AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF DATA SCIENCE AND MACHINE LEARNING (ISSN: 2692-5141)

Volume 05, Issue 02, 2025, pages 401-411
Published Date: - 31-10-2025

Resilient Supply Chain Design under Disruption, Uncertainty, and Strategic Reshoring: An Integrative Framework and Theoretical Elaboration

Shivam R. Patel
Global Supply Chain Research Centre, University of Manchester, United Kingdom

ABSTRACT

Background: Contemporary supply chains face unprecedented levels of volatility driven by demand uncertainty, supplier disruptions, geopolitical shifts, and sudden shocks such as pandemics. Theoretical and empirical work across operations research, logistics, and management science has explored facets of resilience, inventory policy under disruption, forecasting during crises, and strategic decisions such as reshoring. However, fragmented treatments limit a comprehensive understanding of integrative strategies that span forecasting, inventory design, network configuration, and organizational memory.

Purpose: This article synthesizes seminal and recent contributions to provide an integrated, publication-ready theoretical framework for resilient supply chain design. The aim is to unify modelling approaches for inventory under disruption, strategic facility location and reshoring decisions, forecasting and planning under pandemic-like conditions, and learning mechanisms that enhance resilience. The framework emphasizes interactions among stochastic supply interruptions, demand dynamism, strategic relocation, and data-driven detection of hidden supply chain linkages.

Methods: Drawing strictly from the provided literature, the study undertakes an exhaustive conceptual synthesis, weaving robust optimisation and stochastic inventory modelling (including EOQ extensions and partial backordering), facility location robustness, forecasting under pandemic dynamics, graph-based detection of hidden links, and cognitive mapping of domino effects. The methods section elaborates purely text-based methodological constructs: model families, solution philosophies, evaluation metrics, and comparative analytical approaches, all explained without equations or visual constructs.

Results: The synthesis produces a multi-layered resilience design architecture: (1) demand-adaptive inventory policies that combine safety-stock rethinking with partial backordering accommodation and supplier diversification; (2) robust facility-location strategies integrating disruption probabilities and demand uncertainty; (3) forecasting and planning processes that adapt growth-rate estimation under rapid regime shifts; (4) machine-learning-driven network inference to reveal hidden dependencies; and (5) organizational memory and experiential learning as a core resilience capability. Each element is elaborated with theoretical implications, practical trade-offs, and counterfactual analyses based on the literature.

Conclusions: Integrative resilience requires coordinated strategies across forecasting, inventory rules, network design, and organizational learning. Firms should treat reshoring or onshoring as strategic levers to be weighed against diversification and flexibility investments rather than as singular solutions. The framework highlights open research avenues: empirical calibration of integrated models, psychological and organizational barriers to memory adoption, and scalable machine learning tools for link prediction in large, fragmented supply networks.

KEYWORDS

Supply chain resilience, disruption management, inventory with partial backordering, facility location robustness, forecasting during pandemics, reshoring, graph neural networks

INTRODUCTION

The global landscape of production and distribution has evolved into an intricate web of interdependent actors, technologies, and information flows. This complexity yields efficiency gains in stable environments but exposes supply chains to cascading failures when disruptions occur. The urgency of understanding and designing resilient supply systems has been dramatically underscored by recent global events—pandemics, geopolitical tensions, and semiconductor shortages—that have revealed both vulnerabilities and opportunities for strategic redesign (Pettit, Croxton & Fiksel, 2019; Platzer & Sargent Jr., 2016). The body of literature provided spans robust facility location, inventory models under disruption, forecasting in crises, machine learning for hidden network detection, fuzzy cognitive mapping of domino effects, and empirical studies on memory and experience in disruption management. Together, these works form a rich substrate for synthesizing an integrative framework.

Robustness in facility location under demand uncertainty and facility disruptions is a foundational pillar in configuring resilient networks (Cheng, Adulyasak & Rousseau, 2021). Traditional location decisions emphasize cost minimization under predictable demand; however, disruptions introduce an endogenous risk dimension where facility unavailability and stochastic demand deviations must be incorporated into placement decisions (Cheng, Adulyasak & Rousseau, 2021). Complementing network design, inventory policies serve as first-line operational defenses against supply interruptions. Early and enduring contributions to inventory under uncertain supply—including models with random supply disruptions and partial backorders—offer insights into balancing holding costs, backorder penalties, and service-level considerations (Arreola-Risa & DeCroix, 1998; Parlar & Perry, 1996; Salehi, Taleizadeh & Tavakkoli-Moghaddam, 2016). These contributions highlight the multiplicity of decision levers available to operations managers.

Forecasting and planning under pandemic-like dynamics accentuate the limits of standard demand forecasting approaches. Research specifically addressing forecasting during pandemics shows that growth-rate estimation, governmental interventions, and supply chain disruptions intertwine to complicate planning (Nikolopoulos et al., 2021). These challenges necessitate flexible forecasting that can adapt to regime shifts and incorporate policy-driven demand shocks. Simultaneously, advances in machine learning and network science enable the detection of “hidden” ties within supply networks, informing risk-aware decisions that go beyond visible tier-one suppliers (Kosasih & Brintrup, 2022). This link detection is crucial for mapping contagion pathways and understanding latent vulnerability channels.

Beyond quantitative models, conceptual frameworks such as fuzzy cognitive maps have been applied to analyze domino effects and the interactions among factors affecting supply chain resilience, particularly in sectors like fashion where rapid product cycles and supplier heterogeneity amplify risks (Bevilacqua et al., 2020). Moreover, organizational and managerial perspectives stress the role of dynamic capabilities—dynamism and disruption orientation—in translating resilience investments into improved financial performance (Yu et al., 2019). Memory and post-disruption narrative practices further influence how firms learn and adapt over time (Alvarenga, Oliveira & Oliveira, 2023), reinforcing the notion that resilience is simultaneously technical and socio-organizational.

Despite these advances, existing literature is fragmented: modeling efforts often isolate inventory, location, forecasting, machine learning, or organizational learning. There is limited integrative work that situates these domains within a coherent architecture that practitioners and policy-makers can operationalize. The present article addresses this gap by synthesizing the provided references into a comprehensive theoretical framework for designing resilient supply chains under disruption, uncertainty, and strategic reshoring considerations. This work does not present new empirical data; instead, it produces an exhaustive conceptual and theoretical elaboration that integrates multiple model families, managerial levers, and research priorities based on established and contemporary contributions (Cheng, Adulyasak & Rousseau, 2021; Nikolopoulos et al., 2021; Kosasih & Brintrup, 2022; Bevilacqua et al., 2020; Arreola-Risa & DeCroix, 1998; Salehi et al., 2016; Parlar & Perry, 1996; Yu et al., 2019; Alvarenga et al., 2023; Pettit, Croxton & Fiksel, 2019; Pettit, Fiksel & Croxton, 2010; Ponomarov & Holcomb, 2009; Rao & Goldsby, 2009; Saenz, Revilla & Acero, 2018; Platzer et al., 2016; Platzer, Sargent Jr. & Sutter, 2020; Lulla, 2025).

The remainder of the article unfolds as follows. The methodology section articulates, in text form, the methodological palette that can be used to analyze integrated resilience interventions. The results section presents the synthesized framework and descriptive findings stemming from the literature consolidation. The discussion interprets theoretical implications, synthesizes counter-arguments, and outlines limitations and future research directions. The conclusion distills managerial and policy recommendations.

METHODOLOGY

This article pursues an integrative conceptual synthesis guided by rigorous interpretive and comparative analysis. The methodology is descriptive, comparative, and theoretical: no primary data collection or numerical model solving is performed; instead, the study constructs a richly articulated theoretical framework using the insights, model types, empirical findings, and conceptual arguments present in the provided literature. The methodology's transparency and replicability are ensured through a clear mapping between literature elements and proposed framework components. The approach comprises four interlocking methodological steps, each explained in depth below.

First, systematic literature mapping was undertaken internally to identify core themes, model archetypes, and empirical claims across the supplied references. The mapping classifies works into thematic clusters: inventory dynamics under supply uncertainty (Arreola-Risa & DeCroix, 1998; Salehi et al., 2016; Parlar & Perry, 1996), robust facility location under disruptions (Cheng et al., 2021), forecasting and planning in pandemic contexts (Nikolopoulos et al., 2021), machine learning for network link inference (Kosasih & Brintrup, 2022), cognitive frameworks for domino effects (Bevilacqua et al., 2020), dynamic capabilities and performance (Yu et al., 2019), and organizational memory and learning (Alvarenga et al., 2023). Conceptual and policy-oriented works on resilience and industry-specific contexts—such as semiconductor supply chains and reshoring debates—were integrated to contextualize the framework (Platzer & Sargent Jr., 2016; Platzer, Sargent Jr. & Sutter, 2020; Lulla, 2025). Foundational resilience constructs from seminal conceptual works were incorporated to anchor operational suggestions into managerial practice (Pettit, Fiksel & Croxton, 2010; Ponomarov & Holcomb, 2009; Pettit, Croxton & Fiksel, 2019).

Second, model archetype translation was performed. For each cluster, the methodology explicates model families in plain text: for inventory dynamics, this includes EOQ variants with stochastic disruptions, partial backordering, and multi-supplier considerations (Arreola-Risa & DeCroix, 1998; Salehi et al., 2016; Parlar & Perry, 1996); for facility location, robust optimisation approaches that incorporate disruption probabilities and demand uncertainty were described (Cheng et al., 2021); for forecasting under pandemics, regime-switching and growth-rate adaptation approaches were identified conceptually (Nikolopoulos et al., 2021); for network inference, graph neural network and link-prediction paradigms were translated into text-based algorithmic narratives (Kosasih & Brintrup, 2022); for domino analysis, the fuzzy cognitive map method and its interpretive possibilities were detailed (Bevilacqua et al., 2020). Each model archetype is explained with respect to its input requirements, decision variables (described narratively, not mathematically), solution approaches (e.g., robust optimisation, simulation, machine learning), and evaluation metrics (service level, total cost, resilience indices).

Third, cross-model synthesis and interaction mapping were executed. This step explicated how inventory policies interact with facility location decisions, how forecasting uncertainty propagates into inventory sizing and location selection, how hidden-link detection informs supplier diversification, and how organizational memory modulates the rate of learning and the persistence of resilience practices (Yu et al., 2019; Kosasih & Brintrup, 2022; Alvarenga et al., 2023). Interaction mapping was articulated as narrative pathways: for example, forecasting errors under pandemic regimes yield unexpected demand spikes; firms with multi-echelon inventory strategies and partial backordering can buffer short-term disruptions, but facility-level failures necessitate robust location contingency planning (Nikolopoulos et al., 2021; Arreola-Risa & DeCroix, 1998; Cheng et al., 2021). Each pathway is traced in detail with supporting citations.

Fourth, managerial and policy implications were derived through counterfactual analysis and scenario reasoning. The methodology explains how to evaluate reshoring decisions—particularly for sectors such as semiconductors—by juxtaposing supply-chain risk profiles, capacity and capability requirements, and public policy incentives (Lulla, 2025; Platzer et al., 2016; Platzer, Sargent Jr. & Sutter, 2020). The approach recommends evaluation criteria (cost, time-to-recovery, systemic risk reduction, strategic sovereignty) and articulates trade-offs between nearshoring/reshoring and supplier diversification.

Throughout these steps, emphasis is placed on a text-based exposition of methods suitable for operationalization by researchers and practitioners who may translate narrative constructs into formal models. The methodological section intentionally avoids equations or figures but provides actionable guidance for formal modeling: which parameters to prioritise, what distributional assumptions to challenge, what empirical data sources to pursue (e.g., supplier performance histories, tiered network mapping, demand time-series), and what solution strategies to consider (robust optimisation, stochastic programming, simulation-optimisation, graph neural networks). Each methodological claim is supported by references to the literature's relevant contributions.

RESULTS

The synthesis yields a layered resilience architecture and a suite of descriptive findings anchored in the literature. The results are entirely descriptive, summarizing theoretical outcomes, cross-cutting patterns, and managerial constructs that emerge when the referenced works are considered together. These results are presented as theoretical propositions, supported by the relevant literature.

Resilience Architecture: Five Interlocking Components

The integrative framework organizes resilience strategies into five interlocking components: (1) demand-aware inventory policies, (2) robust facility-location design, (3) adaptive forecasting and planning, (4) network intelligence via link prediction, and (5) organizational learning and memory. Each component is elaborated below with explicit linkages to the underlying literature.

1. Demand-Aware Inventory Policies

Inventory systems under supply uncertainty should move beyond static safety-stock formulas and adopt policies that explicitly account for stochastic supply disruptions and partial backordering possibilities (Arreola-Risa & DeCroix, 1998; Salehi et al., 2016; Parlar & Perry, 1996). The literature indicates several consistent insights: first, that random supply disruptions increase optimal safety stock and reorder thresholds when holding costs and backorder penalties are considered (Arreola-Risa & DeCroix, 1998; Salehi et al., 2016). Second, when partial backordering is feasible, firms may accept controlled shortages to balance holding costs against service-level constraints, particularly when supplier recovery rates are predictable (Salehi et al., 2016; Arreola-Risa & DeCroix, 1998). Third, multi-supplier procurement strategies reduce the expected impact of a single-supplier failure, but they also introduce coordination and minimum-order complexities that must be factored into inventory planning (Parlar & Perry, 1996). These insights collectively suggest that inventory design should be modular: short-term tactical buffers (increased safety stock and express replenishment agreements), medium-term contractual mitigations (backordering clauses and priority allocations), and long-term strategic supplierscape redesign (supplier diversification and dual sourcing). Each module aligns with the literature's modeling and empirical suggestions (Parlar & Perry, 1996; Salehi et al., 2016).

2. Robust Facility-Location Design

Facility location decisions must internalize disruption probabilities and demand uncertainty to avoid brittle networks that minimize cost in benign conditions but suffer severe performance degradation under stress (Cheng, Adulyasak & Rousseau, 2021). Robust facility location models introduce uncertainty sets or disruption scenarios into the location decision, prioritising configurations that offer acceptable performance across a range of plausible futures (Cheng et al., 2021). The literature demonstrates that incorporating disruption risk often leads to solutions with more distributed capacity, redundancy in critical regions, or the strategic clustering of facilities near alternative logistics corridors (Cheng et al., 2021). For capital-intensive sectors like semiconductors, where capacity is highly specialized and scarce, location resilience requires balancing proximity to demand markets against supply chain security and geopolitical risk (Platzer & Sargent Jr., 2016; Platzer, Sargent Jr. & Sutter, 2020; Lulla, 2025). Robust location is therefore not a one-dimensional metric—it must be judged by service stability, time-to-recovery, and sovereign capability.

3. Adaptive Forecasting and Planning

Pandemic-era forecasting research underscores the inadequacy of conventional forecasting under regime shifts and policy-driven demand shocks (Nikolopoulos et al., 2021). The literature advocates for forecasting systems that can switch regimes, rapidly re-estimate growth rates, and incorporate policy variables as exogenous drivers (Nikolopoulos et al., 2021). Forecasting errors have immediate operational consequences: underestimated spikes lead to stockouts and lost sales, while overestimates inflate inventory carrying costs and obsolescence risk (Nikolopoulos et al., 2021). Adaptive forecasting integrates scenario-based projections, near-term nowcasting, and cross-validation with supply-chain signals (order cancellations, lead-time expansions) to produce actionable planning inputs. The result is a planning loop in which forecasts inform inventory and location contingencies and, conversely, observed disruptions feed back to recalibrate forecasting models (Nikolopoulos et al., 2021).

4. Network Intelligence via Link Prediction

Hidden interdependencies across tiers of suppliers create vulnerability blind spots that conventional supplier lists often miss. Machine-learning approaches, notably graph neural networks and link-prediction algorithms, can illuminate latent links and common third-party exposures that elevate systemic risk (Kosasih & Brintrup, 2022). The literature documents methods for inferring supplier relationships from fragmented data, such as trade records, shipment patterns, and textual disclosures, enabling managers to detect clusters of suppliers that share critical subcomponents or logistics providers (Kosasih & Brintrup, 2022). Link prediction enhances supply chain visibility and complements traditional audits by identifying non-obvious contagion pathways. Importantly, the deployment of such techniques raises issues of data governance, model interpretability, and the need for human-in-the-loop validation (Kosasih & Brintrup, 2022).

5. Organizational Learning and Memory

Resilience is not only an engineering problem but also an organizational capability. Memory of prior disruptions, structured post-event analyses, and deliberate narrative practices influence how quickly firms adopt resilience-enhancing changes and internalize lessons (Alvarenga, Oliveira & Oliveira, 2023). Cognitive frameworks such as fuzzy cognitive maps help map the domino effects across actors and processes, creating a shared mental model for decision-makers (Bevilacqua et al., 2020). Dynamic capabilities—such as sensing disruptions, seizing opportunities, and transforming operations—mediate the translation of resilience investments into financial outcomes (Yu et al., 2019). The literature suggests that organizations that institutionalize memory (after-action reviews, codified procedures, archival of disruption histories) and that cultivate disruption-oriented capabilities realize more enduring performance benefits (Alvarenga et al., 2023; Yu et al., 2019).

Cross-Component Interactions and Emergent Findings

Beyond characterizing each component, the synthesis reveals cross-component interactions that generate emergent behavior:

• Forecasting errors amplify inventory mismatches and may render robust location decisions insufficient if demand shifts change the geographic centre of gravity for consumers (Nikolopoulos et al., 2021; Cheng et al., 2021). An adaptive forecasting capability mitigates this amplification by rapidly signaling demand rebalancing, enabling temporary reallocation of inventory or activation of contingency facilities.

• Link-prediction insights feed into supplier diversification and inventory policy: when hidden common suppliers are identified, inventory buffers and strategic stockpiles may be reallocated to hedge against correlated failures (Kosasih & Brintrup, 2022; Parlar & Perry, 1996). This shows the importance of combining network intelligence with tactical inventory rules rather than treating them as separate programs.

• Organizational memory influences the speed and fidelity of translating data-driven insights (e.g., link prediction) into procurement policy changes. Firms with strong memory practices institutionalize supplier audits and enforce supplier-risk clauses, whereas firms without such memory risk repeating mistakes (Alvarenga et al., 2023; Bevilacqua et al., 2020).

• Reshoring decisions—often proposed as a policy lever for strategic sovereignty—interact with location design, supplier diversification, and inventory policies in non-trivial ways. Reshoring can improve control and reduce lead-time variability for critical components, but it may increase cost and reduce diversification benefits unless paired with flexible capacity and robust local supplier ecosystems (Lulla, 2025; Platzer et al., 2016; Platzer, Sargent Jr. & Sutter, 2020). The literature thus counsels careful scenario-based evaluation of reshoring rather than binary choices.

Descriptive Propositions

Based on the literature synthesis, the following descriptive propositions summarize the results and provide a platform for future formal modeling and empirical testing:

Proposition 1: Inventory systems that incorporate disruption probabilities and allow for controlled partial backordering achieve lower expected total cost under frequent small disruptions relative to static safety-stock policies, provided the firm calibrates backorder penalties and recovery rate expectations accurately. (Arreola-Risa & DeCroix, 1998; Salehi et al., 2016; Parlar & Perry, 1996).

Proposition 2: Facility location models that optimize across disruption scenarios and demand uncertainty produce more geographically distributed capacity and greater time-to-recovery robustness, albeit at the expense of higher fixed costs in benign scenarios. (Cheng, Adulyasak & Rousseau, 2021).

Proposition 3: Forecasting frameworks that explicitly model regime changes, policy shock variables, and near-term nowcasting signals reduce the mismatch between planned and actual demand during pandemic-like events, improving service levels and lowering emergency replenishment costs. (Nikolopoulos et al., 2021).

Proposition 4: Machine learning-based link prediction enhances supply chain visibility, allowing firms to proactively redesign buffers and contractual arrangements in the presence of latent interdependencies that conventional procurement records do not reveal. (Kosasih & Brintrup, 2022).

Proposition 5: Organizational memory and structured after-action learning mechanisms increase the likelihood that technical resilience measures (inventory, location, forecasting models) are institutionalized and maintained, leading to sustained performance improvements. (Alvarenga, Oliveira & Oliveira, 2023; Bevilacqua et al., 2020; Yu et al., 2019).

Each proposition is anchored in the existing literature and describes qualitative relationships that can guide operational decision-making and model development.

Trade-offs and Managerial Tensions

The integrative synthesis highlights several trade-offs that managers must navigate:

• Cost vs. Resilience: Robust facility locations and higher inventories increase operating costs in stable times but reduce downside risk during disruptions (Cheng et al., 2021; Parlar & Perry, 1996). The literature suggests that resilience investments should be understood through the lens of expected-value trade-offs under realistic disruption frequencies.

• Flexibility vs. Specialization: Reshoring and domestic capacity-building help secure supply for critical components but may reduce access to specialized global suppliers and scale economies, particularly in sectors like semiconductors (Platzer et al., 2016; Lulla, 2025). Managers must weigh the strategic value of sovereign capability against potential reductions in innovation pace or cost effectiveness.

• Visibility vs. Privacy/Cost: Deep network intelligence via machine learning requires data sharing and investment in analytics, raising data governance, and cost concerns (Kosasih & Brintrup, 2022). There is a tension between acquiring enough data to reveal hidden links and maintaining supplier confidentiality.

• Learning Investment vs. Short-Term Pressures: Institutionalizing memory and learning programs requires organizational time and cultural change that may be deprioritized under short-term financial pressures (Alvarenga et al., 2023; Yu et al., 2019). Yet the literature indicates that such investments yield compounding benefits by preventing repeat failures.

DISCUSSION

The theoretical synthesis points toward a holistic view of supply chain resilience that integrates operations research models, data-driven detection methods, and organizational practices. This discussion delves into theoretical implications, counter-arguments, practical applications, and research opportunities, drawing from the referenced literature.

Theoretical Implications

The integrative framework illuminates how traditionally discrete literatures can be combined to offer richer prescriptions. For example, the intersection of inventory models that permit partial backordering with link-prediction methods yields a nuanced hedging strategy: buffer inventories are not simply allocated by product or region but by network-criticality informed by inferred hidden ties (Salehi et al., 2016; Kosasih & Brintrup, 2022).

This suggests an expansion of classical inventory decision spaces to include network-informed priorities.

Robust facility location literature (Cheng et al., 2021) intersects with forecasting under pandemics (Nikolopoulos et al., 2021) to underscore the need for dynamic network designs that can reconfigure in response to demand regime changes. Static robust solutions are valuable but must be supplemented by flexible capacity management and rapid activation protocols—elements more often discussed in operational agility literature than in static location models (Cheng et al., 2021; Pettit, Croxton & Fiksel, 2019). The implication is methodological: researchers should pursue dynamic robust location formulations or scenario-based rolling-horizon approaches that integrate forecast updates.

Organizational learning literature (Alvarenga et al., 2023; Yu et al., 2019) provides the socio-cognitive glue that determines whether technical resilience measures persist. Theoretical models should therefore include endogenous learning dynamics: if firms forget lessons, the efficacy of capital investments in resilience may decay over time. Modeling learning as an endogenous process opens pathways for richer dynamic analyses, including investment timing, depreciation of knowledge, and policy incentives to preserve institutional memory.

Counter-Arguments and Critical Perspectives

While the synthesis advocates integrative resilience strategies, several counter-arguments warrant attention. One critique is that adding complexity to decision frameworks (e.g., network-aware inventory rules, dynamic robust location models) risks overfitting to recent disruptions and increasing managerial burden. Overfitting may lead to solutions that perform well under studied scenarios but poorly under unanticipated future shocks. Mitigating this risk requires emphasizing model parsimony, stress testing across wide scenario sets, and adopting human-in-the-loop validation to ensure relevance (Kosasih & Brintrup, 2022; Cheng et al., 2021).

Another critique concerns the opportunity costs of resilience investments. Firms with limited capital may find that investments in agility (flexible manufacturing, digital platforms) provide more resilience per dollar than large buffer stocks or redundant facilities. The literature supports tailored strategies: high-volume, long-lead-time critical components (e.g., semiconductors) may justify reshoring or dedicated strategic stockpiles, whereas commodity inputs may be better served through diversification and contractual flexibility (Platzer et al., 2016; Platzer, Sargent Jr. & Sutter, 2020; Lulla, 2025).

Data-driven link prediction is powerful but not infallible. False positives (incorrectly inferred links) can lead to unnecessary supplier interventions, while false negatives leave risk unmitigated. This underlines the need for probabilistic outputs, human validation, and cost-sensitive decision rules that weigh the cost of additional audits or contractual changes against the expected risk reduction (Kosasih & Brintrup, 2022).

Institutional memory can become institutionalized bureaucracy if not carefully designed. Memory systems that prioritize documentation over adaptive learning may produce archival compliance without behavioral change. The literature calls for active learning mechanisms—simulations, drills, and cross-functional debriefs—rather than passive archiving (Alvarenga et al., 2023; Bevilacqua et al., 2020). Thus, the quality and application of memory matter more than mere existence.

Managerial Applications and Policy Considerations

The synthesized framework offers clear managerial heuristics:

• Prioritize visibility investments that reveal high-impact hidden dependencies. Use graph-based inference tools to map latent linkages and feed results into supplier risk stratification. Wherever possible, complement algorithmic inferences with targeted supplier audits and cross-validation to limit false signals (Kosasih & Brintrup, 2022).

• Combine inventory strategies with supplier contracts that permit controlled partial backordering and reprioritization during disruptions. Calibrate backorder acceptance to product criticality and customer tolerance (Arreola-Risa & DeCroix, 1998; Salehi et al., 2016).

• Use robust facility-location frameworks not as one-time decisions but as strategic roadmaps for phased investments in redundancy and local capacity. For critical sectors with national security implications, public policy may subsidize resilient capacity to correct market underinvestment (Platzer et al., 2016; Lulla, 2025).

• Institutionalize learning through structured after-action reviews, scenario-based training, and cross-functional knowledge repositories that promote rapid knowledge retrieval and application (Alvarenga et al., 2023; Bevilacqua et al., 2020).

Policy makers, particularly in sectors where supply resilience has systemic implications (semiconductors, critical medical supplies), should design incentives that align private resilience investments with public good considerations. Subsidies, tax incentives for capacity onshoring, or public-private partnerships for strategic stockpiles can bridge capability gaps, but they must be designed to avoid rent-seeking and ensure long-term competitiveness (Platzer, Sargent Jr. & Sutter, 2020; Lulla, 2025).

LIMITATIONS

The study's integrative nature and reliance on provided literature entail several limitations that also suggest avenues for future work. First, the article is conceptual and synthesized; it does not present new empirical estimation or simulations. Empirical testing of the proposed propositions is necessary to quantify trade-offs and validate the framework's predictions. Second, the references, while broad and multi-disciplinary, are not exhaustive; additional literature on behavioural decision-making, supplier finance, and digital twin technologies could enrich the framework. Third, the lack of formal mathematical exposition in the article, by design, may limit operationalization for readers seeking ready-to-run model specifications. Future research should translate the narrative constructs into formal models—dynamic stochastic programming, robust optimisation with endogenous learning, or hybrid machine-learning plus optimization pipelines—and validate them with real-world data. Fourth, sectoral heterogeneity implies that the relative efficacy of resilience measures will vary by industry; empirical cross-sectoral studies are needed to specify context-sensitive prescriptions (Platzer et al., 2016; Lulla, 2025).

Future Research Directions

Building on the synthesis, several promising research directions emerge:

• Integrated Modelling: Develop formal models that combine inventory under random disruptions, robust facility location, and demand forecasting under regime shifts into joint optimisation frameworks. These models should account for endogenous learning and memory depreciation.

• Empirical Calibration: Use empirical data from multiple industries—particularly high-risk sectors like semiconductors—to estimate disruption distributions, recovery rates, and the cost-effectiveness of reshoring investments.

• Human-in-the-loop Analytics: Design and test governance frameworks that combine machine-learning link prediction with human validation processes to manage false positives and to operationalize data-driven insights.

• Organizational Memory Mechanisms: Conduct field experiments on different memory architectures (e.g., centralized repositories vs. embedded narrative exercises) to measure their effect on resilience adoption and persistence.

• Policy Impact Evaluation: Assess the macroeconomic impacts of targeted public support for domestic capacity in critical industries, weighing trade-offs between sovereignty, cost, and innovation.

CONCLUSION

This article provides an integrative, theory-rich framework for designing resilient supply chains under demand uncertainty, supply disruptions, and strategic reshoring considerations. Drawing on a range of literature spanning robust facility location, inventory models with random disruptions and partial backordering, forecasting during pandemics, graph neural network-based link prediction, fuzzy cognitive mapping, dynamic capabilities, and organizational memory, the synthesis proposes a five-component architecture: demand-aware inventory policies, robust facility-location design, adaptive forecasting and planning, network intelligence via link prediction, and organizational learning and memory. These components interact dynamically: forecasting informs inventory and location actions; link prediction enhances visibility for diversification; organizational memory ensures learning is retained and operationalized.

The theoretical propositions distilled from the literature provide actionable guidance for managers and researchers. Implementation requires careful attention to trade-offs—cost versus resilience, flexibility versus specialization, visibility versus data governance—and to the behavioural and organizational conditions that determine whether technical measures endure. Future work must formalize the integrative models, empirically calibrate key parameters, and test governance frameworks for data-driven, human-validated supply chain intelligence.

Supply chain resilience is not an endpoint but a continuous capability; it demands coordinated investments in modeling, data, architecture, and organizational practice. The integrated framework presented here, grounded in the cited literature, offers a coherent roadmap for both scholarship and practice in pursuing resilient, adaptive, and strategically balanced supply chains.

REFERENCES

1. Cheng, Chun & Adulyasak, Yossiri & Rousseau, Louis-Martin, 2021. "Robust facility location under demand uncertainty and facility disruptions," Omega, Elsevier, vol. 103(C).

2. Nikolopoulos, Konstantinos & Punia, Sushil & Schäfers, Andreas & Tsinopoulos, Christos & Vasilakis, Chrysovalantis, 2021. "Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions," European Journal of Operational Research, Elsevier, vol. 290(1), pages 99-115.

3. Maurizio Bevilacqua & Filippo Emanuele Ciarapica & Giulio Marcucci & Giovanni Mazzuto, 2020. "Fuzzy cognitive maps approach for analysing the domino effect of factors affecting supply chain resilience: a fashion industry case study," International Journal of Production Research, Taylor & Francis Journals, vol. 58(20), pages 6370-6398, October.

4. Antonio Arreola-Risa & Gregory A. DeCroix, 1998. "Inventory management under random supply disruptions and partial backorders," Naval Research Logistics (NRL), John Wiley & Sons, vol. 45(7), pages 687-703, October.

5. Edward Elson Kosasih & Alexandra Brintrup, 2022. "A machine learning approach for predicting hidden links in supply chain with graph neural networks," International Journal of Production Research, Taylor & Francis Journals, vol. 60(17), pages 5380-5393, September.

6. Wantao Yu, Mark A. Jacobs, Roberto Chavez & Jiehui Yang, 2019. "Dynamism, disruption orientation, and resilience in the supply chain and the impacts on financial performance: A dynamic capabilities perspective," International Journal of Production Economics, Elsevier, vol. 218(C), pages 352-362.

7. Hossein Salehi & Ata Allah Taleizadeh & Reza Tavakkoli-Moghaddam, 2016. "An EOQ model with random disruption and partial backordering," International Journal of Production Research, Taylor & Francis Journals,

vol. 54(9), pages 2600-2609, May.

8. Mahmut Parlar & David Perry, 1996. "Inventory models of future supply uncertainty with single and multiple suppliers," Naval Research Logistics (NRL), John Wiley & Sons, vol. 43(2), pages 191-210, March.
9. Luis A. San-José & Joaquín Sicilia & Manuel González-De-la-Rosa & Jaime Febles-Acosta, 2020. "Best pricing and optimal policy for an inventory system under time-and-price-dependent demand and backordering," Annals of Operations Research, Springer, vol. 286(1), pages 351-369, March.
10. Murilo Zamboni Alvarenga & Marcos Paulo Valadares de Oliveira & Tiago Oliveira, 2023. "Let’s talk about bad experiences instead of forgetting them: An empirical study on the importance of memory for supply chain disruption management," International Journal of Production Economics, Elsevier, vol. 261(C).
11. K. Lulla, 2025. "Reshoring GPU production: Testing strategy adaptations for US-based factories," International Journal of Applied Mathematics, vol. 38(10s), pages 2411-2440.
12. Pettit, T., Croxton, K., & Fiksel, J., 2019. "The Evolution of Resilience in Supply Chain Management: A Retrospective on Ensuring Supply Chain Resilience," Journal of Business Logistics, pp. 1-10.
13. Pettit, T., Fiksel, J., & Croxton, K., 2010. "Ensuring Supply Chain Resilience: Development of a Conceptual Framework," Journal of Business Logistics, Vol. 31, No.1.
14. Platzer, M., & Sargent Jr., J., 2016. "U.S. Semiconductor Manufacturing: Industry Trends, Global Competition, Federal Policy," Washington D.C.: Congressional Research Service.
15. Platzer, M., Sargent Jr., J., & Sutter, K., 2020. "Semiconductors: U.S. Industry, Global Competition, and Federal Policy," Congressional Research Service.
16. Ponomarov, S., & Holcomb, M., 2009. "Understanding the Concept of Supply Chain Resilience," International Journal of Logistics Management, Vol. 20, No. 1, pages 124-143.
17. Rao, S., & Goldsby, T., 2009. "Supply Chain Risks: A Review and Typology," International Journal of Logistics Management, Vol. 20, No.1, pages 97-123.
18. Saenz, M., Revilla, E., & Acero, B., 2018. "Aligning Supply Chain Design for Boosting Resilience," Business Horizons.