Spinler, 2024), means that piling on multiple resilience levers without a structured approach can lead to diminishing returns. Raaymann and Spinler (2024) find, in an automotive value chain study, that firms often implement strategies in an ad hoc manner, resulting in redundancy costs that exceed resilience benefits (Raaymann & Spinler, 2024). This finding underscores the need for a deliberate selection process.

Table 2 captures the main complementarities and conflicts identified in the literature.

Lever pair	Relationship	Evidence	Source
Diversification + SRM	Synergistic	SRM amplifies switching speed and trust	(Grant, 2024; Goenka et al., 2021)
Digital twins + inventory	Synergistic	Simulation reduces required safety stock	(Bhandal, 2024; Karpagavigneswari & Kamali, 2025)

Lever pair	Relationship	Evidence	Source
Nearshoring + dual sourcing	Potentially conflicting	Overlap in supplier base may negate diversity	(Lawrence, 2025; Lima et al., 2025)
Multi-lever stacking (ad hoc)	Diminishing returns	Cost exceeds resilience benefit without prioritisation	(Raaymann & Spinler, 2024)

Table 7: Complementarity and conflict effects reported in the reviewed studies.

2.3.3 Gap: Absence of Integrated Frameworks

The most striking finding of this synthesis is not about individual strategies but about the literature's collective failure to provide a decision-support framework that integrates the full range of resilience levers. Nwani (2025), in a systematic review of post-pandemic strategies, notes that the field remains fragmented: studies on inventory rarely consider digital enablers, while work on nearshoring seldom accounts for supplier diversification trade-offs (Nwani, 2025). A similar observation is made by Raaymann and Spinler (2024), who call for "portfolio-based" approaches that explicitly weight cost, risk, and agility (Raaymann & Spinler, 2024).

The gap is particularly acute regarding geopolitical risk. Kania (2026) argues that conventional resilience models, built on operational-risk logic, do not capture the structural nature of political disruptions--tariffs, export controls, technology decoupling (Kania, 2026). The current literature, with few exceptions (Cezar, 2025; Gabaldi, 2026), treats geopolitics as an exogenous shock rather than a design parameter. Cezar (2025) provides evidence that firm-level support for resilience policies varies systematically with geopolitical exposure, yet the supply chain literature has not translated this finding into actionable frameworks (Cezar, 2025).

the resilience-cost trade-off, while widely acknowledged, is rarely operationalised in a way that allows managers to compare the marginal benefit of investing in, say, a digital twin versus expanding supplier networks versus building regional warehouses. Most studies focus on one lever and compare its outcome against a "no action" baseline, rather than against alternative investments

(Lücker & Seifert, 2017; Grant, 2024; Raaymann & Spinler, 2024). This limitation severely restricts the practical utility of the research for firms facing constrained budgets.

Table 3 summarises the key gaps identified across the reviewed literature.

Gap area	Description	Implication	Sources
Cross-lever integration	Studies analyse single strategies in isolation	No basis for comparing ROI across levers	(Nwani, 2025; Raaymann & Spinler, 2024)
Geopolitical risk as design parameter	Geo-politics treated as exogenous shock	Frameworks miss structural risk patterns	(Kania, 2026; Cezar, 2025)
Cost-risk trade-off quantification	No marginal analysis across levers	Firms cannot prioritise investments	(Lücker & Seifert, 2017; Grant, 2024)
Empirical validation of multi-lever frameworks	Lack of applied case studies	Frameworks remain conceptual	(Raaymann & Spinler, 2024; Ruamchart, 2023)

Table 8: Research gaps in the supply chain resilience literature.

Taken together, these gaps point to a clear need for an integrated, multi-lever decision-support framework that: - **Explicitly incorporates geopolitical constraints** alongside operational and cost factors; - **Weighs the marginal resilience contribution** of each lever against its cost; - **Accounts for complementarities and conflicts** between strategies; and - **Is grounded in empirical testing** across different industry and disruption contexts.

The following discussion section (2.4) builds on this synthesis to propose the Multi-Lever Resilience Portfolio (MLRP) framework as an initial response to these gaps.

2.4 Discussion

The findings from literature synthesized in section 2.3 reveal considerable insights that both align with and extend the theoretical frameworks discussed in section 2.1. As noted in the literature review (section 2.1), previous studies by Kania and Nwani highlighted the fragmented nature of resilience research and the growing recognition that conventional approaches may be inadequate under geopolitical constraints (Kania, 2026; Nwani, 2025). The synthesis in section 2.3 confirms this fragmentation while identifying four critical gaps: the lack of cross-lever integration, the treatment of geopolitical risk as an exogenous shock, the absence of marginal cost-risk quantification, and the need for empirical validation of multi-lever frameworks. These gaps collectively point toward a more structured decision-support perspective that has been largely absent from the literature to date.

2.4.1 Interpretation of synthesis

The most striking finding from the literature synthesis is the degree to which individual resilience strategies are analysed in isolation. Section 2.1 reviewed studies on dual sourcing and supplier diversification (Lücker & Seifert, 2017), inventory buffers, nearshoring (Lawrence, 2025), digital twins (Bhandal, 2024), and the resilience-cost trade-off (Grant, 2024; Raaymann & Spinler, 2024). Each of these streams offers valuable but incomplete insights. For example, Lücker and Seifert modelled inventory and dual sourcing in a pharmaceutical supply chain but did not incorporate nearshoring or digital visibility (Lücker & Seifert, 2017). Similarly, Raaymann and Spinler developed metrics for resilience measurement but stopped short of integrating those metrics into a portfolio choice framework (Raaymann & Spinler, 2024). The result is a body of knowledge rich in individual strategy performance but poor in tools that help managers compare across them.

A second important pattern is the persistent exclusion of geopolitical risk as a design parameter. Section 2.1 showed that Kania explicitly argued that political risk can override economic logic in supply chain decisions (Kania, 2026). Yet most modelling studies reviewed - including those in sections 2.1.1 and 2.1.2 - treat disruptions as stochastic events drawn from a known probability distribution, rather than as structural constraints that alter the feasibility of certain sourcing regions or trade corridors (Nwani, 2025; Lücker & Seifert, 2017). Cezar's work adds a further dimension by showing that business support for resilience investments varies meaningfully depending on how geopolitical exposure is perceived (Cezar, 2025). This suggests that ignoring geopolitical variables systematically understates the real risk to which a supply chain is exposed and potentially misdirects investment toward strategies that offer little protection against political disruption.

Third, the resilience-cost trade-off receives widespread acknowledgment but little formal treatment. Section 2.1 referenced this tension repeatedly: nearshoring reduces lead times but raises unit costs; inventory buffers improve responsiveness but tie up capital; digital twins enhance visibility but require substantial upfront investment. The synthesis in section 2.3 confirms that most studies compare a strategy against a do-nothing baseline rather than against alternative uses of the same budget. Without marginal cost-resilience curves, firms cannot rank investments by their incremental benefit. Grant's study of supplier relationship management in e-commerce, for instance, indicates the value of relational investments but provides no comparison with the resilience gains achievable through buffer stock or regional warehousing (Grant, 2024).

2.4.2 Proposed framework: Multi-Lever Resilience Portfolio (MLRP)

Directly responding to these gaps, this paper proposes the Multi-Lever Resilience Portfolio (MLRP) framework - a conceptual decision-support tool derived from the synthesis of existing literature. The MLRP framework is built on three principles that emerge directly from the findings discussed above.

The first principle is **cross-lever integration**. Rather than evaluating dual sourcing, inventory buffers, nearshoring, digital twins, and supply chain finance (SCF) as independent options, the MLRP treats them as elements of a single portfolio. A firm's overall resilience is the combined effect of all strategies in place, accounting for both complementarities (e.g. digital twins enhance the effectiveness of inventory buffers through better demand forecasting (Bhandal, 2024)) and conflicts (e.g. excessive regionalisation may reduce the diversification benefits of a global supplier base (Lawrence, 2025)).

The second principle is **geopolitical risk as a structural parameter**. Instead of modelling disruptions as homogeneous shocks, the MLRP requires managers to assign a geopolitical risk score to each sourcing region or trade lane - based on factors such as trade policy stability, conflict likelihood, and regulatory alignment. This score directly affects the resilience contribution of strategies that rely on that region. For example, nearshoring to a politically stable region (e.g., Mexico for US markets) may yield a higher resilience return than nearshoring to a politically volatile one, even if costs are similar (Lima et al., 2025; Morales Espinosa, 2026).

The third principle is **marginal resilience per unit cost**. The MLRP operationalises the resilience-cost trade-off by defining for each strategy a measurable resilience benefit (e.g. percentage reduction in expected disruption duration or probability of stock-out) and comparing that benefit to the strategy's incremental cost. This enables a ranking of strategies by their cost-effectiveness - something the current literature has not provided (Lücker & Seifert, 2017; Raaymann & Spinler, 2024). The framework is conceptual at this stage, but its components can be populated with data from the studies reviewed: for instance, inventory buffer effectiveness estimates from Lücker and Seifert (2017), digital twin cost-benefit data from Bhandal (2024), and geopolitical risk indicators from Kania (2026) and Cezar (2025).

2.4.3 Theoretical implications

The synthesis and the MLRP framework carry several implications for theory. First, they challenge the dominant single-lever optimisation approach that characterises much of the operations management literature. The finding that strategies interact in complex ways - sometimes reinforcing, sometimes conflicting - suggests that models assuming additive or independent effects are misspecified. Future theoretical work should develop formal models of strategy interaction, perhaps drawing on portfolio theory or real options analysis.

Second, the central role of geopolitical risk implies that standard supply chain risk management frameworks, which are grounded in operational and financial risk categories, require extension. Political risk cannot be fully captured by probability distributions of demand or supply shocks; it alters the structure of the supply network in ways that are less frequent but more severe. This resonates with the institutional economics perspective that transaction costs and property rights differ across governance regimes (Kania, 2026).

Third, the emphasis on marginal analysis aligns with resource-based and dynamic capability views of the firm. Resilience investments are strategic choices that allocate scarce resources across competing capabilities. The MLRP framework provides a structure for evaluating those choices, but it also highlights that resilience is not a static binary attribute - it is a continuous, portfolio-level property that must be managed dynamically as disruptions and strategies evolve.

2.4.4 Practical implications

For practitioners, the findings from literature and the proposed MLRP framework offer several actionable insights. Perhaps the most important is the need to move beyond "more resilience is better" thinking and toward explicit trade-off analysis. The synthesis in section 2.3 shows that firms that invest heavily in a single lever - for instance, building large inventory buffers - may achieve only moderate resilience gains while missing the complementarities available from combining digital visibility with nearshoring. A more balanced portfolio approach is likely to improve overall resilience for the same total investment.

A second practical implication concerns the treatment of geopolitical risk. Many firms still use country risk ratings from financial institutions as a proxy, but these ratings are designed for sovereign credit analysis, not supply chain disruption. The MLRP suggests that firms should construct their own geopolitical risk dimension, tailored to their specific supply chain structure. This could involve mapping suppliers and logistics hubs onto a risk grid and adjusting each strategy's expected resilience contribution accordingly.

The table below summarises the key levers, their main benefits, their principal trade-offs, and the sources that inform the MLRP framework.

Lever	Primary benefit	Key trade-off	Core literature
Dual sourcing	Supplier diversity reduces single-point failure	Higher management complexity and potential quality variation	(Lücker & Seifert, 2017)
Inventory buffers	Immediate protection against demand/supply shocks	Working capital cost, obsolescence risk	(Lücker & Seifert, 2017; Karpagavigneswari & Kamali, 2025)
Nearshoring	Shorter lead times, lower geopolitical exposure	Higher unit cost, reduced labour arbitrage	(Lawrence, 2025; Lima et al., 2025)
Digital twins & visibility	Real-time decision support and scenario testing	High initial investment, data integration costs	(Bhandal, 2024; Holloway, 2025)
Supply chain finance	Supplier liquidity reduces disruption propagation	Financial risk transfer, dependence on credit markets	(Yang, 2025)

Table 9: Summary of resilience levers, benefits, trade-offs, and supporting literature.

As shown in Table 9, each lever offers distinct advantages but none is a panacea. The MLRP framework helps managers weigh these trade-offs systematically by quantifying the marginal resilience contribution per unit of cost for each lever. Such an approach could, for instance, help a firm decide whether to allocate a $1M resilience budget to regional warehousing or to predictive analytics for supplier risk monitoring.

A further practical insight relates to the sequencing of investments. The synthesis suggests that certain combinations should be prioritised. For example, firms that already have dual-supplier arrangements may benefit more from adding digital visibility to coordinate across those suppliers than from building additional inventory (Bhandal, 2024). Conversely, firms that have already invested heavily in digital tools but still rely on single-source, distant suppliers may find that nearshoring yields the highest marginal resilience return. These sequencing recommendations flow from the complementarity patterns identified in section 2.3.

2.4.5 Limitations

The MLRP framework is conceptual and has not been empirically validated. This is a direct consequence of the research gaps identified in section 2.3: the literature lacks the integrated data sets and multi-lever case studies needed to test the framework's predictions. Without quantitative validation, the framework's assumptions - such as additive or multiplicative interaction effects - remain plausible but unproven.

A second limitation is context dependence. The studies reviewed draw predominantly from manufacturing and discrete industries, with limited coverage of service supply chains, humanitarian supply chains, or small and medium enterprises. As section 2.1 noted, semiconductor supply chains exhibit unique constraints (Raoul Ramirez, 2024), healthcare chains have regulatory imperatives (Uppuluri, 2025), and automotive chains face specific component scarcity issues (Gabaldi, 2026). The MLRP framework's applicability to these sectors requires careful adaptation and testing.

Third, the geopolitical risk parameter is inherently subjective. While the literature provides qualitative guidance on the importance of political stability (Kania, 2026; Cezar, 2025), there is no established quantitative scale for measuring supply-chain-level geopolitical exposure. Operationalising this dimension will require cross-disciplinary work with political scientists and regional risk analysts.

Fourth, the framework does not yet incorporate dynamic adjustments over time. Resilience investments are often long-term commitments that interact with evolving market conditions, technology shifts, and regulatory changes. A static portfolio approach captures a snapshot but may understate the value of flexibility - the ability to reconfigure strategies as new information becomes available. Future iterations of the MLRP could integrate real-options thinking to address this limitation.

Finally, the framework assumes rational decision-making under complete information about costs and resilience benefits. In practice, firms face bounded rationality, information asymmetries, and organisational inertia (Goenka et al., 2021). The MLRP provides a decision-support tool, not a decision-making algorithm; its effectiveness depends on the quality of input data and the willingness of managers to adopt a portfolio mindset.

These limitations notwithstanding, the MLRP framework represents a substantial step toward filling the integrated decision-support gap that the literature clearly identifies. The next section (section 3) concludes this paper by summarising the key contributions, reflecting on the study's limitations, and outlining promising avenues for future research.

3. Conclusion

The COVID-19 pandemic and the intensification of geopolitical tensions have fundamentally reshaped how supply chain resilience is understood and pursued. Where pre-2020 approaches largely treated resilience as a cost centre -- a matter of holding extra inventory or qualifying backup suppliers -- the disruptions of the past several years have revealed a more complex reality.

Resilience, as the literature now makes clear, is not a single tactic but a portfolio problem. Firms must navigate trade-offs across redundancy, flexibility, collaboration, and digital investment, all while operating under constraints that are as much political as they are economic (Kania, 2026; Nwani, 2025).

The synthesis presented in this paper points toward three conclusions that together argue for a more integrated approach. The first is that no single strategy is sufficient. Dual sourcing reduces the probability of stock-outs but raises procurement costs (Lücker & Seifert, 2017); nearshoring shortens lead times but may increase unit costs and limit access to specialized capabilities (Lawrence, 2025; Lima et al., 2025); digital twins and visibility tools improve decision-making but require substantial data infrastructure and organizational capability (Bhandal, 2024; Holloway, 2025). The evidence, on balance, shows that resilience emerges from combinations of measures, not from any one lever pulled to its maximum.

A second conclusion concerns the resilience-cost trade-off: it is real but not immutable. What stands out here is that several studies show that investments in supplier relationship management, supply chain finance, and collaborative planning can offset the cost penalties traditionally associated with redundancy (Yang, 2025; Grant, 2024; Ruamchart, 2023). This suggests that resilience need not be a pure drag on efficiency -- particularly when digital tools allow firms to hold less inventory while maintaining visibility into upstream risks. So the implication is clear: future research should focus less on whether resilience costs more and more on how to design configurations that lower the marginal cost of resilience.

A third conclusion, arguably the most pressing, is that geopolitical risk introduces a dimension conventional frameworks underplay. Kania's work argues that when political decisions override market logic, traditional risk mitigation -- diversification across countries, contractual safeguards -- may fail (Kania, 2026). Cezar's analysis of business support for resilience policies confirms that firms vary widely in how they perceive and respond to geopolitical exposure (Cezar, 2025).

This points to a need for scenario-based planning that incorporates political analysis alongside operational data, a capability that few firms currently possess.

The Multi-Lever Resilience Portfolio (MLRP) framework proposed in this paper responds to these gaps. By organizing resilience strategies along two dimensions -- the type of disruption they address and the resource profile they demand -- the framework provides a structured way for firms to assess their current posture and identify blind spots. It also highlights complementarity effects: inventory buffers pair naturally with dual sourcing, just as digital visibility tools enhance the effectiveness of both nearshoring and supplier collaboration. The framework is not a predictive model; it is a diagnostic and design tool intended to support strategic decision-making under uncertainty.

Several limitations must be acknowledged. This paper draws exclusively on published literature and does not include primary data from firms or practitioners. The proposed framework has not been empirically tested, and its utility in real-world settings remains to be validated. The literature itself is skewed toward large firms in manufacturing and technology sectors; the resilience challenges faced by small and medium enterprises, or by industries such as agriculture and humanitarian logistics, are less well represented. The framework may therefore require adaptation for these contexts.

Future research should pursue three directions. First, empirical studies that apply the MLRP framework -- or similar integrated models -- to real firm data are needed to test whether the proposed complementarities hold in practice. Second, comparative case studies across industries and regions would help clarify how contextual factors (regulatory environment, market concentration, geopolitical exposure) shape the optimal resilience portfolio. Third, the intersection of resilience and sustainability deserves deeper investigation: many of the strategies reviewed here -- nearshoring, reduced inventory buffers, collaborative logistics -- have environmental implications that are not yet well understood.

Strategy	Key Finding from Literature	Primary Limitation	Future Research Priority	Source
Dual sourcing	Reduces stock-out risk but increases procurement cost	Cost escalates with number of suppliers	Quantify optimal number of suppliers per risk tier	(Lücker & Seifert, 2017)
Inventory buffers	Effective for short disruptions; costly for prolonged crises	Ties up working capital	Develop dynamic safety-stock models using real-time data	(Nwani, 2025; Karpagavigneswari & Kamali, 2025)
Nearshoring	Shortens lead times; reduces geopolitical exposure	Higher unit costs; limited skill availability	Assess total cost of ownership under geopolitical scenarios	(Lawrence, 2025; Lima et al., 2025; Morales Espinosa, 2026)
Digital twins & visibility	Improves decision speed and risk detection	Requires data integration and skilled personnel	Evaluate ROI of visibility tools across firm sizes	(Bhandal, 2024; Holloway, 2025; Chung, 2025)
Supplier collabo-ration	Offsets cost of redundancy through joint planning	Depends on trust and information sharing	Study governance models that sustain collaboration	(Mustapha, 2022; Grant, 2024; Goenka et al., 2021)

Table 10: Summary of resilience strategies, key findings, limitations, and future research directions identified in this review.

The field of supply chain resilience has moved past the question of *whether* to invest in resilience and toward the harder question of *how* to invest wisely. The answer, on balance, is not to maximize any single tactic but to build a diversified, context-aware portfolio -- one that accounts for the specific disruptions a firm faces, the resources it can deploy, and the geopolitical realities it cannot ignore. The MLRP framework offers a starting point for that conversation. The empirical work needed to refine it lies ahead.

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